 DOI: https://doi.org/10.7494/geotour.2021.1-2(64-65).35

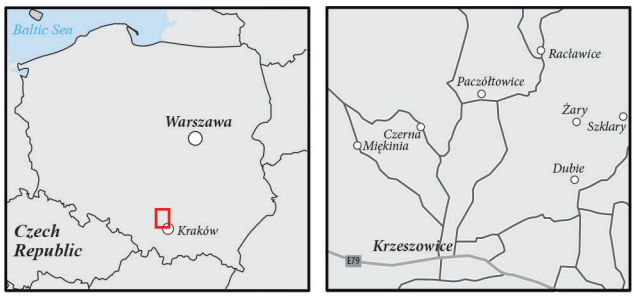
Educational trails of the Racławka Valley Nature Reserve and their potential for geoeducation

Ścieżki edukacyjne Rezerwatu Przyrody Dolina Racławki i ich potencjał geoedukacyjny

Anna Szreter[1]*, Sylwia Skoczylas-Śniaz[1,2], Katarzyna Wierzba[1], Paulina Czoch[1], Szymon Bolek[1], Justyna Kowal-Kasprzyk[1]

[1] AGH University of Science and Technology, al. A. Mickiewicza 30, 30-059 Krakow, Poland
[2] W. Szafer Institute of Botany, Polish Academy of Sciences, Krakow, Poland
iguania@op.pl, sylw.skoczylas@gmail.com, katarzyna.a.wierzba@gmail.com, paulinaczoch@gmail.com, szymonbolekofficial@gmail.com, kowalj@agh.edu.pl

* Corresponding Author



Article history:
Received: 2 November 2022
Accepted: 13 January 2023
Available online: August 2023

Abstract: *The Racławka Valley is located west of Krakow, in the Krakow-Częstochowa Upland. This is a place of high bio- and geodiversity, where various rocks of different ages outcrop in vast excavation pits, narrow gorges or form characteristic monadnocks. The richness of various morphological forms and special habitats led to the constitution of a nature reserve, covering most of the Racławka Valley and adjacent, southern parts of the Szklarka Valley. Three educational trails lead through the reserve, connecting a number of geosites. The Geotourism Students' Scientific Club (GSSC) from AGH University of Science and Technology examined the usability of these trails for geoeducation. After completing geotourism valorisation, adequate teaching materials were prepared, and different age groups were guided around the trails. Their comprehension has been verified by quizzes and opinions gathered through questionnaires. On the bases of these, the three educational trails were widely described and assessed in respect for their terrain difficulty, accessibility, and infrastructure. Each trail has a leitmotif and a specific theme, however geosites from different trails can be combined together to get a route of a chosen theme. The GSSC also released three new geotourism guidebooks, one for each trail, as a result of AGH rector's grant projects in the years 2018–2020.*

Keywords: *geosites, didactic paths, geotourism valorisation, Krakow-Częstochowa Upland*

Treść: *Dolina Racławki położona jest na zachód od Krakowa, na Wyżynie Krakowsko-Częstochowskiej. Stanowi ona obszar o dużej bio- i georóżnorodności, gdzie rozmaite skały o różnym wieku odsłaniają się w rozległych wyrobiskach, na ścianach wąwozów lub w postaci ostańców. Ze względu na bogactwo form morfologicznych i wykształcone na nich siedliska, większość doliny Racławki i przyległą, południową część doliny Szklarki objęto rezerwatem przyrody. Przez obszar rezerwatu prowadzą trzy ścieżki dydaktyczne łączące szereg geostanowisk. Koło Naukowe Geoturystyka (KNGt) z Akademii Górniczo-Hutniczej zbadało ich przydatność dla geoedukacji. Po dokonaniu waloryzacji geoturystycznej opracowano materiały dydaktyczne, a następnie po ścieżkach oprowadzono różne grupy wiekowe. Za pomocą quizów sprawdzono zrozumienie przez uczestników omawianych tematów, a opinie zebrano w formie ankiet. Działania te umożliwiły dokładne opisanie ścieżek oraz ich ocenę pod kątem trudności terenu, dostępności i infrastruktury. Każda ze ścieżek ma motyw przewodni, można je jednak z powodzeniem łączyć, by zaplanować trasę o określonej tematyce. KNGt przygotowało też trzy przewodniki geoturystyczne po dolinie Racławki, po jednym dla każdej ze ścieżek, w ramach Grantu Rektora AGH w latach 2018–2020.*

Słowa kluczowe: *geostanowiska, ścieżki dydaktyczne, waloryzacja geoturystyczna, Wyżyna Krakowsko-Częstochowska*

Introduction

Geology is one of the disciplines which are impossible to learn just from books. For this reason, lessons or lectures are often supplemented by fieldwork. To conduct such activities, clearly visible forms and processes, exemplary rocks and good accessibility are required. The geotourism potential of a geosite can be defined as its scientific and educational values juxtaposed with its accessibility, visibility, existing infrastructure, threats and risks of degradation, and some additional values (Kubalíková, 2013). The Racławka Valley meets these requirements. The vicinity of Krakow and high bio- and geodiversity make it a potential area for geoeducation (e.g. Gołas-Siarzewska, 2010; Szczurek *et al.*, 2016).

For the 2018 rector's grant project, which was later extended to three years of complex work, the Geotourism Students' Scientific Club (GSSC) from AGH University of Science and Technology in Krakow chose the Racławka Valley Nature Reserve. This is a protected area of unique natural values, easily accessible from Krakow (around 1 hour by bus) and with some already existing tourism facilities, including educational trails, which made this area perfectly suitable for the GSSC's research (Maciejowski *et al.*, 2013). The aim of GSSC is to explore such places of high geological values, get familiar with their current development, analyse the existing facilities and work out how to improve them. This was done in the Racławka Valley Nature Reserve. Along the three educational trails, all marked or spotted geosites, defined as pieces of geosphere particularly important for the comprehension of the Earth's history (Reynard, 2004), were examined. Using them for geoeducation and recreation enabled students to recognize what was done well, and what was missed on the educational boards and in the field.

This article presents the potential of the Racławka Valley Nature Reserve in the context of geoeducation. Visual, cognitive and functional values of each trail were carefully assessed, analysed and compared, based on the valorisation method proposed by Doktor *et al.* (2015). Particular attention was paid to the educational aspects of geosites and the management of the trails. The accessibility of currently existing educational boards was examined, with the application of quizzes, solved by the target groups. The same groups supported us with questionnaires, which revealed the demand for some new educational materials. Their answers made it possible to select trails and topics appropriate for the wants and needs of different groups of hikers. Exemplary topics of field trips were proposed, together with accessible educational materials, facilities and impediments connected with the trails. Finally, some possible improvements were considered, in light of the changes to come.

Study area

The Racławka Valley Nature Reserve (area: 473.92 ha) is situated in the Olkusz Upland, which is a part of the Krakow-Częstochowa Upland. It lies between the villages Dubie and Paczółtowice, 30 km NW from Krakow.

Geologically, it is situated in the Krakow-Silesian Monocline, built of Permian-Mesozoic rocks, dipping to the NE (Gradziński, 1972). In the Racławka Valley area Jurassic limestones and less common clastic rocks are represented. Permian terrestrial and magmatic rocks are also typical of the southern part of the monocline, and Permian intrusions and terra rossa also are observed in the described field. Additionally, the lower – Variscan – structural level is well outcropped in the studied area and represented by the Devonian limestones and dolomites (Gradziński, 1972). The area was modified by both the Variscan and Alpine tectonic movements. The Variscan structural level is folded and faulted, while the Alpine orogeny caused monoclinal dipping of the area, as well as its division into horsts and grabens by a series of faults (Fig. 1; Dżułyński, 1953; Gradziński, 1972).

The reserve is abounded with various geomorphological forms, which were made by intensive erosion, weathering, mass movements and other geological processes. The most common forms in this area are gorges with steep walls, formed by long-standing surface grooving by water. The Racławka stream cuts through the valley and enriches the local relief in alluvia. On the whole, underground and surface karst formations play a vital role in the landscape. Due to limestone prevalence, the valley is a mosaic of various karst shapes, outcrops, as well as hollows. The most curious formations are the caves, where the main karst structures are clearly visible (Olaczek, 2008; Joniec & Słomka, 2012; Dmytrowski *et al.*, 2013). Adequacy of rock resources created good conditions for the development of quarries, mining rock raw materials (Olaczek, 2008; Joniec & Słomka, 2012).

However, only one of them is still working. Besides, the presence of diverse rock outcrops, limestone monadnocks, tectonic formations, such as folds and faults, and various types of joints perfectly depict the richness of the valley relief.

The Racławka Valley Nature Reserve is located in a temperate climate, distinctive for Polish Highlands. Not only are geological structures important here, but also flora and fauna. The diversity of geomorphological formations together with various habitat conditions determine the great floral and faunal richness in this area (Dmytrowski *et al.*, 2013). A vast majority of the terrain is overgrown with forests, predominantly beech (Carpathian, acidophilous and subthermophilous). In addition, xerothermic grasses and bushes can be found on the rocky ridges of the valley.

Altogether, 27 plant species in the reserve are protected, especially the martagon lily (*Lilium martagon*) and mezereon (*Daphne mezereum*) (Olaczek, 2008; Joniec & Słomka, 2012). Mammals such as boars, does, hares and rodents are commonly found there. There are also rare species of birds such as the black stork (*Ciconia nigra*) and the goshawk (*Accipiter gentillis*), as well as different species of invertebrates and insects (Dmytrowski *et al.*, 2013).

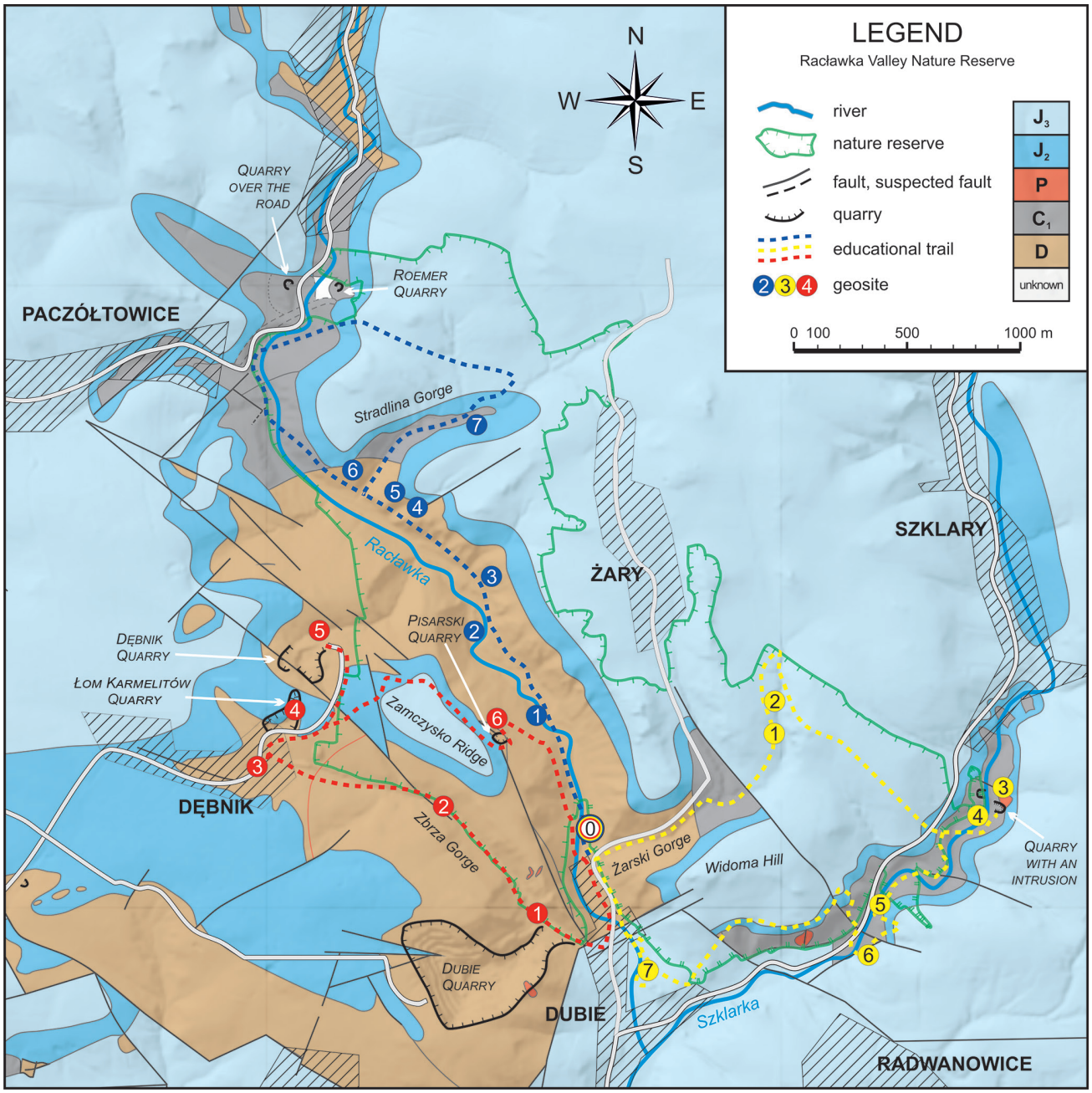


Fig. 1. Simplified geological map of the Racławka region with marked geoeducational trails and geosites. Uncovered map, without Quaternary sediments. Only the most significant Permian intrusions, outcropping in the vicinity of the trails, were marked. Base map according to Paszkowski (1997), modified (shading after www3)

The Racławka Valley Nature Reserve is situated within the Dolinki Krakowskie Landscape Park and Natura 2000 area "Dolinki Jurajskie", hence wildlife conservation and environmental protection are particularly essential (Dz.Urz. Woj. Małop. z 2020 r., poz. 3481).

Methods

In this research, three dominant methods were used, according to the geotourism methodology presented by Miśkiewicz *et al.* (2007): experimental (quizzes), statistical (valorisation) and opinion polls (questionnaires). Each trail was evaluated with respect to its availability, topicality (e.g. legibility of particular forms) and significance. Sketches, photographs and samples were gathered. This was followed by preparing trips (field lessons) for school, university and adult groups. In 2020, trips (along the red trail) could not be held due to pandemic restrictions.

An important means of expert assessment of the geosites value is geotourism valorisation of geological objects. It is used to assess the cognitive, visual and functional value,

as well as their availability for potential recipients (Doktor *et al.*, 2015). The following geotourism valorisation was done for all of the geological objects from three educational trails of the Racławka Valley. All of these objects are subject to assessment in three categories: visual, cognitive and functional values. Selected categories from the investment values were assessed separately. Particular criteria were based on the valorisation proposed by Doktor *et al.* (2015) and specified in the Supplementary Material. Non-differentiating traits were also included to enable the comparison with other works where this valorisation was applied. It is important to mention that despite being widely accepted in geotourism, the valorisation method is strongly subjective, being influenced by the researcher's personal perception (Doktor *et al.*, 2015), so using some supplementary methods is reasonable.

The other two methods, quizzes and questionnaires, were both connected with field trips. The field trips depended on guiding a group through geosites of an educational trail, and explaining geological issues related to the geology of the Racławka Valley. At each stop, participants solved open tasks included in the so-called "quizzes". The quizzes were directed not only at testing the general understanding of introduced topics, but also testing the comprehensiveness and sufficiency of current educational boards. To achieve this, students were asked to solve each task first after just looking around and reading the board, and then to add some supplements, if necessary, after our explanation, using another colour. It enabled us to differentiate these two stages. Our explanation was performed with the use of additional educational materials, e.g. drawing board or printed schemes.

To avoid a subjective analysis and base our report on both the geoeducation organisers' and recipients' point of view, a third method was implemented – surveying the participants of our trips. The questionnaires outlined the general image of the audience and revealed the need for particular forms of geoeducation materials that could be prepared for the trails.

After completing fieldwork and valorisation, the authors decided to exclude some geosites from the trails presented in Tables 1–3, in Figure 1 and in further description (in Tables 4 and 5 and Supplementary materials those are marked). The reason was poor availability (especially in the growing season), poor visibility or presence of other, more significant geosites with similar features elsewhere along the trails. This was balanced by adding some new points. We intended to present some important geological forms, processes or other rock types in those places.

Trails description

Blue educational trail

Leading along the Racławka Valley bottom, the blue educational trail is the most popular among visitors and the easiest as well. It is the only trail heading there and back, with just a small loop at the final part. It takes 2.5 h to complete the 7 km walk with 120 m of total ascent. The trail presents in general the natural values of the reserve, both biotic and abiotic. In this work, only geological sites are presented (7 out of 13 stops; Tab. 1).

Table 1. Geosites on the blue educational trail. Authors' work based on vast literature (e.g. Gradziński, 1972; Szulc, 1997; Szczurek *et al.*, 2016)

No.	**Geosite** GPS coordinates	**Description**	**Lithology and age**	**Forms; structures; processes**
1	**Racławka Stream** N 50° 09' 52.1" E 19° 41' 20.5"	Winding river with distinct eroded and accumulative banks. It shaped one of numerous parallel valleys in this region, and this process is explained on the board	Quaternary river deposits (sand, gravel), alluvium	meander, bluff, accumulative bank; lateral erosion
2	**Calcareous Tufa** N 50° 10' 05.8" E 19° 41' 05.5"	A vast outcrop of calcareous tufa in a bluff over a meander of Racławka stream, on its left bank. Bedded tufa deposits include some thin peat beds. Numerous floral encrustations and imprints occur in the rock	Quaternary calcareous tufa	bluff, meander, outcrop; bedding, encrusted plant remains, imprints; solution, precipitation, biomineralization
3	**Carpathian Beech Forest** N 50° 10' 08.8" E 19° 41' 05.9"	On a forested slope some effects of mass movements, including rockfall and creep can be observed	–	reaction wood; mass movements, rockfalls, creep

Table 1 cont.

4	**Skałka z Nyżą Rock** N 50° 10' 22.2" E 19° 40' 45.0"	Numerous karst hollows can be seen in the Skałka z Nyżą rock, built of stromatoporoid limestone. In some niches Quaternary lichen stromatolites can be found	Upper Devonian stromatoporoid limestone	monadnock, rock shelter, lichen stromatolites, organogenic limestone; karst
5	**Stradlina Gorge** N 50° 10' 25.5" E 19° 40' 35.3"	A small valley with features differing from dell through the gorge to the gully. Ammonites can be found on its dry bottom with pebbles. Occasionally, joints are observed in some outcrops	Devonian limestone, Carboniferous limestone, Middle Jurassic sandstone	gorge, gully, dell; joints (joint system), fossils; linear erosion, vertical erosion
6	**Bażana Spring** N 50° 10' 27.0" E 19° 40' 32.2"	Karst spring of significant flow (5 m^3/s). It is not well exposed and looks rather like a gutter outflow on the forest bottom	Upper Devonian stromatoporoid limestone and dolomite	karst spring; superficial karst
7	**Middle Jurassic Deposits** N 50° 10' 38.0" E 19° 41' 03.2"	The Middle Jurassic sandstone crops out in the vast rock shelter. Cross-bedding and wavy beds are outlined by ferruginous impurity. Coarser grains, including numerous pebbles, are visible in a flat roof surface	Middle Jurassic pebbly sandstone	rock shelter, overhang; parallel bedding, ripple cross-bedding; sea currents, falls

The path generally borders on the winding Racławka stream at the very bottom of the valley (Fig. 1). In some parts it rises on the slopes to give a better view of the calcareous tufa scarp and some slope processes. The final part leads up the Stradlina Gorge to the Middle Jurassic deposits outcrop (Fig. 2). A brief description of each stop, including lithology, rock age, geological forms and processes, is given in Table 1.

The first half of the trail is equipped with some facilities like benches and trash bins. All the way long, the trail is well marked and perfectly visible in terrain. However, some educational boards are missing or damaged, and the stops without boards are not tagged in any other way so they can be easily passed by. Some sections of the path are accompanied by bicycle (black) and hiking (green and yellow) trails.

Yellow educational trail

The yellow educational trail is located in the eastern part of Racławka Valley Nature Reserve (Fig. 1). It takes about 3–4 hours to complete the 6 km route with 140 m of total ascent. The loop encompasses both the southern piece of the Racławka Valley and the southwestern part of the Szklarka Valley. Seven geosites situated on differential terrain are contained in the yellow trail.

Due to intensive geological processes in the Racławka area, there are different types of rocks, various karst forms and tectonic structures, which are significant for geological and geotourism studies of this terrain (Tab. 2). The path begins in the steep Żarski Gorge, where the most spectacular form of underground karst – the Żarska Cave – is situated. Further, it crosses the Widoma hill and heads down to the Szklarka Valley bottom, where numerous remnants of prehistoric life and tectonic, erosion and accumulation processes can be observed along the river and on the slopes (Fig. 3). Generally, the trail passes through the most interesting and valuable geosites in terms of geological history. Two of them (Quarry with an Intrusion and Calcareous Tufa) are additionally protected as documentation sites.

However, one of the points (Calcareous Tufa) was relocated, within the documentation site, due to the poor visibility of the calcareous tufa neighbouring the educational board. Moreover, one geosite (Rock by the Bridge) has been omitted because of the steepness of the slope and poor accessibility.

The yellow educational trail is rather poorly marked, and it crosses the river several times. The route is characterised by a variable morphology with difficult terrain, where the denivelation exceeds 100 m, so good orientation in the field, as well as fair physical condition, are required.

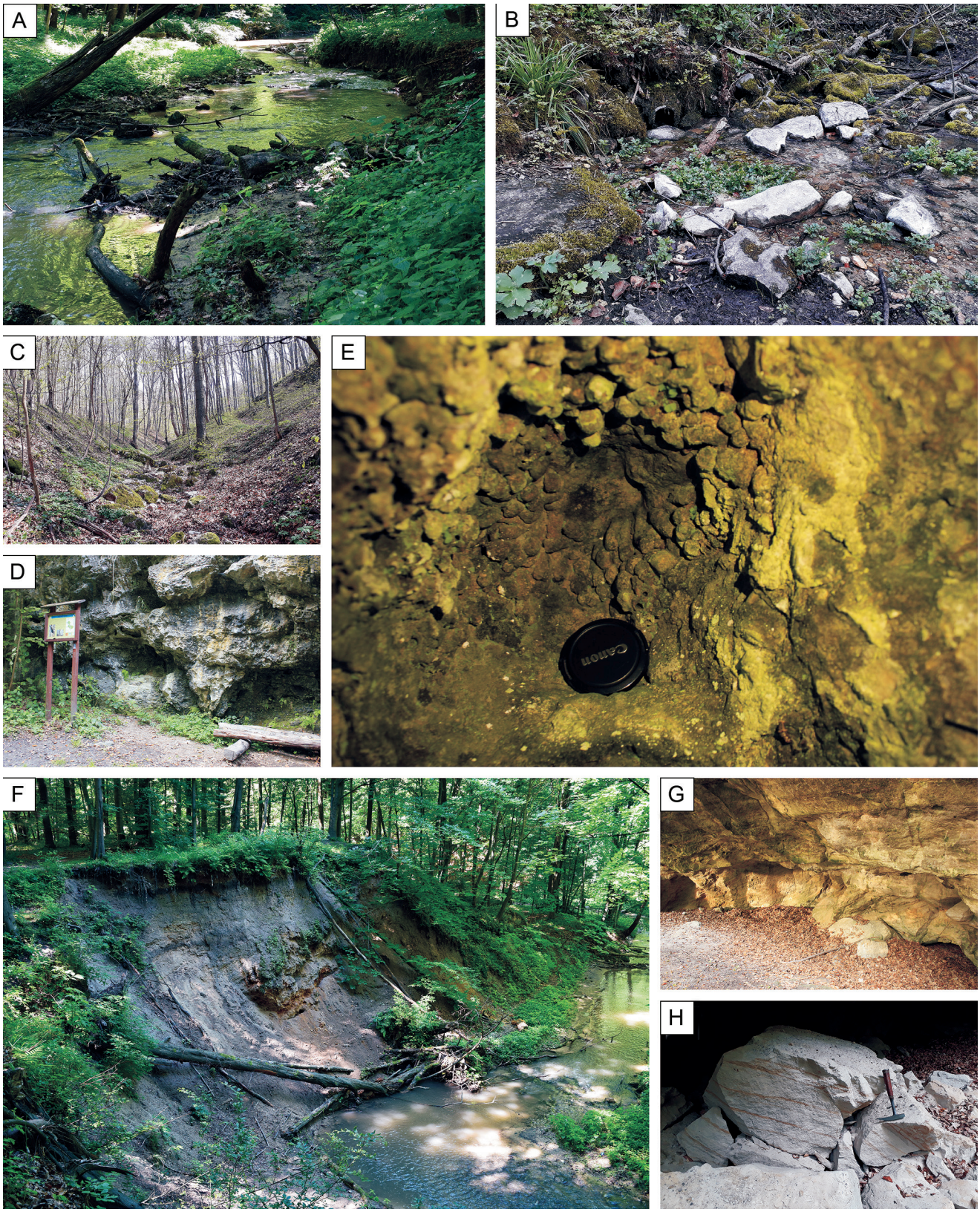


Fig. 2. Geosites on the blue educational trail: A – the Racławka Stream near the beginning of the trail; B – water flowing from the Bażana Spring; C – Stradlina Gorge in upper part of the trail; D – Skałka z Nyżą Rock; E – lichen stromatolites in one of the niches on Skałka z Nyżą; F – calcareous tufa outcrop; G – outcrop of Middle Jurassic deposits; H – unweathered surface of rock on a block of Middle Jurassic sandstone fallen from the outcrop in 2020. Photos: E. Gałka (A, F, G), K. Rzepka (D, E), A. Szreter (B, C, H)

Table 2. Geosites on the yellow educational trail. Authors' work based on vast literature (e.g. Gradziński, 1972; Gromczakiewicz-Łomnicka, 1979; Radwanek-Bąk, 2009; Kędzierski *et al.*, 2013; Matyszkiewicz *et al.*, 2015)

No.	Geosite GPS coordinates	Description	Lithology and age	Forms; structures; processes
1	**Żarski Gorge** N 50° 09' 49.6" E 19° 42' 11.2"	Gorge is a typical geomorphological form in this area. This formation is a result of rainfall and erosion. It is characterised by high walls and a very deep, narrow bottom. Numerous rock shelters are visible in the walls.	Upper Jurassic massive limestone (subordinately Devonian and Carboniferous limestone)	gorge, rock shelter; vertical erosion, headward erosion, denudation
2	**Żarska Cave** N 50° 09' 54.4" E 19° 42' 13.0"	In the higher part of the gorge there is a cave with an extremely narrow entrance. This is an example of a karst cave where various karst structures are present.	Upper Jurassic massive limestone	cave, stalactite, stalagmite, flowstones, drapery, columns, straws; subsurface karst
3	**Quarry with an Intrusion** N 50° 09' 40.9" E 19° 43' 01.2"	Near the stream bank a small old quarry occurs. Permian porphyry dyke cut through Lower Carboniferous limestone beds. Limestone adjacent to the dyke changed due to a contact metamorphism.	Lower Carboniferous limestone, Lower Permian rhyolite	anthropogenic outcrop (quarry); dyke, siliceous concretion; magmatism, intruding, contact metamorphism
4	**Calcareous Tufa** N 50° 09' 39.0" E 19° 42' 57.8"	Natural embankments of Szklarka river are built of redeposited calcareous tufa. It is a sedimentary rock formed during the erosion of a hard type of calcareous tufa, then the sediment was transported and deposited in different places.	Quaternary calcareous tufa	pile accumulated by the river bank; erosion, river transport
5	**Group of Carboniferous Rocks** N 50° 09' 25.9" E 19° 42' 36.2"	The Carboniferous limestone full of fossils is one of the Paleozoic rocks in the area. They are remnants of the warm and shallow sea that covered that area 350 Ma ago.	Carboniferous limestone	monadnock; fossils, organogenic limestone
6	**Jurassic Rocks** N 50° 09' 19.2" E 19° 42' 28.5"	The outcrop of Carboniferous limestone near to the Jurassic limestones indicates occurence of a fault. It is visible in the field as a long, but relatively narrow depression. Many joints in the Jurassic limestones are also related to the fault.	Upper Jurassic massive limestone	monadnock; organogenic limestone, reefs; joints, fault; Alpine tectonic activity
7	**Group of Limestone Rocks in Dubie** N 50° 09' 14.1" E 19° 42' 41.2"	The group of monadnocks represent Jurassic massive limestones originated as an microbial-sponge organic buildups (reefs). They are very common in the Krakow-Częstochowa Upland, and often occur as monadnocks. These monadnocks are used for rock climbing nowadays.	Upper Jurassic massive limestone	monadnock; joint, organogenic limestone, reefs, superficial karst; weathering, erosion

Red educational trail

The red educational trail is located in the western part of the Racławka Valley Nature Reserve (Fig. 1) and is 5 km long with 150 m of total ascent. It takes about 3 h to complete the loop, which begins and finishes at the car park in Dubie. There are six geosites on the route. Five out of six points are of anthropogenic origin. On the trail, numerous methods of stone quarrying, diverse rocks and tectonic structures can be observed (Tab. 3).

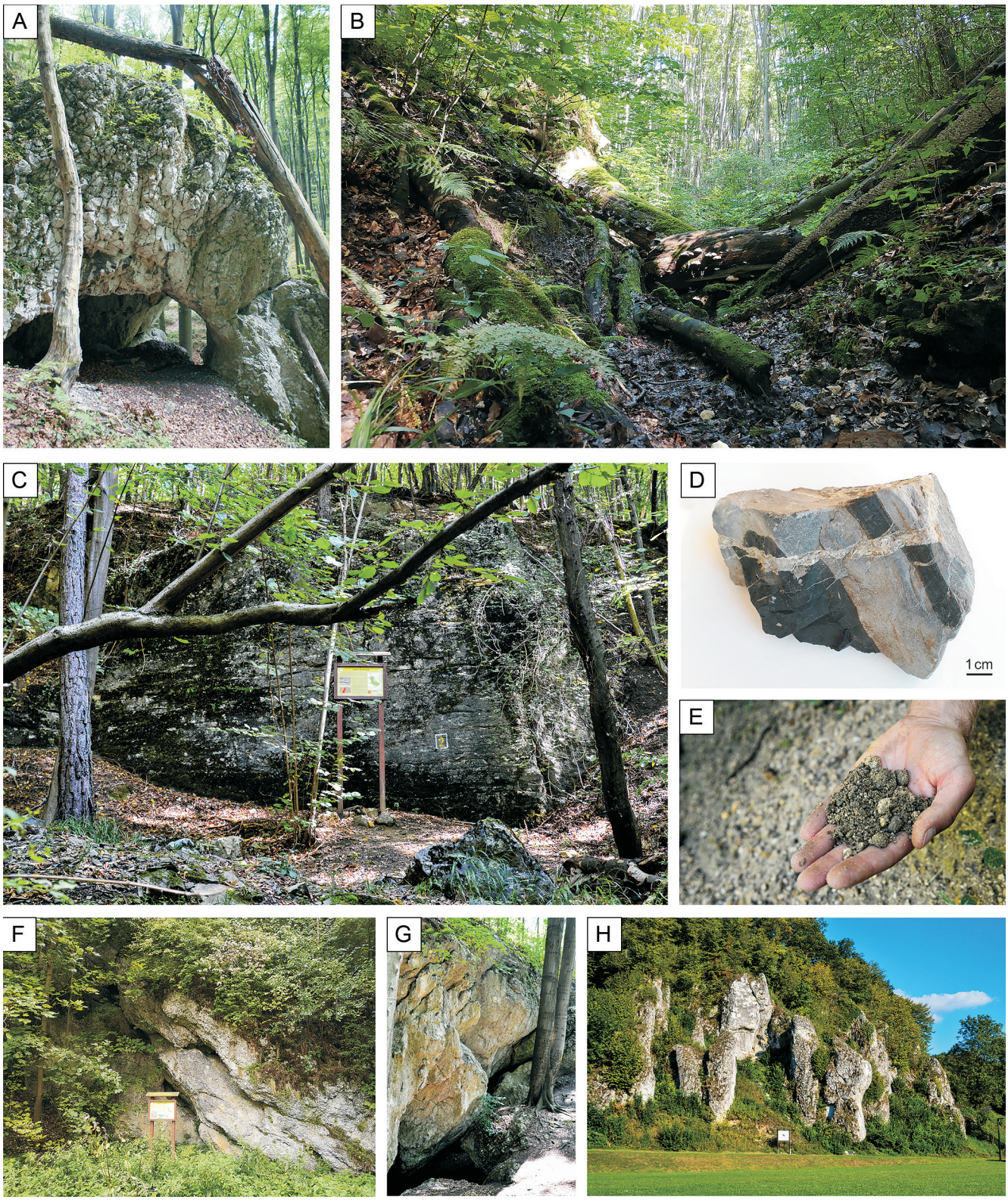


Fig. 3. Geosites on the yellow educational trail: A – rock shelter with a window in the Żarski Gorge; B – Żarski Gorge; C – Quarry with an Intrusion; D – tectonics in micro scale in Lower Carboniferous limestone with flints from Quarry with an Intrusion; E – loose variety of calcareous tufa from a pile strewn by the Szklarka River side; F – Jurassic rocks; G – entrance to the Żarska Cave; H – group of limestone rocks in Dubie. Photos: D. Andrejko (A, C, E, G, H), S. Bolek (B, F), A. Szreter (D)

The beginning of the trail is located along the fence of an active dolomite quarry. The andesite dike (Permian magma intrusion) can be spotted here. Next, the trail leads along the Zbrza Gorge, where one can find the oldest rocks exposed on the surface in the area of Krakow – the Zbrza dolomites. The next points on the trail are closed quarries in Dębnik: Siwa Góra, Karmelitów and the newest one. Two of them have been added to the existing trail by the authors – the first one as an accessible terra rossa outcrop, the last one because of its impressive excavation and various nodular structures clearly visible in the limestone (Fig. 4). The way back leads through the Pisarski quarry with the perfectly visible Variscan fault.

The red educational trail is well marked and not very demanding, although it leads through more difficult terrain than the blue educational trail. Next to the red educational trail, an active quarry in Dubie is situated. It can be inconvenient for visitors, because of noise and the danger associated with blasting works or increased traffic of cars transporting the spoil.

Table 3. Geosites on the red educational trail. Authors' work based on vast literature (e.g. Gradziński, 1972; Bednarczyk, 1990; Lewandowska *et al.*, 2007; Słomka, 2012)

No.	Geosite GPS coordinates	Description	Lithology and age	Forms; structures; processes
1	**Dubie Quarry** N 50° 09' 39.1" E 19° 40' 57.9"	The large, active quarry of Zbrza dolomite. This is the oldest rock in the Krakow region. In the wall of the quarry karst forms can be seen (e.g., sinkholes), small faults and an andesite dyke (Permian magma intrusion).	Middle Devonian Zbrza dolomite, Permian andesite and terra rossa	anthropogenic outcrop (quarry); andesite dike, sinkholes, faults; metasomatism, contact metamorphism
2	**Zbrza Gorge** N 50° 09' 42.0" E 19° 40' 51.2"	Zbrza Gorge is formed in the Devonian dolomite. They are the oldest rocks found on the surface in the Krakow region. Their name – the Zbrza dolomites – comes from the name of the gorge, rich in outcrops of this rock.	Middle Devonian Zbrza dolomites, Pleistocene loess	gorge; downward erosion, mass movements, downhill creep
3	**Siwa Góra Quarry** N 50° 09' 43.3" E 19° 40' 14.1"	Small old quarry on the slope of Siwa Góra is a place of the former mining of the so-called Dębnik limestone. There are also large accumulations of terra rossa related to palaeokarst.	Middle Devonian Dębnik limestone, Permian terra rossa	anthropogenic outcrop (quarry); sinkholes, palaeokarst; chemical weathering
4	**Karmelitów Quarry** N 50° 09' 52.8" E 19° 40' 18.9"	This old quarry was the source of the most famous building stone in the vicinity of Krakow. The limestone is one of the oldest rocks in the region. Sinkholes, clastic dyke and limestones changed by metamorphism and metasomatism can be observed there.	Middle Devonian Dębnik limestone, Dungeon Marble	anthropogenic outcrop (quarry); sinkholes filled with terra rosa, clastic dyke, superficial karst; metasomatism, tectonic processes
5	**New Quarry in Dębnik** N 50° 10' 02.6" E 19° 40' 29.8"	Dębnik limestone – with such fossils as amphiporas and corals – constitutes a remnant of the Devonian sea. Nodular limestone indicates changes of the sedimentary condition, such as sea level or environmental fluctuations.	Middle Devonian Dębnik limestone	anthropogenic outcrop (quarry); nodular limestone, fossils
6	**Pisarski Quarry** N 50° 09' 52.1" E 19° 41' 07.9"	Dębnik limestone and stromatoporoid limestone crop out in the old quarry. A fault plane is clearly visible in the wall of the quarry. The fault is related to the tectonic movements of the Variscan orogeny.	Middle Devonin Dębnik limestone, Upper Devonian stromatoporoid limestone	anthropogenic outcrop (quarry); fault, joints; faulting, Variscan tectonic activity

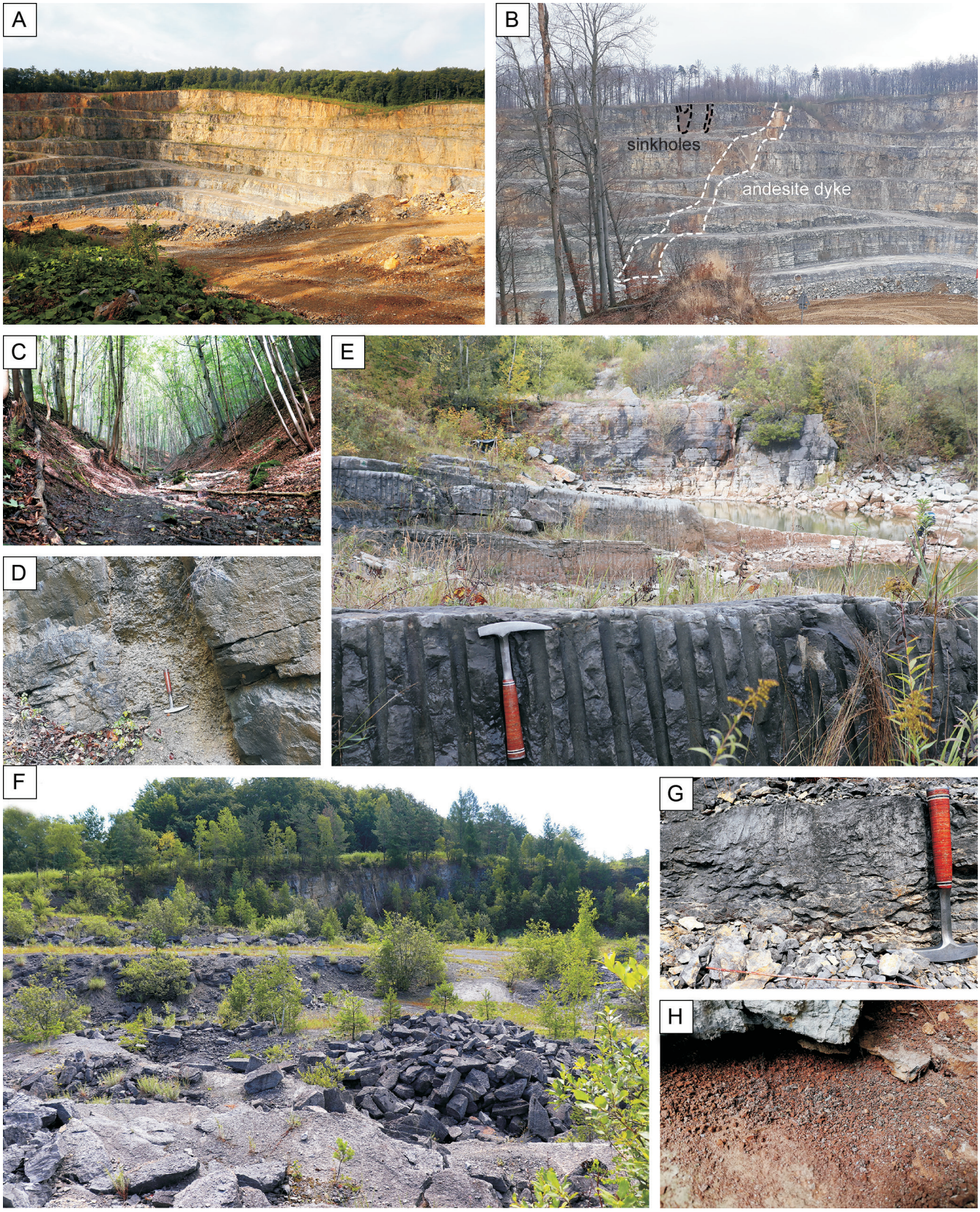


Fig. 4. Geosites on the red educational trail: A – vast pit of the Quarry in Dubie; B – andesite dyke in the SE wall of the Quarry in Dubie; C – Zbrza Gorge; D – dyke in the Karmelitów quarry; E – wedge marks in the the Karmelitów quarry, the quarry itself in the background; F – the new quarry in Dębnik; G – nodular structures in Devonian limestone in the new quarry in Dębnik; H – terra rossa in the Siwa Góra quarry. Photos: K. Rzepka (A, C, E-G), S. Skoczylas-Śniaz (H), A. Szreter (B, D)

Results

Geotourism valorisation

The results of the geotourism valorisation of all 21 geosites located along the three educational trails are given in the Supplementary Material and summarised in Table 4. The evaluated criteria are divided into three categories mentioned above.

Visual values are essential for individual geoeducation, because these are the first to be noticed by the visitors. The willingness to learn more about an object is strongly related to the first impression. If a tourist becomes interested in an object, they will start to ask questions such as: "Why is it there?", "How did it appear?", "Why does it look like this?" etc. (Różycki, 2006). It is clear that the geosites composing each trail have diversified visual values, with the most visually attractive objects located at the beginning and close to the end of each trail. This can encourage visitors to continue their trip, and it leaves a good impression and memories after completing the trail. Moreover, objects with the highest visual values can be used in the promotion of the reserve, as intriguing sights and spots attracting tourists. For example, in the three geotourism guidebooks prepared by the GSSC, such points were used on the covers.

Cognitive values as a category can be used to assess in a straightforward way the educational quality of a given object, its uniqueness and representativeness. The better a geosite represents the theory, the more successful geoeducation takes place in practice (Doktor *et al.*, 2015). In the Racławka Valley Nature Reserve, cognitive values of geosites vary strongly within each trail and between the trails. On the one hand, this justifies the need for the existence of all three trails. On the other hand, it can be helpful in spotting sites for intense exploration of geoheritage, as well as those that are more suitable for presenting less complex issues or just for rest and breaks. One criterion of geodiversity, the number of readable features, was split into particular features and presented in Table 5, as especially important for geoeducational purposes.

It is not surprising that the red trail collected the highest notes, with a mean value of 11.7. Relatively young, anthropogenic outcrops in open pit mines, which dominate this trail, exhibit a vast range of geological forms and processes. These geosites are also broadly described in the literature. On the yellow trail, the Żarska Cave and the Quarry with an Intrusion are outstanding, while other geosites on the left bank of the Szklarka stream received relatively low scores. The blue trail is balanced with respect to the cognitive value of its geosites. The only outstanding points are Calcareous Tufa and Racławka Stream. The low difficulty of this trail corresponds well with its intermediate educational values.

Functional values are especially important from the organiser's point of view (i.e. for a teacher, lecturer or guide), as they are connected with safety conditions (Doktor *et al.*, 2015). The comfort of the visitors is not so important for geoeducation, however, travel difficulties may limit access for some groups. The red trail again wins in this aspect, thanks to its good marking, relative ease and accessibility from both Dębnik and Dubie villages (two 'ends', or most distant points of a loop). It received additional points for cultural sites in Dębnik. The blue trail is relatively balanced in this aspect. Potential difficulties in completing the yellow trail are reflected in its functional values score. Some investments improving the safety of visitors are inevitable here. An outstanding point along this trail is located in the Trout Valley (Dubie park) – a well-developed area, perfect for rest after completing any of the three trails.

Table 4. Summarized geotourism valorisation results. The detailed valorisation is given in the Supplementary Material

Category	Points	Blue trail							Yellow trail								Red trail					
		1. Racławka Stream	2. Calcareous Tufa	3. Carpathian Beech Forest	4.Skałka z Nyżą Rock	5. Stradlina Gorge	6. Bażana Spring	7. Mid-Jurassic Deposits	1. Żarski Gorge	2. Żarska Cave	3. Quarry with an Intrusion	4. Calcareous Tufa*	5. Carbonifereous Rocks	6. Jurassic Rocks	7. Limestone Rocks	- Rock by the Bridge**	1. Dubie Quarry	2. Zbrza Gorge	3. Siwa Góra Quarry	4. Karmelitów Quarry	5. New quarry in Dębnik	6. Pisarski Quarry
Visual values	0–6	5	6	3	3	4	1	5	6	4	4	1	3	5	5.5	1.5	5	4	1.5	5.5	6	4
	mean	3.9							3.8								4.3					
Cognitive values	0–28	12	14	8	9	8.5	7	8	11	17	14	11	6	8.5	10	8.5	13	11	7.5	18	13	8
	mean	9.4							10.7								11.7					
Functional values	0–18	12	6	12	9.5	11	11	6	9,5	5	7	5	5.5	7	15	8	13	10	13	13	8	8
	mean	9.4							7.7								10.8					

* For this geosite the authors proposed a new location. Data presented in the table evaluate the original position of the geosite

** Geosite from the original trail, removed from the proposed trail and not presented on the map

Table 5. Evaluation of specific features of geosites (1 point – a feature is clearly visible; 0.5 point – it can serve as an example when additional educational materials are used, e.g. a fault is not visible in an outcrop, but its presence between two outcrops can be deduced, or some fossils present in a rock are macroscopically invisible, but can be shown on a thin section)

Feature		Points	Blue trail							Yellow trail								Red trail					
			1. Racławka Stream	2. Calcareous Tufa	3. Carpathian Beech Forest	4. Skałka z Nyżą Rock	5. Stradlina Gorge	6. Bażana Spring	7. Mid-Jurassic Deposits	1. Żarski Gorge	2. Żarska Cave	3. Quarry with an Intrusion	4. Calcareous Tufa*	5. Carbonifereous Rocks	6. Jurassic Rocks	7. Limestone Rocks	- Rock by the Bridge**	1. Dubie Quarry	2. Zbrza Gorge	3. Siwa Góra Quarry	4. Karmelitów Quarry	5. New quarry in Dębnik	6. Pisarski Quarry
2.1. Geodiversity	geomorphology	0–0.5–1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	0	1	0	0	0	0
	hydrology	0–0.5–1	1	1	0	0	1	1	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0
	mineralogy	0–0.5–1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	0	1	0	0
	palaeontology	0–0.5–1	0	1	0	1	0	0	0	0	1	0	1	0.5	0.5	0.5	0.5	0	0	0	1	1	0
	pedology	0–0.5–1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	petrography	0–0.5–1	1	1	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
	sedimentology	0–0.5–1	0.5	1	0	0	0	0	1	0.5	1	1	1	0	0.5	0.5	0	1	0	1	1	1	0
	stratigraphy	0–0.5–1	0	0	0	0.5	0	0	0	0	0	0.5	0	0.5	0	0	0	1	1	1	1	1	0
	tectonics	0–0.5–1	0.5	0	0	0	1	0	0	0	1	1	0	0.5	0.5	1	0.5	1	0	0	1	0	1
	volcanology	0–0.5–1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0
	recent geological processes	0–0.5–1	1	0	1	0	1	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0
	others	0–0.5–1	0	0	1	1	1	1	0	1	1	0	0	0	1	1	0	1	0	0	1	1	0
	Sum of points	0–12	5	6	3	4.5	5	2	4	5	8	5.5	5	3.5	4.5	5	3	7	5	3	9	5	2

* For this geosite the authors proposed a new location. Data presented in the table evaluate the original position of the geosite

** Geosite from the original trail, removed from the proposed trail and not presented on the map

0 – absent; 0.5 – present, but invisible macroscopically; 1 – clearly visible in the field

Geoeducational information

In the quizzes designed for the guided groups, each question tested the understanding of a term used on an existing educational board. The translation of particular sections of the boards on the blue trail and questions related to them are given in Table 6. In all of the questions, the use of additional materials by a guide improved the participants' understanding of the topics presented on educational boards almost by two times or more (Fig. 5). In some cases, the terms were too specific and completely unclear for the participants without any further explanation. In fact, the explanation and materials used in this research were also not ideal, since the understanding of some terms barely reached 30%. Selected terms, like "stromatoporoid", may be too difficult for tourists, but others, like "monocline" (just 50% understanding), cannot be omitted on the boards.

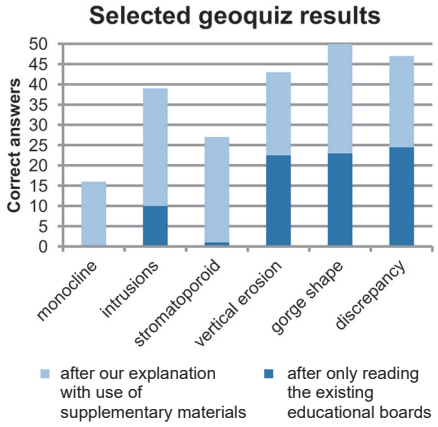


Fig. 5. Selected geoquiz results from the blue educational trail. Answers by 50 participants of four trips are divided into those given just after reading the educational board in place (firstly) and supplements made after our explanation (secondly)

Table 6. Selected questions from the quiz conducted on the blue educational trail and specific sections of the educational boards on which the questions were based. Original boards and quizzes were in Polish

Topic	Quotation from the board (translated, originally in Polish)	Question/task form the quiz
Monocline	There are also widespread Jurassic sediments, which were formed around 170–140 Ma ago, and later **monoclinally inclined**.	Draw the monocline.
Intrusions	In several places, the **Permian volcanic veins** are exposed, which cross the above-mentioned Devonian and Lower Carboniferous rocks.	Draw the Permian volcanic veins, crossing the Devonian and Carboniferous rocks.
Stromatoporoid	The rock exposes thick-bedded **stromatoporoid limestones formed on the seabed** at the turn of the Devonian and Carboniferous.	How were the stromatoporoid limestones formed?
Vertical erosion	The flowing water "cuts" into the rocks, constantly carving the bottom of the gorge. There are mainly **two types of erosion** here: **linear erosion** and **vertical erosion**.	What is the linear erosion and vertical erosion? Draw or write.
Gorge shape	The flowing water "cuts" into the rocks, constantly **carving the bottom of the gorge**. There are mainly two types of erosion here: linear erosion and vertical erosion.	Sign the pictures. Indicate the shape of a gorge and a gully.
Unconformity	**They lie inconsistently** on Devonian and Carboniferous limestones. This unconformity consists in the presence of Jurassic settlements at a different angle than the Devonian and Carboniferous rocks below.	What does it mean that the rocks lie inconsistently? Draw.

Questionnaires

Questionnaires were composed of 6 general, introductory questions, connected with visitors' previous experiences, and 4 specific questions, examining the perception of geoeducational materials, already available there on the spot and prepared by the authors.

The first part paints a general picture of the recipients. Although the groups came from Krakow or Olkusz (within 1 hour drive from the Racławka Valley), over 80% of participants were visiting the reserve for the first time. However, nearly half of them visited at least one of the other valleys near Krakow, and the Będkowska Valley was the most popular amongst them (37% of recipients have been there).

Despite the group consisting of tourists interested in Earth Sciences and prepared for geoeducation, the main factors drawing attention both in the field and on the educational board remained visual values (general outlook, pictures or schemes). The perception of the information presented on educational boards varied with age: high school students were partly satisfied with its range, while for adult groups the information available was usually insufficient. Consequently, for some pupils a few difficult terms appeared in our additional materials, while adult recipients found it rather comprehensible.

During field trips, we used separate boards or schemes to support geoeducational stories, but our long-term aim was to create a guidebook. What we learned from the questionnaires is that a mobile app would be another useful form of a 'guidebook'.

Discussion

Geoeducational potential of the trails

As presented above, each trail has its main theme and characteristics. However, most of the geosites present more than just one process, form or structure. It is possible, as such, to select and combine features from different stops or even trails, in order to prepare lessons and field trips focusing on a particular issue.

A good example is karst. These processes are widespread in the Krakow-Częstochowa Upland, and they can be spotted along all the three trails. The most spectacular is obviously Żarska Cave (yellow trail), with a variety of speleothems inside (note that currently, it is accessible only during some events organised by the Zespół Parków Krajobrazowych Województwa Małopolskiego – The Complex of Landscape Parks of the Małopolska Region, due to nature protection). Numerous monadnocks on blue and yellow trails exhibit small caves and niches often visible from the path. Water flowing out of the Bażana karst spring (blue trail) is evidence of its presence within the rocks around. Former karst activity left its mark on the red trail. On the walls of two quarries, mining activity excavated Permian/Triassic sinkholes filled with terra rossa (Gradziński, 1972). Although all three trails are out of reach during a single trip, it is possible to combine the blue trail with the Żarska Cave or the yellow trail with palaeokarst in the quarry in Dubie.

Another issue straight from the schoolbooks is a set of traces of endogenous processes shaping the Earth's surface.

A small volcanic dyke is hidden in the Quarry with an Intrusion on the yellow trail. The rhyolite itself is strongly weathered there, and yellow, metamorphosed limestone in the contact zone is better evidence of the volcanic processes. More spectacular changes of rocks in the contact zone (from black limestones or dolomites to white or colourful ones) can be observed in quarries in Dubie and Dębnik on the red trail (e.g. Muszyński & Wyszomirski, 1998; Kania *et al*., 2016). In addition, in Dubie an andesite dyke is perfectly visible in the quarry's south-east wall. Other intrusions shaped the landscape on the Zamczysko Ridge (close to the red trail), where a small pass appeared over metamorphosed, weakened rocks, while rhyolite dikes make up the elevated parts. Combining those venues with tectonic faults, fissures and cleavage occurring on each trail (big ones on the yellow trail, smaller on blue and red) with a short explanation of rock formations make up a field lesson concerning endogenous processes.

Exogenous processes like weathering, erosion or mass movements are even better visible and more abandoned along the trails. Less exposed, but thanks to this more mysterious and intriguing, are the palaeontological venues. The youngest – Quaternary – fossils are present on the blue trail, in calcareous tufa exposure (imprints, encrustations and subfossil remains) and Skałka z Nyżą Rock (lichen stromatolites). The latter formation itself is a buildup of another organism, stromatoporoid, which cannot be spotted at the outcrop. The yellow trail offers two more stories about the marine life of the past. The Group of Carboniferous Rocks is built of limestone with brachiopods, a very characteristic group for this period of time. Neighbouring Jurassic rocks are made of sponges. However, fossils are far better visible in the Karmelitów quarry and, occasionally, in the new quarry in Dębnik on the red trail. For this reason, combining the red trail and parts of the blue trail should work well. Popular fossils, like Jurassic ammonites, can be found at the bottom of the Racławka stream.

The above-mentioned issues do not exhaust the topic. Sessions concerning mineralogy, petrography, palaeoenvironments or relations between human and abiotic nature can be successfully prepared as well.

Target groups

Educational trails in the Racławka Valley can be useful for pupils and students as a supplement of knowledge, which they gain during education. One of the target groups consists of high school students of geography at an advanced level. The current core curriculum assumes that students will acquire knowledge of the lithosphere related to the structure of the earth's interior, tectonics, processes shaping the Earth's surface, and types of rocks that build the Earth's crust. Students should be able to identify the most important Earth modelling processes or the main types of rock (Dz.U. z 2017 r., poz. 59, 949 i 2203). The geosites in the Racławka Valley give a real example of these issues. Specific examples in the field will demonstrate the basic processes shaping the Earth's surface, such as the karst phenomena, as well as perfectly display the rocks occurring in the area of the nature reserve.

For students, educational trails in the Racławka Valley can become a place for field classes in the field of Earth sciences. Students of fields such as geology, geography, geotourism, and even nature conservation can take field classes there, because the geosites located on the educational trails illustrate the issues included in the curricula. In this case, along all three trails, students will be able to spot the most important issues raised during classes in the lecture halls and systematise the acquired knowledge.

For individual tourists, the Racławka Valley can be a place for an interesting trip, combining open-air activities with learning new topics. When planning a trip, either as individuals or for a group, it is essential to pay attention to the trails' special traits (mentioned in the Trails description above and Limitations below), as some of the paths are suitable for leisure walks, and some exhibit features that make them rather adventurous.

Limitations

All three trails are marked with symbols of the appropriate colour. Both the blue and the red trails have very good markings. The last trail – the yellow one – is not clearly marked out, and it can be difficult to find the path and signs, especially in the growing season (Fig. 6).

Fig. 6. Unmarked ford in the Szklarka Valley, yellow educational trail. Photo: A. Szreter

Infrastructure for tourists including benches, tables and litter bins is restricted to the blue trail, and lacking in others. Noteworthy are the car parks located right next to the trails, which enable starting the hike directly along the chosen trail. However, it should be mentioned that the trails (especially the yellow and red ones) are not adapted to the elderly or people with physical disabilities. Therefore, for some groups of tourists, trips to the Racławka Valley Nature Reserve may be difficult.

The blue educational trail is the longest and the easiest in terms of terrain difficulties and fitness requirements. The

route runs along the bottom of the Racławka Valley, through generally flat terrain, with only a few ascents. The gentle nature of the trail makes it popular and easily accessible even for families with small children and prams or cyclists. No special equipment or good stamina is required to complete it. Only for elder people it can be demanding, as there are no benches along the second half of the trail. The situation is completely different with the yellow trail, running through difficult terrain with considerable ascents. Due to poor signs and no bridges, walking this trail can be a challenge or an interesting adventure – provided that one is well prepared. Both good stamina and orientation in the field will be useful there. The red educational trail is relatively easy and straightforward, however, it can be difficult for people with small children and prams due to uphill climbs. It should not be a problem for average tourists, but it requires a certain level of good physical condition.

The vast majority of the educational trails are located in the Racławka Valley Nature Reserve. Only fragments of the yellow and red trail go beyond the reserve area or run along its border. These parts are still included in a landscape park, however, some elementary geological fieldwork is possible on those restricted sections of the trail.

The red trail runs almost through the area of the active quarry in Dubie. For this reason, it is important to observe special safety precautions. Due to the work of the quarry, from Monday to Friday from 10 a.m. to 3 p.m. shooting may occur. At this time visitors are not allowed to approach the quarry, because there is a risk of getting hit by a piece of rock.

Sources of information

There are various, though insufficient ways to find out more about the Racławka Valley before the visit. Geological studies and tourism publications about the reserve are available mainly in Polish (e.g. Gołas-Siarzewska, 2010; Joniec & Słomka, 2012). Literature in English is usually more specific and connected with particular geosites (e.g. Lewandowska *et al.*, 2007; Kania *et al.*, 2016). Some records about the Racławka Valley are contained in tourism guidebooks, drawn up by specialists from ZPKWM, which include publications about various landscape parks (e.g. Dmytrowski *et al.*, 2013). Unfortunately, this is usually restricted to short notices, and geology is barely mentioned. Publications are available at the ZPKWM head office, and for a free download from their website (zpkwm.pl). Publications more devoted to the Racławka Valley are usually old. The most extensive guidebook was published half a century ago (Gradziński, 1972), and even some pieces of information from the guidebook "Georóżnorodność i atrakcje geoturystyczne województwa małopolskiego" (Radwanek-Bąk, 2009) are no longer valid.

It is also possible to find information on the Internet, for example on amateur travel blogs, however geological information contained in those blogs can be uncertain or unreliable. There is no official website of the reserve. On the one of ZPKWM, there is only a brief mention of the geology and geomorphology of the landscape park. Even more so, there are no interactive sources of information, like mobile apps. The demand for such was pointed out in the questionnaires. However, creating them would be challenging, as there is no coverage in the valleys and GPS precision can be restricted, so the app would have to be based on other solutions.

All these points emphasise the need for creating new, reliable materials of that kind, already pointed out by Gołas-Siarzewska (2010). Trying to answer that demand, the Geotourism Students' Scientific Club created its own three geological tourism guidebooks, one for each educational trail (Fig. 7). The guidebooks contain geological descriptions written in a reader-friendly way, sketches, diagrams, photos, and extra information about objects marked on the routes and other interesting places in the Racławka Valley Nature Reserve. Being an effect of the rector's grant projects in the years 2018–2020, the guidebooks were printed only in a limited number of copies (available from the GSSC). Efforts are made to publish them in a more accessible form.

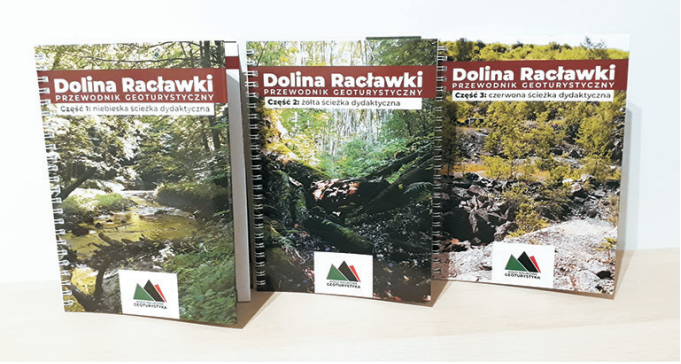


Fig. 7. Geotourism guidebooks around the trails in Racławka Valley Nature Reserve, prepared by the GSSC as a part of rector's grant projects in the years 2018–2020. Photo: A. Szreter

In the field, three educational trails are equipped with fourteen geological information boards. They used to be located at every geosite on the routes. Currently some are missing or in poor condition. Containing geological cross-sections, maps, parts of the stratigraphic charts and short descriptions of processes that shape landforms, the boards show some part of local geological history. In 2021, information boards on the red trail were replaced with new ones. Unfortunately, some misleading solutions were used on the new boards, e.g. marking quarries and heaps with colours on a geological map (where colours are reserved for the age of particular rock formations), mixing two fault divisions on one sketch without notice (as a result, no difference can be seen between normal and dip-slip fault) or imprecise marking of the geosite (according to the map, there is neither a quarry nor the described rock formations). Introducing some substantive corrections would be useful, as well as taking this into account during preparation of new boards for the remaining trails.

Fig. 8. Guided tour for high school students led by the GSSC members. Photos: GSSC archives (left), E. Wojtasik (right)

Finally, visitors can get to know the Racławka Valley in an active way. GSSC drew up quests and quizzes for this purpose, which are included in the mentioned guidebooks. Along three educational trails, visitors will estimate geological knowledge and learn more about the Racławka Valley nature. They can also use an interactive open-air exhibition with a lapidarium in Dubie. Furthermore, during some local events (e.g. annual Trout Days) guided trips are held in the reserve, and some periodic tours (though mostly focused on biotic nature) are advertised on the ZPKWM fanpage. At other times, organising a guided trip is possible in collaboration with the GSSC (Fig. 8). Students have developed educational materials for amateurs that explain the Racławka Valley geology in an accessible manner. More information is available on the group website (geoturystyka.agh.edu.pl).

Development opportunities

Although advantageous in many ways, the educational trails in the Racławka Valley Nature Reserve are not new, and a few upgrades can be proposed (such issues have already been raised by Gołas-Siarzewska in 2010). This is especially true for the yellow trail, which requires a thorough reconstruction: better marking of the trail, creating safe passages and building footbridges over the river. Seasonal differences in visibility of marks, connected with vegetation, should be taken into account. In fact, an unmarked pass across the river is at present (June 2022) perhaps the biggest challenge for visitors (Fig. 6). Some other difficulties are connected with private property extending to some of the geosites. In ZPKWM, there are some plans to change the course of the trail to just one side of the river, which would also solve the problem at the expense of four geosites from the trail (ZPKWM management, pers. comm., 2021). Omitting these sites should not deplete the trail of its key values, while it can substantially improve the comfort and safety of sightseeing. Only the Quarry with an Intrusion should definitely be preserved on the trail as a documentation site with outstanding cognitive values, having no equivalents elsewhere along the trails. The most popular blue trail could be made accessible for older people by installing some facilities (especially benches) along the second half of the trail. For geoeducational purposes, one thing has to be improved on the trail: Calcareous Tufa, geosite with the highest visual and cognitive values, is currently unmarked and lacking an educational board. A more ambitious idea would be presenting the rock's structure in situ, on polished fragments of some outcrops. This approach is currently underutilised in other parks, but where it has been taken it has been successful (Koptík, 2009; point 3.6; photo 3). Alternatively, such a presentation could be prepared in the lapidarium in Dubie.

Some of the improvements have already begun when the project "Raj w Dolinie Racławki" (eng. "Paradise in the Racławka Valley") was awarded in the Civic Budget of the Lesser Poland Voivodeship voting in 2016. The project was proposed by a local activist from Krzeszowice and is currently implemented by ZPKWM (www1, www2). Eventually, the ZPKWM is planning to develop tourism infrastructure in the Racławka Valley and to make Żarska Cave, the most unique and worth seeing place for potential visitors, available for tourists (ZPKWM management, pers. comm., 2021).

Conclusions

Owing to its landscape value, the multiplicity of interesting geological objects and the considerable size of the area, the Racławka Valley Nature Reserve, with its three trails is an interesting area for tourism and geoeducation. Educational trails in the reserve lead along more than twenty geosites, encompassing a wide range of geological forms and processes, as well as morphological forms and traces of ancient life. Each trail has its main theme, and they can also be combined in order to spot numerous forms connected with one topic during a single trip. The trails are also diversified

in terms of length, elevation, facilities and accessibility of geosites, thus appropriate for various groups and types of activities. This should be taken into account when planning a trip. Nevertheless, high school and university students can manage all those routes, which makes it possible to realise part of their curriculum during field lessons in the Racławka Valley. Visitors can gain geological knowledge from educational boards placed along the trails or from a few publications, including the three geotourism guidebooks designed in the years 2018–2020 by the Geotourism Students' Scientific Club. However, there is still a demand for some new materials, both printed and digital. Despite the great attractiveness of this terrain, it is necessary to focus on improving the development of the reserve area. It is especially important for the managers of the reserve to take care of the condition of the educational boards and trail markings. It is expected that the trails and related infrastructure will be renovated within a few years. After completing these works, the trails can successfully serve as geoeducation sites for individual tourists. With the current level of development, they are most suitable for organised forms of geoeducation.

Acknowledgments

The three-year-long, complex project has been led by 15 students in total, some of whom continued this work year by year. The idea came from late Prof. Marek Doktor, and the precursor among students was Katarzyna Rzepka. The project was financed from the rector's grant annual competition organised by the Vice-Rector of Student Affairs in the years 2018–2020. We are grateful for all the support received mostly (but not only!) from the AGH UST employees, especially from Dr Ewa Welc, whose advice improved the quality of valorisation. Our thanks go to Dr Elżbieta Gałka, the GSSC's tutor in the years when the project was held. We would like to thank Dr Mariusz Paszkowski and the second reviewer for their helpful comments, with special thanks to the former for sharing the map with us. Words of gratitude are also due to the students from XVI LO in Krakow (and teacher Małgorzata Borońska-Dąbroś), II LO in Krakow (and teacher Eliza Wojtasik) and IV LO in Olkusz (and teacher Anna Kula), who participated in guided tours and supported this research with quizzes, questionnaires and helpful comments.

References

Bednarczyk J., 1990. Geneza struktur gruzłowych w wapieniach dębnickich (żywet/fran) w świetle badań sedymentologicznych i analizy zawartości izotopów stałych węgla i tlenu. *Przegląd Geologiczny*, 38(4): 206–209.

Dmytrowski P., Gał A. & Kołodziejczyk M., 2013. *Park Krajobrazowy Dolinki Krakowskie. Miniprzewodnik*. Zawartka J. (red.), Zespół Parków Krajobrazowych Województwa Małopolskiego, Kraków.

Doktor M., Miśkiewicz K., Welc E.M. & Mayer W., 2015. Criteria of geotourism valorization specified for various recipients. *Geotourism*, 3–4(42–43): 25–38.

Dz.U. z 2017 r., poz. 59, 949 i 2203 – *Rozporządzenie Ministra Edukacji Narodowej z dnia 30 stycznia 2018 r. w sprawie podstawy programowej kształcenia ogólnego dla liceum ogólnokształcącego, technikum oraz branżowej szkoły II stopnia. Załącznik nr 1. Podstawa programowa kształcenia ogólnego dla czteroletniego liceum ogólnokształcącego i pięcioletniego technikum*.

Dz.Urz. Woj. Małop. z 2020 r., poz. 3481 – *Uchwała nr XX/276/20 sejmiku województwa małopolskiego z dn. 27 kwietnia 2020 roku w sprawie ustanowienia planu ochrony dla Parku Krajobrazowego Dolinki Krakowskie uwzględniającego zakres planu zadań ochronnych dla obszaru Natura 2000 Dolinki Jurajskie PLH120005, Załącznik nr 1. PLAN OCHRONY DLA PARKU KRAJOBRAZOWEGO DOLINKI KRAKOWSKIE uwzględniającego zakres planu zadań ochronnych dla obszaru Natura 2000 Dolinki Jurajskie PLH120005.*

Dżułyński S., 1953. Tektonika południowej części Wyżyny Krakowskiej. *Acta Geologica Polonica*, 3(3): 325–440.

Gołas-Siarzewska M., 2010. Krzeszowice – turystyka w zgodzie z naturą. *Wszechświat*, 111(04–06): 132–136.

Gradziński R., 1972. *Przewodnik geologiczny po okolicach Krakowa*. Wydawnictwa Geologiczne, Warszawa.

Gromczakiewicz-Łomnicka A., 1979. Conodont stratigraphy of the Uppermost Devonian and Lower Carboniferous rocks in the Racławka and Szklarka valleys west of Cracow. *Acta Geologica Polonica*, 29(4): 489–498.

Joniec A. & Słomka T., 2012. The Racławka River Valley. Exceptional valley near Kraków unites the scenic landscape with the plethora of geosites and geological processes. In: Słomka T. (red.), *Katalog obiektów geoturystycznych w obrębie pomników i rezerwatów przyrody nieożywionej / The Catalogue of Geotourist Sites in Nature Reserves and Monuments*. AGH Akademia Górniczo-Hutnicza. Wydział Geologii Geofizyki i Ochrony Środowiska. Katedra Geologii Ogólnej i Geoturystyki, Kraków: 271–275.

Kania M., Muszer A. & Maliszewski M., 2016. Przejawy okruszcowania U-Pb-Zn-Cu-Ni w kopalni dolomitów Dubie (Wyżyna Krakowsko-Częstochowska). *Górnictwo Odkrywkowe*, 4: 39–45.

Kędzierski M., Kołodziej B., Hoffmann M., Machaniec E., Stworzewicz E. & Szulc J., 2013. Budowa geologiczna i paleontologia regionu krakowskiego: dolny perm, środkowa i górna jura, górna kreda. Sesja terenowa B. In: Kędzierski M., Kołodziej B. (red.), *Aktualizm i antyaktualizm w paleontologii. XXII Konferencja Naukowa Sekcji Paleontologicznej Polskiego Towarzystwa Geologicznego, Tyniec, 27–30 września 2013 r., materiały konferencyjne.* Polskie Towarzystwo Geologiczne, Tyniec: 27–30.

Koptík J., 2009. *Plán péče o přírodní památku Granátová skála na období 2010–2019*. DAPHNE ČR – Institut aplikované ekologie, České Budějovice.

Kubalíková L., 2013. Geomorphosite assessment for geotourism purposes. *Czech Journal of Tourism*, 2(2): 80–104.

Lewandowska A., Banaś M. & Zygoń K., 2007. K-Ar dating of amphiboles from andesite of complex dyke in Dubie (southern Poland). *Geochronometria*, 27: 11–15.

Maciejowski W., Skalski T. & Kędzior R., 2013. Waloryzacja środowiska przyrodniczego rezerwatu krajobrazowego Dolina Racławki dla potrzeb turystyki i rekreacji. *Studia i Materiały Centrum Edukacji Przyrodniczo-Leśnej*, 37(4): 206–212.

Matyszkiewicz J., Felisiak I., Hoffmann M., Kochman A., Kołodziej B., Krajewski M. & Olchowy P., 2015. Transgressive Callovian succession and Oxfordian microbial-sponge carbonate buildups in the Kraków Upland. In: Haczewski G. (ed.), *Guidebook for field trips accompanying 31st IAS Meeting of Sedimentology, held in Kraków on 22nd–25th of June 2015*. Polish Geological Society, Kraków: 51–73.

Miśkiewicz K., Doktor M. & Słomka T., 2007. Naukowe podstawy geoturystyki – zarys problematyki. *Geotourism*, 4(11): 3–12.

Muszyński M. & Wyszomirski P., 1998. Przeobrażenia kontaktowe węglanowych skał dewonu w okolicach Dubia koło Krakowa. *Geologia / Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie*, 24(3): 199–217.

Olaczek R., 2008. *Skarby przyrody i krajobrazu Polski*. Zakrzewski M. (red.), MULTICO Oficyna Wydawnicza, Warszawa.

Paszkowski M., 1997. *Uppermost Devonian and Missisippian perilittoral and subaerial carbonate deposits in Dębnik area*. Unpublished PhD Thesis. Institute of Geological Sciences, Polish Academy of Sciences, Kraków.

Radwanek-Bąk B. (ed.), 2009. *Georóżnorodność i atrakcje geoturystyczne województwa małopolskiego. Przewodnik*. Departament Rolnictwa i Geologii Urzędu Marszałkowskiego Województwa Małopolskiego, Zespół Geologii, Wydawnictwo Compass, Kraków.

Reynard E., 2004. Geosite. In: Goudie A.S. (ed.), *Encyclopedia of Geomorphology* (vol. 1). Routledge, London.

Różycki P., 2006. Metodyka prowadzenia imprez geoturystycznych. *Geoturystyka*, 2(5): 29–32.

Słomka T. (red.), 2012. *Katalog obiektów geoturystycznych w obrębie pomników i rezerwatów przyrody nieożywionej / The Catalogue of Geotourist Sites in Nature Reserves and Monuments*. AGH Akademia Górniczo-Hutnicza. Wydział Geologii Geofizyki i Ochrony Środowiska. Katedra Geologii Ogólnej i Geoturystyki, Kraków.

Szczurek S., Bąk M. & Dulemba P., 2016. The Racławka Valley – an example of an educational geosite related to the development of a Paleozoic carbonate platform. *Geotourism/Geoturystyka*, 1–2(44–45): 45–56.

Szulc J., 1997. Lichen stromatolites. In: *Guidebook and Abstracts. 3rd Regional Symposium of International Fossil Algae Association, 3rd International Meeting of IGCP 380, September 14–20, 1997, Cracow, Poland*. Institute of Geological Sciences, Jagiellonian University, Cracow: 36–37.

www1 – https://zpkwm.pl/o-nas/nasze-projekty/raj-w-dolinie-raclawki/ [access: 2022.07.05].

www2 – https://bo.malopolska.pl/wyniki/1-edycja [access: 2022.07.05].

www3 – https://geologia.pgi.gov.pl/arcgis/apps/MapSeries/index.html?appid=8d14826a895641e2be10385ef3005b3c [access: 2022.07.05].

SUPPLEMENTARY MATERIAL:
Geotourism valorisation results

Evaluated trait			Points	Blue trail							Yellow trail								Red trail					
				1. Racławka Stream	2. Calcareous Tufa	3. Carpathian Beech Forest	4. Skałka z Nyżą Rock	5. Stradlina Gorge	6. Bażana Spring	7. Mid-Jurassic Deposits	1. Żarski Gorge	2. Żarska Cave	3. Quarry with an Intrusion	4. Calcareous Tufa[1]	5. Carboniferous Rocks	6. Jurassic Rocks	7. Limestone Rocks	- Rock by the Bridge[2]	1. Dubie Quarry	2. Zbrza Gorge	3. Siwa Góra Quarry	4. Karmelitów Quarry	5. New quarry in Dębnik	6. Pisarski Quarry
1. Visual values	1.1. Prominence in the landscape (indistinct/distinct)[3]		0–1	1	1	0	0	1	0	1	1	0	1	0	0	1	1	0	1	1	0	1	1	1
	1.2. Dominant element	A. Size (indistinct/distinct)	0–1	1	1	1	0	1	0	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1
		B. Shape (indistinct/distinct)	0–1	1	1	0	1	1	0	1	1	1	1	0	0	1	1	0	1	1	0	1	1	1
		C. Colour (indistinct/distinct)	0–1	1	1	1	1	0	0	1	1	1	0	0	1	1	1	0	1	0	1	1	1	0
	1.3. Naturalness of landscape (industrial zone or high-density housing / scattered settlement/ undeveloped area)		0–0.5–1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.5	0.5	0	1	0.5	0.5	1	1
	1.4. Outlook (absent/present)		0–1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	1	1	0
	Sum of points for visual values		**0–6**	**5**	**6**	**3**	**3**	**4**	**1**	**5**	**6**	**4**	**4**	**1**	**3**	**5**	**5.5**	**1.5**	**5**	**4**	**1.5**	**5.5**	**6**	**4**
2. Cognitive values	2.1. Geodiversity	A. Number of readable features[4]	0-12	5	6	3	4.5	5	2	4	5	8	5.5	5	3.5	4.5	5	3	7	5	3	9	5	2
		B. Preservation (poorly visible / partly visible / distinct)	0–0.5–1	1	1	1	0.5	0.5	0	1	1	1	1	1	0.5	1	1	0.5	1	1	0.5	0.5	1	1
		C. Uniqueness (local scale / country scale / worldwide)	0–0.5–1	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.5	0
		D. Representativeness (no/yes)	0–1	1	1	1	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	0	1	1

Evaluated trait				Points	Blue trail							Yellow trail								Red trail					
					1.	2.	3.	4.	5.	6.	7.	1.	2.	3.	4.	5.	6.	7.	-	1.	2.	3.	4.	5.	6.
2. Cognitive values	2.1. Geodiversity	E. Appearance in the literature[5]	scientific, international (no/yes)	0–1	1	1	1	1	0	0	0	0	1	1	1	1	0	0	1	1	1	0	1	1	0
			scientific, domestic (no/yes)	0–1	1	1	0	0	1	1	0	1	1	1	1	0	0	0	0	1	1	0	1	1	1
			popular science (no/yes)	0–1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	2.3. Cultural links	A. Geomithology (legends, cults, cult sites) (absent/present)[6]		0–1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		B. Historical/archeological importance (absent/present)		0–1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0
		C. Mining, industrial, technical heritage (absent/present)		0–1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	1	1	1
		D. Industrial stones in construction and architecture (absent/present)		0–1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
		E. Others (artistic, cultural landscape, history of science) (absent/present)		0–1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0
	2.4. Additional values	A. Specific fauna/flora habitat (absent/present)[7]		1	0	0	1	0	0	0	0	1	0	0	0	1	1	1	0	1	0	0	0	0	1
		B. Form of domestic legal protection	site protection (absent/present)	0–1	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
			areal protection (absent/present)	0–1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	1
			cultural monument (absent/present)	0–1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		C. International appreciation (absent/present)		0–1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
	Sum of points for cognitive values			**0–28**	**12**	**14**	**8**	**9**	**8.5**	**7**	**8**	**11**	**17**	**14**	**10**	**6**	**8.5**	**10**	**8.5**	**13**	**11**	**7.5**	**18**	**13**	**8**
3. Functional values	3.1. Accessibility	A. Availability (closed area / limited / full)		0–0.5–1	1	0.5	1	1	1	0.5	1	1	0	1	0	1	1	1	1	0	1	1	0	1	1
		B. Transport modes (less than 100 m from the object)	public transport (absent/present)[8]	0–1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			private transport (absent/present)	0–1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0
			bike trail (absent/present)	0–1	1	1	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0

3. Functional values		C. Pedestrian access – distance to be covered by walk (no pathway / more than 500 m / less than 500 m)[9]		0–0.5–1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1	0.5	1	0	0.5	0.5	1	0	1	0.5	1	1	1	0.5
		D. Trail difficulty rating (difficult/moderate/easy)		0–0.5–1	1	1	1	1	0.5	1	0.5	0.5	0.5	0	0	0	0.5	1	0.5	1	1	1	1	1	0.5
	3.2. Location of other tourism objects (up to 1 km)	A. Natural objects (no/undeveloped/developed)[10]		0–1	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0.5	0.5	0.5	0	0.5	0	0	0
		B. Cultural objects (absent/present)		0–1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0,5	1	1	1	1	0,5
		C. Settlement with services (absent/present)		0–1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3.3. Trip hazards (present/absent)			0–1	1	1	1	1	1	1	0	1	1	0	0	0	0	1	0	1	1	1	1	1	1
	3.4. Tourism infrastructure	A. Parking (absent/present)		0–1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
		B. Technical and sanitation infrastructure (picnic sites, toilets, bins) (absent/present)		0–1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
		C. Gastronomic facilities on site (absent/present)		0–1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		D. Accommodation (within 1 km distance) (absent/present)		0–1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		E. Blazed trails in the vicinity (tourist, thematic, etc.) (absent/present)		0–1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	3.5. Blazing	A. Blazed access to the object (absent/present) e.g. maintained and blazed route		0–1	1	0	1	1	1	1	0	1	0	1	1	0	1	1	0	1	1	0	1	0	1
		B. Information on site (absent/present)		0–1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	0	1
	3.6. Information about the object[11]	A. General information materials	available on site (absent/present) e.g. contents of information panels	0–1	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0
			available outside the object (absent/present) e.g. webpages, leaflets	0–1	1	0	1	0	1	1	0	1	1	0	0	0	0	1	0	1	0	1	1	0	0

Evaluated trait				Points	Blue trail							Yellow trail								Red trail					
					1.	2.	3.	4.	5.	6.	7.	1.	2.	3.	4.	5.	6.	7.	-	1.	2.	3.	4.	5.	6.
	3.6. Information about the object	B. Geoeducational information materials (popular science)	available on site (absent/present) e.g. contents of information panels	0–1	0	0	0	1	1	1	1	1	0	1	1	1	1	0	1	1	1	0	1	0	1
			available outside the object (absent/present) e.g. webpages, leaflets	0–1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Sum of points for functional values			**0–18**	**12**	**6**	**12**	**9.5**	**11**	**11**	**6**	**9.5**	**5**	**7**	**5**	**5.5**	**7**	**15**	**8**	**13**	**10**	**13**	**13**	**8**	**8**

[1] For this geosite the authors proposed a new location. Data presented in the table evaluate the original position of the geosite.

[2] Geosite from the original trail, removed from the proposed trail and not presented on the map.

[3] 1.1. Prominence in the landscape. In this category, the visibility of an object in the close surroundings was taken into account. Otherwise, no diversification would occur, with the only point for the Group of Jurassic Rocks in Dubie, which are visible from further distance. For comparison with valorisations of other areas, such points should be used instead of the presented ones. The main reason for this is the location of all three trails in the forested valleys.

[4] 2.1.A. Number of readable features. Features: geomorphology, hydrology, mineralogy, palaeontology, pedology, petrography, sedimentology, stratigraphy, tectonics, volcanology, recent geological processes, others. Points for this category are presented separately in Table 5 in the article.

[5] 2.1.E. Appearance in the literature. Scientific, international and domestic. Points in this category were assigned to the geosites which were a subject of scientific research, not neccesarily in geology (also e.g. hydrography in Racławka Stream or hiropterology and archeology in Żarska Cave), either as a main sampling area or one of many locations, all of which were important for the obtained results. Popular science. Points in Popular Science category were awarded for appearance in printed popular science materials, longer than just mentioning a geosite (at least brief description was needed).

[6] Categories which do not apply to this area, showing no differentiation between the geosites, are marked with white background (without trail colour shading).

[7] 2.4.A. Specific fauna/flora habitat. Points in this category were given for habitats or biocenoses connected with geological setting, rock assembladges or geomorphology (e.g. riparian forest or xerothermic turf).

[8] 3.1.B. Transport modes (less than 100 m from the object). Public transport. Due to frequent changes in the public communication schedules, changes may occur in this category (there are numerous bus stops in this area, currently out of use).

[9] 3.1.C. Pedestrian access. Note that score 0 in this category means lack of a path leading straight to the object; it is still possible to cover the final section walking through the forest or bushes.

[10] 3.2.A. Natural objects. Other than the ones included in the three educational trails.

[11] 3.6. Information materials available outside the object. It is important to mention that because of the lack of coverage in many places along the trails, such information should be read before the trip or taken with the tourist in printed form (e.g. guidebooks).