Evaluation of the geotouristic attractions from the Wojcieszów area

Ocena walorów geoturystycznych okolic Wojcieszowa

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Abstract: *The paper presents the results of geological and landscape studies in the Wojcieszów area (the Kaczawskie Mountains), which include investigation, inventory, documentation and a first evaluation of its geotourism objects. This area has high values of the natural environment and a rich geodiversity associated with a complicated geological structure (the Kaczawa unit, the metamorphic Kaczawa Complex). Some of the anthropogenic activities (mining), which have revealed interesting fragments of the geological structure, have also influenced the increase of geotourism attractions in this area. The area is one of the best examples of the region in the Sudetes, where economic considerations predominate over the protection of the natural environment. Since the 16th century, the crystalline Wojcieszów limestone was mined in numerous quarries (e.g. Silesia, Gruszka, Połom, Miłek). In the limestone, intensive karst processes occurred mainly in the Paleogene (numerous caves and speleothems). As a result of economic activity, some of the caves had been permanently destroyed and the former "Połom" nature reserve was liquidated in the late 1970s. Currently, the only nature reserve is the "Góra Miłek in Wojcieszów". The area around Wojcieszów is rich in numerous quarries, where other construction materials were obtained (e.g. phyllites, greenschists, metarhyodacites). Since the 12th to 20th centuries, copper ore was also exploited (adits and shafts) in the Żeleźniak massif (east of Wojcieszów in the Radzimowice area). In the 20th century, uranium ore was sought at the Chmielarz Hill adit. Recently, the Cambrian limestones (Połom) and Quaternary deposits (Okrajnik, Stara Kraśnica) have been exploited. Paradoxically, economic activity, which caused destruction of some protected objects, has also enriched the geodiversity of the Wojcieszów region. The results of the evaluation proved the significant geotouristic potential of the studied area. The most attractive geosites around Wojcieszów demonstrate typical lithologies of the Kaczawa Succession and depict the pre-Variscan geological evolution of the area.*

Key words: *Western Sudetes, Kaczawa metamorphic unit, geotourism potential, geosites, mining heritage sites, evaluation*

Treść: *W artykule przedstawiono wyniki badań geologicznych i krajobrazowych rejonu Wojcieszowa (Góry Kaczawskie), które obejmowały inwentaryzację, dokumentację i pierwszą waloryzację jego obiektów geoturystycznych. Obszar ten jest cenny pod względem przyrodniczym oraz charakteryzuje się bogatą georóżnorodnością, związaną ze skomplikowaną budową geologiczną (metamorfik kaczawski, kompleks kaczawski). Na wzrost walorów geoturystycznych tego obszaru wpłynęły też niektóre działania antropogeniczne (górnictwo), które odsłoniły ciekawe fragmenty budowy geologicznej. Okolice Wojcieszowa stanowią jeden z najlepszych w Sudetach przykładów regionu, w którym względy gospodarcze przeważają nad ochroną przyrody. Już w XVI wieku zaczęto w okolicy wydobywać wapień krystaliczny zwany wojcieszowskim, odsłonięty w licznych kamieniołomach (np. Silesia, Gruszka, Połom, Miłek). W wapieniach* *przebiegały intensywne procesy krasowe, które zachodziły głównie w paleogenie (bardzo liczne jaskinie, szata naciekowa). Na skutek działalności gospodarczej część jaskiń została bezpowrotnie zniszczona, a dawny rezerwat przyrody "Góra Połom" został zlikwidowany pod koniec lat 70. Obecnie jedynym rezerwatem jest "Góra Miłek" w Wojcieszowie. W okolicach Wojcieszowa występują liczne łomy, w których pozyskiwano inne surowce budowlane (m.in. fyllity, zieleńce, metaryodacyty). Od XII do XX wieku w masywie Żeleźniaka (na wschód od Wojcieszowa w rejonie Radzimowic) eksploatowano również rudy miedzi (sztolnie i hałdy). W XX wieku poszukiwano rud uranu (sztolnia na Chmielarzu). Współcześnie eksploatowane są kambryjskie wapienie (Połom) oraz osady czwartorzędowe (Okrajnik, Stara Kraśnica). Paradoksalnie, działalność gospodarcza, niszcząc niektóre obiekty chronione, jednocześnie wpłynęła pozytywnie na wzrost georóżnorodności w rejonie Wojcieszowa. Wyniki ewaluacji udowodniły znaczący potencjał geoturystyczny badanego obszaru. Zaproponowano najbardziej atrakcyjne obiekty geoturystyczne okolic Wojcieszowa, przedstawiające litologię dolnej części sukcesji kaczawskiej i ukazujące przedwaryscyjską ewolucję tego obszaru.*

Słowa kluczowe*: *Sudety Zachodnie, metamorfik kaczawski, potencjał geoturystyczny geostanowiska, obiekty dziedzictwa górniczego, waloryzacja

Introduction

The Kaczawskie Mts. and Kaczawa Foothill represent one of the "first-rate" regions of the Sudetes with highest geotouristic values and best developed infrastructure (see Rogowski, 2016). There are some publications, which present its geotouristic values, potential and possibilities of geotouristic development (e.g. Pijet-Migoń & Migoń, 2009; Migoń & Pijet-Migoń, 2010; Migoń, 2014). This region is known mainly for the Palaeozoic and the Cenozoic volcanism (the Land of Extinct Volcanoes) and some mining objects (Goldmine "Aurelia" and gold museum in Złotoryja, open-air museum of mining and metallurgy in Leszczyna). In addition, some cyclical events are offered for tourists (e.g. Agate Summer in Lwówek, the International Gold Panning in Złotoryja). There are eleven educational paths and two tourist trails (Rogowski, 2016). Against this background, the Wojcieszów sub-region remains underrated in terms of tourism.

The Wojcieszów sub-region has been for a long time an interesting area for many researchers, not only because of its various geological structure (e.g. Gürich, 1929; Schwarzbach, 1939; Gunia, 1967; Baranowski & Lorenc, 1978, 1981; Lorenc, 1983; Baranowski *et al.*, 1990; Cwojdziński & Kozdrój, 1994; Cymerman, 2002; Kryza *et al.*, 1990; Kryza, Muszyński, 1992, 2003; Białek *et al.*, 2007), but also because of the importance of rock raw materials (Manecki & Młodożeniec, 1959, 1960; Manecki, 1962, 1963, 1965; Dziekoński, 1972; Holeczek & Janeczek, 1991; Siuda, 2001, 2002, 2003, 2004; Mikulski, 2005, 2007; Madziarz, 2009). In recent years, several papers on geotourism potential and the geotourism attractiveness of this area have been published (Kryza 2008; Mianowicz & Brzozowska, 2009; Łodziński *et al.*, 2009; Różycka, 2014), but an evaluation of its geosites has not been carried out. Inventory and evaluation of geosites is required for the proper use of georesources of the region.

The aim of this paper is to present the results of geoattraction studies in the vicinity of Wojcieszów and their connection with the exploitation of rock raw materials and nature protection. Fieldworks were prepared in the years 2008–2011, during the research project "The Sudetic Geostrada – geological and landscape studies heritage with an inventory of the objects of abiotic nature" (see Bartuś *et al.*, 2009; Łodziński *et al.*, 2009; Słomka *et al.*, 2009). The project included documentation of the diversity of landforms, the complexity of geological structures, the geological-mining heritage and abiotic nature in selected parts of the Sudetes. The Wojcieszów area belongs to the western sector of the Sudetic Geostrada. The main aim of the project was to popularize geotourism to improve the tourist industry in the region. The concept of geotourism is closely related to the concept of geoconservation, which means "protection of geodiversity for the regard of its intrinsic ecological value and geological heritage" (see Sharples, 2002).

Economic development often takes place at the expense of the natural environment (see Redclif, 1992). This conflict is therefore inherent in the development of civilization. Kassenberg and Marek (1986) presented a classification of conflicts from the point of view of both location and values that the conflict arises in (see Kistowski, 1996). These authors have distinguished overlapping (where resources and values occur in the same area) and neighborhood conflicts (where the use of resources in a particular area restricts the use of neighboring areas).

Until the 1989, in Poland, the exploitation of all available resources took place, but only occasional forms of conservation were introduced (Otok, 1990). Recent requirements, concerning plans of spatial development in Poland, include the recognition and respect for the values of the natural environment. They also seek to improve the environment, especially in regions where it has been neglected for many years.

Methodology

Selected objects of geoheritage in the Wojcieszów area were examined as potential sites or site-sets for geotourism. The field works included inventory, photographic documentation, topography and basic geological investigation of geosites located in the 10 km zone, on both sides of the main trail of the Sudetic Geostrada (the Geostrada belt). Geographic coordinates and elevation of geosites also were determined. Each geosite was classified into one of the categories: e.g. active quarry, closed quarry, natural outcrop, rock, cave, gravel-mine, adit, shaft, heap, lime kiln, spring (see Tab. 1).

The valuation class method was used to estimate all geosites of the Sudetic Geostrada. Evaluation of the geosites was the sum of six criteria, which include: scientific value (1–5 pts.), educational value (1–5 pts.), degree of conservation (1–5 pts.), position relative to the hiking trails (1–3 pts.), availability (1–5 pts.) and the overall attractiveness of tourist facilities (1–5 pts.) (see Słomka *et al.*, 2009; Bartuś, 2015). In total, fifty nine geosites in the Wojcieszów area were catalogued and valorized and the most attractive objects are presented in Table 1.

Tab. 1. The most attractive geosites in the vicinity of Wojcieszów and their evaluation

No	Geosite name	Geosite type	Scientific value (1-5 pts.)	Educational value (1-5 pts.)	Degree of conservation (1-5 pts.)	Position relative to the hiking trails (1-3 pts.)	Availability (1-5 pts.)	Overall attractiveness of tourist facilities (1-5 pts.)	Total
1	The marble quarry Silesia in Wojcieszów	closed quarry	5	5	5	3	5	5	28
2	The marble quarry Gruszka in Wojcieszów	closed quarry	5	5	5	3	5	4	27
3	The marble quarry at the Połom Hill in Wojcieszów	active quarry	5	5	5	2	3	5	25
4	Lisie Skały - Fox Rocks in Wojcieszów	rocks	5	4	4	3	4	3	23
5	Biały Kamień -White Stone in Wojcieszów	rocks	3	4	4	3	5	3	22
6	The phyllites quarry in Wojcieszów	closed quarry	4	4	4	3	4	3	22
7	The marble quarry at the Miłek Hill in Wojcieszów	closed quarry	4	4	3	3	5	3	22
8	Księży Kamień -Priest's Stone near Radzimowice	rocks	4	4	3	3	4	2	20
9	Adit uranium at the slope of Chmielarz Hill	adit	4	4	5	3	1	3	20
10	Gravel-mine in Okrajnik	gravel-mine	3	3	5	2	4	3	20
11	Lime kiln in Wojcieszów near the Gruszka quarry	lime kiln	3	3	4	3	4	2	19
12	Greenstones at the top of Marciniec Hill	rocks	3	4	4	2	3	3	19
13	"Arnold" shaft in Radzimowice	shaft	4	3	5	3	1	2	18
14	Metatrachytes at the Rogacz Hill	rocks	3	3	4	2	3	3	18
15	The spring Miłek in Wojcieszów	spring	3	2	3	3	5	1	17
16	Marbles at the slope of Cisowa summit (Miłek Hill)	rocks	2	2	5	2	2	3	16
17	Natural outcrop of sericite shales in Wojcieszów Dolny	natural outcrop	3	3	4	1	3	2	16
18	Marbles at the Młyniec summit (Miłek Hill)	rocks	2	2	4	2	3	2	15
19	The heap in Radzimowice	heap	2	2	4	2	3	2	15
20	Exploration shafts in Radzimowice	shaft	2	2	3	2	4	2	15
21	The Cave Schron Miłek in Wojcieszów	cave	2	2	4	1	3	1	13
22	Metadiabases at the slope of the Zadora Hill	rocks	3	2	3	1	2	1	12

Geological setting

The Wojcieszów area is located in the southern part of the Kaczawa Unit, in the West Sudetes. The unit is composed of two structural complexes: the Variscan basement and epi-Variscan cover (Baranowski *et al.*, 1990). The Bolków – Wojcieszów antiform (Fig. 1) is the main structure of this part of the Kaczawa Unit (Schwarzbach, 1939; Baranowski *et al.*, 1990). Wojcieszów extends over three tectonic units, the Świerzawa unit in the northern part, Radzimowice unit (previously interpreted to be a part of the Bolków unit) and the Bolków unit in its southern part (see Baranowski, 1988; Kryza & Muszyński, 1992).

The Variscan basement is exposed in Świerzawa and Bolków units and comprises the Kaczawa Complex (sensu Kryza & Zalasiewicz, 2008), which was metamorphosed and strongly deformed during the Variscan orogeny. The complex is composed of various fragments of the Kaczawa Succession (metavolcanic and metasedimentary rocks) of the Cambrian up to the Viséan age, locally associated with polygenetic mélange bodies of assumed the Late Devonian – Early Carboniferous age (Baranowski *et al.*, 1990; Kryza & Muszyński, 2003 and references therein; Kryza, 2008).

In the vicinity of Wojcieszów, mainly lower part of the Kaczawa Succession is exposed (Kryza, 2008). It contains metavolcanic-metasedimentary rocks of the Cambrian-Ordovician age (Haydukiewicz, 1987), which are represented by mafic and felsic metavolcanic rocks (basaltic pillow lavas, metarhyodacites and metatrachytes), metavolcaniclastic rocks, crystalline limestones (Wojcieszów limestones) and clastic metasedimentary rocks (mainly metamudstones).

The problem of age of the Wojcieszów limestone was analyzed by many authors for over 125 years (e.g. Gürich, 1929; Schwarzbach, 1936, 1939; Gunia, 1967; Baranowski & Lorenc, 1978, 1981; Skowronek & Steffahn, 2000). Recently, the Lower Cambrian archaeocyates were found in this limestone (Białek *et al.*, 2007) and finally settled its age. According to Baranowski & Lorenc (1981), the Wojcieszów limestones form isolated bodies of various sizes within the greenstones lenses, in some places limestones intimately intercalated with greenstones. The limestones with associated greenstones (at first mafic volcanic rocks) are the oldest elements of the Kaczawa Succession.

The metarhyodacites and metatrachytes were dated using the SHRIMP U-Pb zircon method at. c. 500 and 485 Ma, respectively (Kryza *et al.*, 2007). Rocks of the lower part of the Kaczawa Succession are regarded as products of initial rift processes within the Early Paleozoic continental crust setting (Furnes *et al.*, 1994; Kryza & Zalasiewicz, 2008).

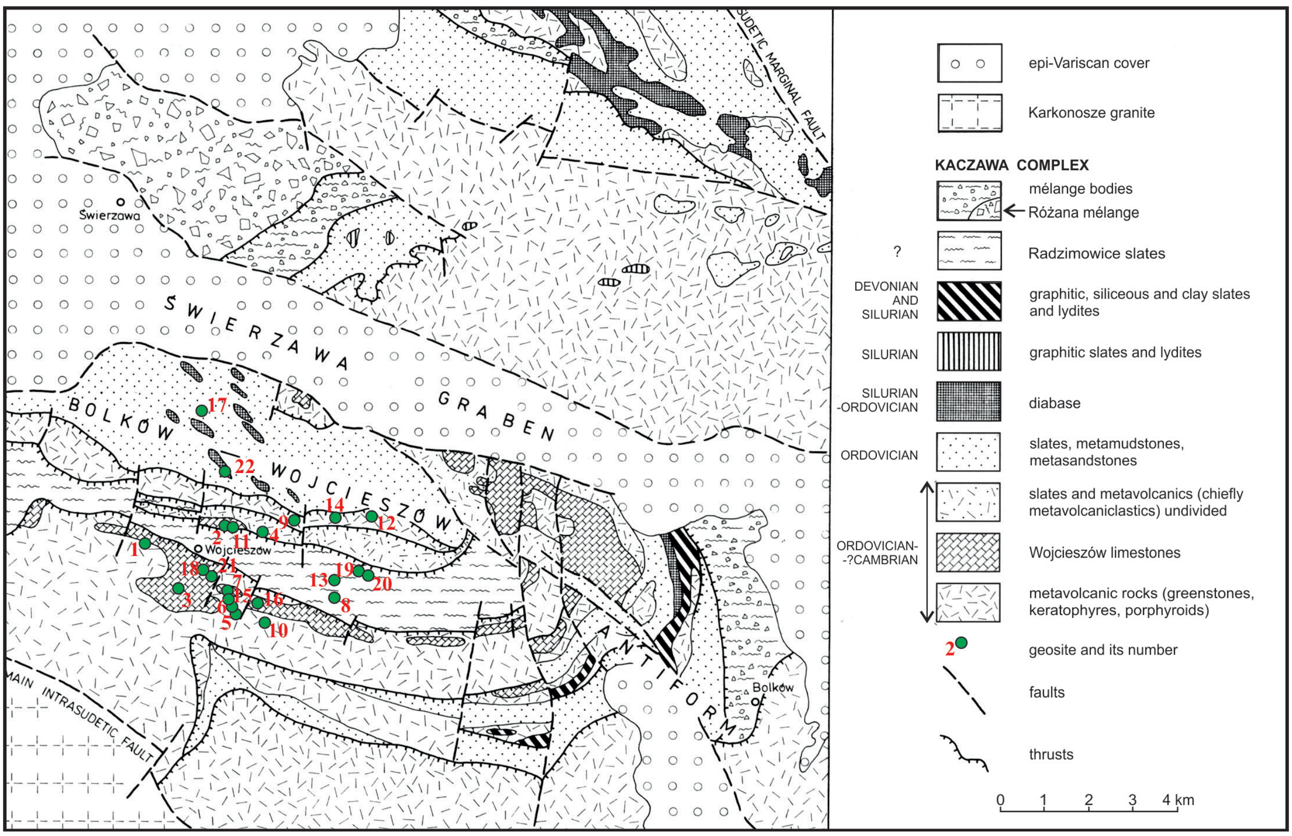

Fig. 1. Simplified geological map of the central part of the Kaczawa Unit based on Baranowski *et al.* (1990) with proposed attractive geosites (numbers as in Table 1)

The upper part of the Kaczawa Succession is exposed mainly in the Rzeszówek-Jakuszowa and Dobromierz tectonic units. It is represented by large metabasalt pillow lavas of the MORB-type (mid-ocean-ridge basalts) affinity, associated with condensed, black graptolitic slates and cherts of the Silurian – Devonian age. These rocks had developed in a mature basin, with a rifting regime (see Furnes *et al.*, 1994; Kryza & Zalasiewicz, 2008).

The Radzimowice unit, probably of the Early Palaeozoic age, comprises assemblages of dark-grey slates with intercalations of siliceous slates, greywackes and quartzites. The Radzimowice Slates have a thickness over 1 km. Their age has been documented by conodonts as no older than the Ordovician, but the upper age limit is still problematic (Urbanek & Baranowski, 1986). These rocks originally were represented by shaly flysch-type sedimentary rocks and next were metamorphosed at greenschist facies (Baranowski *et al.*, 1990; Kryza & Muszyński, 2003; Kryza & Zalasiewicz, 2008). According to Baranowski (1988), the dominance of mudstones over sandstones and the turbidite features of the slates are compatible with sedimentation in a trench-floor or trench-slope basin setting. The new detrital zircon ages obtained by Tyszka *et al.* (2007) show, that the Radzimowice Slates were deposited as an extensional basin-fill (see Kryza & Zalasiewicz, 2008). As stated by Baranowski *et al.* (1990), the margins of the Radzimowice schists are tectonic (faults). This unit separates the Świerzawa unit and the Bolków unit (Kryza & Muszyński, 1992).

The mélange-type rocks encompass various-sized blocks (clasts and olistoliths) of greywackes, cherts and rare volcaniclastic rocks embedded in a dark, mud-dominated matrix (Kryza, 2008; Kostylew *et al.*, 2017). Rare conodonts and graptolites documented the Ordovician – Devonian age of these blocks, while the matrix includes the Devonian – lower Carboniferous material (Haydukiewicz & Urbanek, 1987). This part of the Kaczawa Succession was developed in an accretionary prism environment during the Variscan Orogeny (Baranowski *et al.,* 1990; Kryza & Zalasiewicz, 2008).

In general, the metamorphic grade in the Kaczawa Unit varies from very-low grade (Kostylew, 2008) to blueschist-overprinted by greenschist-facies conditions (Kryza *et al.*, 1990; 2011). The late-orogenic Variscan magmatism, which is represented by small subvolcanic intrusions (e.g. the Żeleźniak and Bukowinka intrusions) provide an upper age limit for deeper-level tectonic and metamorphic processes in the Kaczawa accretionary prism (Machowiak *et al.*, 2008). The Variscan deformation also caused WNW- directed thrusting and subsequent ESE-directed normal faulting (Cymerman, 2002; Kryza, 2008 and references therein).

The epi-Variscan cover is separated from the basement by a regional unconformity and formed mainly the North Sudetic Synclinorium and the Świerzawa Graben. It comprises the upper Pennsylvanian, Permian, Triassic, Upper Cretaceous, Neogene and Quaternary mainly sedimentary rocks, with also the occurrence of volcanic rocks. Variscan structures of the Kaczawa Complex were also modified (rotation and tilting of small blocks) during the Laramian and young Alpine tectonic movements (Teisseyre, 1956; Oberc, 1972).

Characteristic and evaluation of selected geosites

Rocks which make up the area are very diverse lithologically (sedimentary, volcanic and metamorphic rocks) as well as in age (the early Palaeozoic, late Palaeozoic and Cenozoic). The most attractive geosites in the vicinity of Wojcieszów were selected (Fig. 1, numbers of geosites as in Tab. 1) and proposed to show typical lithologies of the lower part of the Kaczawa Succession (bimodal within-plate metavolcanics and metasedimentary rocks) and pre-Variscan geological evolution of the area. Relics of past mining operations are also described among geological and geomorphological objects. From all analyzed objects, there are twenty two geosites, which are particularly recommendable (Tab. 1).

The most attractive and the largest geosites are numerous quarries of crystalline Wojcieszów limestone (e.g. Silesia, Gruszka, Miłek, Połom; Figs 2–6, Fig. 10). This rock material has been mined since the 16th century. Wojcieszów limestones (marbles) are represented by different varieties: dark gray, well-layered, light-gray, yellowish, laminated, thin-bedded to striped (Lorenc, 1983). They became sediments in shallow water or deeper marine environments. Limestones and greenstones occur also as blocks (olistoliths) in the epimetamorphic Radzimowice Slates (Baranowski, 1988; Kryza, 2008). Among numerous marble quarries, only the Połom quarry is active. In the marble quarry Silesia, one of the biggest and best preserved, the spectacular isolated blocks (probably olistoliths) of Wojcieszów limestones occur within greenstones (Fig. 3). The marble quarry Gruszka lies on the educational path “Gruszka” and is easily accessible and prepared for tourists (Fig. 4). Currently, in the quarry the “Gruszka Recreation and Leisure Park” and a climbing wall for children and youth are to be found. The Polish Championships in Caves Techniques and the Alpine Festival are organized here. Lime kilns were often situated near marble quarries. A well preserved lime kiln from the 18th century is located near the Gruszka quarry (Fig. 7). Marbles often form hills (e.g. Połom, Miłek), escarpments and towers. The latter are especially visible at the slope of the Cisowa summit (Miłek Hill) (Fig. 8).

Fig. 2. The well preserved marble quarry "Silesia" in Wojcieszów (top view), photo J. Muszer

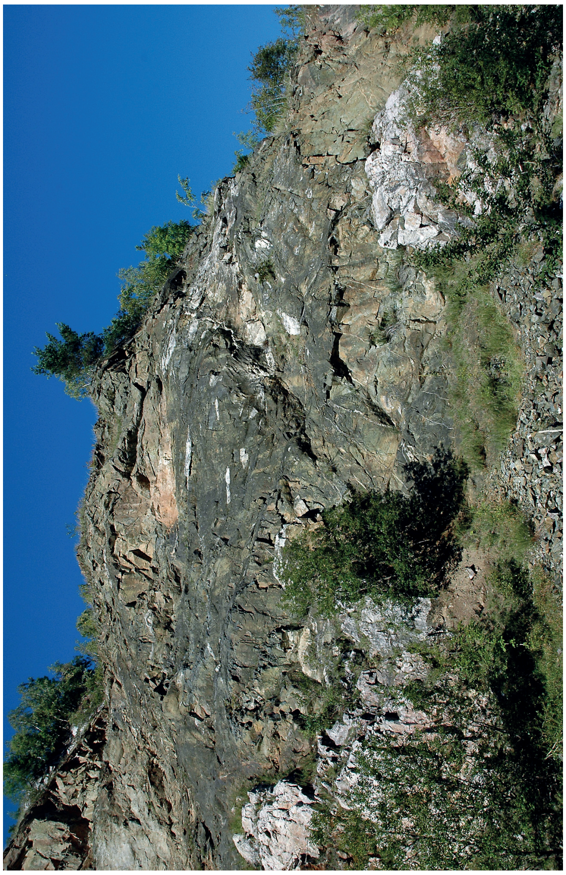

Fig. 3. The isolated blocks (olistoliths) of the Wojcieszów limestones within greenstones. The marble quarry "Silesia" in Wojcieszów, photo J. Muszer

Fig. 4. The marble quarry "Gruszka" in Wojcieszów, photo J. Muszer

Fig. 5. The marble quarry "Gruszka" in Wojcieszów, with a visible entrance hole of the cave, photo J. Muszer

Fig. 6. The marble quarry "Miłek" in Wojcieszów, partly overgrown with vegetation, photo J. Muszer

Wojcieszów limestones are also very interesting for another reason. In this part of the Sudetes, the most intensive karst processes took place in the Paleogene. They have evolved within the limestones at two height levels (see Mianowicz & Brzozowska, 2009). The upper horizon lies at an altitude of 540–590 meters, and the lower horizon occurs at an altitude 400–430 m. An example of the cave from the upper horizon is the Schron Miłek Cave (Fig. 9), while the cave Aven from the marble quarry Miłek is located at the lower horizon. Archaeological investigations indicate that these caves were used by the Paleolithic man (e.g. Bronowicki, 2001; Mianowicz & Brzozowska, 2009). Caves are a natural wealth of inanimate nature of the Wojcieszów region, but many of them were destroyed during the exploitation of limestones, especially in the Połom Hill (Fig. 10). Access to existing caves is difficult (example from the quarry Gruszka; Fig. 5), and therefore cannot be used for normal tourist traffic.

The spring Miłek in Wojcieszów (Fig. 11), located at the southern foot of the Miłek Hill on the right bank of the Kaczawa River, is also related to the crystalline Wojcieszów limestones. It is a karst spring, situated near the marble quarry Miłek (Fig. 6), on the "blue" hiking trail. However, geotouristic attractiveness of the spring is not displayed, because the spring is hooded by a well. Water from this spring is bottled and distributed as "Wojcieszowianka" (Marszałek *et al.*, 2008).

Fig. 7. A lime kiln in Wojcieszów situated near the marble "Gruszka" quarry, photo J. Muszer

Fig. 8. Marbles at the slope of the Cisowa summit forming escarpments and towers (the Miłek Hill), photo J. Muszer

Fig. 9. Entrance of the "Schron Miłek Cave", Miłek Hill, photo J. Muszer

Fig. 10. The active marble quarry "Połom" in Wojcieszów, photo J. Muszer

Fig. 11. The spring "Miłek" in Wojcieszów, photo J. Muszer

Its temperature is almost stable (12.8–13.4°C). Chemical analysis shows low alkaline pH (7.1–7.6), mineralization between 209–409 mg/L and HCO_3-Ca-(Mg) type of waters (Bocheńska *et al.*, 2002; Marszałek *et al.*, 2008).

The lower part of the Kaczawa Succession also is represented by metarhyodacites (“porphyroids”), which occur in the southern part of Wojcieszów (Wojcieszów Górny) at the foot of the Miłek Hill and form rocks called “Biały Kamień” – White Stone (Fig. 12). They are strongly sheared, represent a felsic member of the “bimodal volcanic suite” (likely volcaniclastic origin) and dated circa 500 Ma (Kryza, 2008). They were formed during initial continental-rift setting during the Cambrian/Ordovician times. A closed quarry of phyllites is located near these rocks. In this quarry, intensively folded quartzite-sericitic shales occur, with quartzite inserts (Fig. 13). Additionally, these rocks are characterized by goffering.

Another very interesting geosite called “Lisie Skały” – Fox Rocks (Fig. 14) is located at the western slopes of the Chmielarz Hill, about 1.1 km from the center of Wojcieszów. There are schistosited metarhyodacites intersecting folded sericite-chlorite slates, with greenstones and silica slates inserts. These rocks also contain numerous quartz lenses and veins. The object lies on the nature-educational path “Gruszka”.

Natural outcrops of sericite shales (Fig. 15) and metadiabases at the slope of the Zadora Hill (Fig. 16) also occur in the northern part of Wojcieszów (Wojcieszów Dolny). However, these geosites are rather small, less attractive, partly overgrown by vegetation and located away from hiking trails.

Other interesting geosites are located near Wojcieszów, about 3–4 km to the east, in the Radzimowice area. The different types of rocks occur in these geosites. “Księży Kamień” – Priest’s Stone (Fig. 17) is located about 1 km south of Radzimowice. The Radzimowice Unit (the Radzimowice Slates) is exposed in this geosite. The epimetamorphic slates are green-gray with lenses of graphite and siliceous slates. Attractive outcrops of greenstones occur at the top of the Marciniec Hill (Fig. 18) and magnificent rocks of metatrachytes protrude at the Rogacz Hill (Fig. 19).

At the southern and eastern slopes of the Żeleźniak Hill near Radzimowice, there are a lot of traces of the former mining of polymetallic ores (Manecki & Młodożeniec, 1959, 1960; Manecki, 1962, 1963, 1965; Dziekoński, 1972; Holeczek & Janeczek, 1991; Siuda, 2001, 2002, 2003, 2004; Mikulski, 2005, 2007; Madziarz, 2009). The polymetallic Au-As-Cu deposit of Radzimowice, formerly known as “Stara Góra”, occurs in the Radzimowice Unit. In the early Pennsylvanian (the late Carboniferous, late Namurian, c. 315 Ma) the schists were crosscut by volcanic dykes and subvolcanic Żeleźniak intrusion (see Machowiak, 2002; Machowiak *et al.*, 2008 and references herein), which has the shape of a laccolith (see Mikulski, 2007). The upper part of the intrusion is built up of rhyolites, rhyodacites, dacites and trachyandesites, whereas its deeper part is represented by granitoids (see Machowiak & Niemczyk, 2005). The Radzimowice Slates and the intrusion are crosscut by lamprophyres (kersantites) (Manecki, 1965).

The deposit of Radzimowice was exploited intermittently since the end of 12th century up until year 1925 (Mikulski, 2007). This ore-deposit is genetically connected with hydrothermal activity of the Żeleźniak intrusion and consists of some ore veins crosscutting Radzimowice Slates and volcanic rocks. The most common minerals of veins are arsenopyrite, chalcopyrite, pyrite, marcasite, galena and sphalerite, while bournonite, boulangerite, tetrahedrite, bismuth, gold, löllingite, stibnite and cobaltite have also been reported (Manecki, 1965; Zimnoch, 1965; Mikulski, 2005). The main subject of exploitation was the gold-bearing arsenopyrite and chalcopyrite. The remains of the mining activity are an extensive system of adits and shafts. The “Arnold” shaft (Fig. 20) and small exploration shafts in Radzimowice (Fig. 21) are good examples of this activity. The heap in Radzimowice (Fig. 22) is located near “blue” hiking trail and the “Luis” shaft. However the heap is partly overgrown by vegetation and access to it is difficult.

Probably uranium anomalies are associated with the same intrusion in the region of the Chmielarz Hill. The adit uranium at the slope of this hill (Fig. 23) is a remnant of the prospection for this element after the Second World War. It is currently inaccessible for sightseeing and is protected by the chiropterological company “ProNatura”.

The last proposed geosite is the active gravel-mine in Okrajnik (Fig. 24) located on the pass between the Wroniec Hill and the Osełka Hill. This object is large, with well exposed gravels and sandstones of fluvioglacial origin and the Quaternary (Pleistocene) age. Another smaller gravel-mine is located in Stara Kraśnica.

Fig. 12. Metarhyodacites of "Biały Kamień" – White Stone in Wojcieszów, photo J. Muszer

Fig. 13. The phyllites quarry in Wojcieszów. Quartzite-sericitic shales with quartzite inserts are intensively folded, photo J. Muszer

Fig. 14. "Lisie Skały" - Fox Rocks in Wojcieszów. Metarhyodacites intersecting folded sericite-chlorite slates, with greenstones, photo J. Muszer

Fig. 15. A natural outcrop of sericite shales in Wojcieszów Dolny, photo J. Muszer


Fig. 16. Metadiabases at the slope of the Zadora Hill, photo J. Muszer


Fig. 17. “Księży Kamień – Priest’s Stone” near Radzimowice, photo J. Muszer


Fig. 18. Outcrop of greenstones at the top of Marciniec Hill, photo J. Muszer


Fig. 19. Metatrachytes at the Rogacz Hill, photo J. Muszer

Fig. 20. The “Arnold” shaft in Radzimowice, photo J. Muszer

Fig. 21. Small exploration shafts in Radzimowice, photo J. Muszer

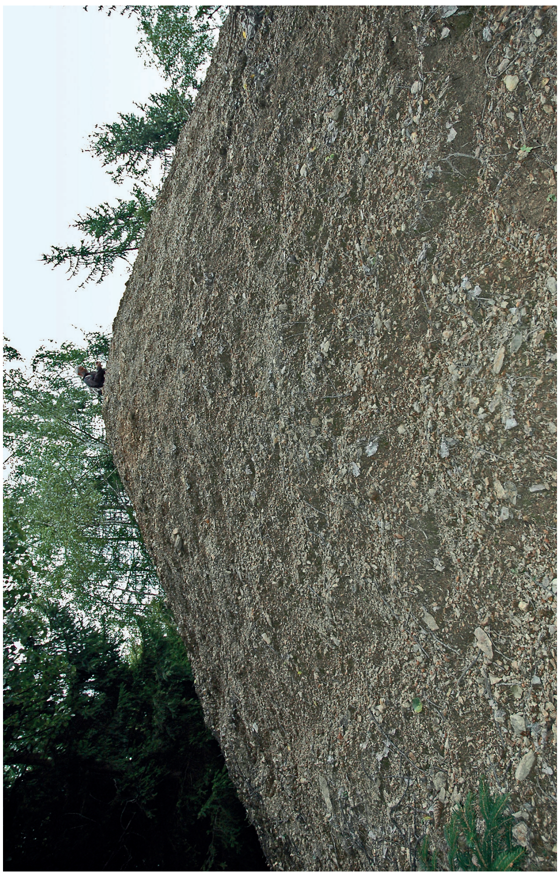

Fig. 22. The heap in Radzimowice, photo J. Muszer

Fig. 23. The adit uranium at the slope of the Chmielarz Hill, photo J. Muszer

Fig. 24. The active gravel-mine in Okrajnik, photo J. Muszer

Nature protection and quarry management

Currently, the Miłek Hill (596 m a.s.l.) is the only legally protected reserve in the Wojcieszów area. Rocks on the summits of the hill were considered as natural monuments even before the Second World War. A nature reserve "Góra Miłek" of 141.36 hectares was created in 1994. It protects the forest communities of fertile beech forest and warm-weather orchid beech forest, as well as thermophilic plant associations on outcrops of limestone rocks (Mianowicz & Brzozowska, 2009). There are 24 protected floral species (e.g. *Cypripedium*, *Platanthera bifolia*, *Cephalanthera longifolia*, *Cyclamen purpurascens*) in the reserve and some unique species of invertebrates (e.g. gastropod *Pyramidula rupestris* and spider *Prospotheca corniculas*) (see Mianowicz & Brzozowska, 2009). There are also numerous species of bats.

The Połom Hill (667 m a.s.l.), which is located on the left bank of the Kaczawa River, opposite to Miłek Hill, is also built of the Cambrian crystalline limestones, which are locally dolomitized with many calcite veins. This hill was formerly a nature reserve, which was liquidated in the late 1970s. Exploitation of marble has continued for hundreds of years, leading to the characteristic "biting" outline of the hill. Quarries on the Połom Hill are very extensive, multi-level, with walls of exploitation level exceeding 20 m in height (Fig. 10). The most famous caves in the Wojcieszów region are located on the Połom Hill (33 documented caves), but a dozen of them (13 caves) were destroyed or buried as a result of progressing work (e.g. Pulina 1996; Zyzańska & Szynkiewicz 2003). Unfortunately their total number is unknown, due to the limited access of scientists and speleologists to the quarries. Some of the described caves no longer exist: Porcelanowa, Naciekowa, Meandrująca, Jasna and Gwiaździsta (see Mianowicz & Brzozowska 2009). The efforts of environmentalists and speleologists have so far failed to produce any results, and there is no plan to establish legally protected areas in the quarry.

Problems of quarry management after end of limestone exploitation on the Połom Hill were presented by Zyzańska & Szynkiewicz (2003). These authors ascertained that the main method of "post-mining reclamation" were infilling of quarries with wastes (mining, industrial and municipal). Cited authors suggested several alternation solutions e.g. protection part of rocks escarpment as a geological document point or as nature monuments (especially caves) or as teaching geological path. Some fragments of quarries could also be used for optional caving, climbing, diving, fishing and recreation.

Another example of improper use of quarries was the localization of a dump site in the area. In the 20th century, in the Wojcieszów area, there was a dump site in one of the marble quarries, which is situated only about 1.5 km from the center of the town. Rubbish fills the lower part of the quarry and makes a very depressing impression (Fig. 25). On 31 May of 2009, this dump site was closed, because it threatened the pollution of groundwater.

Wojcieszów, which is picturesquely situated in the valle River, is heavily neglected and has a poorly developed tourist infrastructure. Contemporary, local authorities, among other activities, aim to develop tourism in the region through the implementation of many ecotourism and geotourism projects in accordance with the principles of sustainable development. It is planned to create trails showing the traces of the old mining in the Radzimowice area.

Fig. 25. Dump site in the marble quarry in Wojcieszów closed since 2009, photo J. Muszer

Since 2008, the Wojcieszów area was included in the Special Area of Conservation The Kaczawskie Mts. and Kaczawa Foothill (Góry and Pogórze Kaczawskie) (PLH020037) of Natura 2000, which is a network of protected sites across the European Union. This area of conservation is very important in the Lower Silesia and protects twenty five types of habitats (Świerkosz *et al.*, 2012). It can help in the development of ecotourism and geotourism in this area.

Conclusions

Łodziński *et al.* (2009) presented only one geosite (the marble quarry Miłek) as the most important in this region. Our evaluation of geosites in the studied area shows that there are much more interesting sites in Wojcieszów (see Table 1, large marble quarries: Silesia, Gruszka, Połom; natural exposures of metaryodacites Lisie Skały and Biały Kamień; the phyllites quarry). The main geotouristic values of the Wojcieszów area are: enormous diversity of geological structure, lithology and relief in a relatively small area, numerous exposures and quarries and spectacular human impact. The natural resources of this area since the 16th century have contributed to the development of this town. Rock raw materials (crystalline limestone, phyllites, metaryodacides, etc.) and also metallic minerals (copper, iron, gold, etc.) have been mined there. In addition, natural springs of water have been exploited. The most attractive geosites surrounding Wojcieszów demonstrate typical lithologies of the Kaczawa Succession, which shows the geological pre-Variscan evolution of the area.

As a result of human activity in the vicinity of Wojcieszów, the environment has changed significantly. Many caves, habitats and even landscapes have been destroyed (e.g. slope damage, heaps, numerous excavations, adits, shafts). Economic considerations also have determined the liquidation of the Połom Hill reserve. In the analyzed area, both resources and values at the same time, so the conflict between economic development and nature protection overlaps.

However, economic activity, which destroyed some protected objects has also paradoxically contributed positively to the geodiversity of this area (with exception of the Połom Hill). Potential tourists can explore the rocks of this region, geological and mining history, find interesting minerals and fossils, practice speleology and enjoy mountain tourism. The proposed geosites can be used both in the sustainable development of the town and in the municipality, as well as in shaping the positive image of the sub-region for tourism, especially geotourism.

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