GEOTOURISM POTENTIAL OF SHOW CAVES IN POLAND

Artur Zieliński [1], Aneta Marek [2], Zbigniew Zwoliński [3]

[1] Department of Geography and Environmental Sciences, Jan Kochanowski University in Kielce, Poland
[2] Department of Geography and Regional Development, University of Wrocław, Poland
[3] Institute of Geoecology and Geoinformation, Adam Mickiewicz University in Poznań, Poland

Manuscript received: March 10, 2022
Revised version: May 14, 2022

Zieliński A., Marek A., Zwoliński Zb., 2022. Geotourism potential of show caves in Poland. *Quaestiones Geographicae* 41(3), Bogucki Wydawnictwo Naukowe, Poznań, pp. 169–181. 7 figs, 4 tables.

Abstract: In the modern world, tourism is a very dynamically growing industry with significant impact on the economic prosperity of many regions or even countries. The paper presents the geotourism potential of the 12 show (commercial) caves in Poland before and during the current pandemic time. Survey results demonstrate that caves are major geotourist attractions. In 2019, they were visited by a total of almost 950,000 people. The attendance might have exceeded even a million if the popular Mroźna Cave in the Tatras had not been temporarily closed to visitors due to a rockfall in winter period 2018/2019. In 2020, all the show caves combined were visited by a more than 390,000 people, which amounted to about 41% of the total attendance recorded for 2019. The most visited cave proved to be Smocza Jama (Dragon's Den) in the centre of Kraków, which recorded almost 422,000 visitors in 2019. A preliminary assessment of the attractiveness of the caves as geosites is given. The most attractive caves as geosites were identified as: Bear Cave, Upper Wierzchowska Cave, and Bat Cave. It is possible to confidently assert that the celebration of the International Year of Caves and Karst (IYCK) in 2021–2022 will increase interest in caves and translate into a revival of cave tourism.

Key words: geotourism, show caves, commercial caves, visitors, Poland

Corresponding author: Artur Zieliński, artur.zielinski@ujk.edu.pl

Introduction

Tourism having geosites as its chief interest (geotourism) occupies a special niche in the economy in that it is neither capital- nor labour-intensive, but, provided it is successful, yields substantial returns on the (typically marginal) capital employed or resources invested. It is also very significant socially. Recent years have witnessed a rise in the popularity of geotourism (Dowling, Newsome 2017) and the role of geotourism sites such as caves (Pachrová et al. 2020). Cigna and Forti (2013) and Cigna (2016) estimate that about each of the 500 existing show caves are visited by at least 50,000 people annually. These authors believe the annual cave attendance on our planet to be over 250 million. Caves, together with the surrounding infrastructure, generate the income for about 100 million people.

A significant number of natural features are located in Poland. They are some of the tourist attractions with the highest visitor numbers and the biggest potential (Kruczek 2014). Among them, caves are becoming increasingly popular. World caves started to be accessible to tourists over 400 years ago (Cigna, Forti 2013). In Poland, they were the object of scientific exploration and visitor interest as early as in the late 18th and the early 19th centuries (Urban 2006a). One should expect a growing interest in caves because of the currently celebrated International Year of Caves and Karst (IYCK), which will continue into 2022.

https://doi.org/10.14746/quageo-2022-0032
ISSN 2082-2103, eISSN 2081-6383

The slogan of this international project is: *Explore, understand and protect*. It will enable better understanding of the value and attractiveness of caves, and the karst processes occurring in them. The karst landscape and landforms, especially the show caves are among the best publicly accessible examples of geodiversity (Zwoliński 2004).

Karst areas are common on the Earth and they can be very extensive (Zieliński 2013). Their presence can create a lot of economic problems, but also enhance geodiversity and biodiversity and the landscape value of an area (Zieliński 2010). Caves are some of the most interesting landforms that can arise owing to the presence of karst phenomena. They are the subject of very extensive interdisciplinary research dealing with problems covering both natural and anthropogenic issues. An important part of these studies concerns inventorying, discovery of new sites, their accessibility by the public (e.g. Urban 1996, Andrejczuk, Kaźmierczak-Bereszka 2007, Kasza 2009, Cigna 2010, Łyskowski et al. 2014) and the impact over time that this can have on their condition, and the need for their legal protection (e.g. Urban 2006a, b). Another important group comprises papers discussing the genesis and classification of caves, the problem of their endangerment (Urban, Kasza 2008, Constantin et al. 2021) or the possible usage in cave tourism (Rubinowski 1974, 1977, Pflitsch et al. 1999, Forti et al. 2003, Bočić et al. 2006, Kambesis 2007, Marciniak 2007, 2008, Kim et al. 2008, Lobo et al. 2008, Lobo, Moretti 2009, Marek, Olszak 2012, Marek 2015, Cigna 2016, Crane, Fletcher 2016, Zagożdżon, Zagożdżon 2016, Okonkwo et al. 2017, Rindam2014, Rindam Tičar et al. 2018, Čech et al. 2021).

A lot of such landforms are particularly noteworthy. Their status is highlighted by the forms of protection they are subject to (due to their location e.g. within a national park, nature reserve or landscape protection area). A special group are caves in the UNESCO list of World Natural Heritage sites, e.g. Skocjan Caves (Škocjanske jame) and Postojna Cave (Postojnska jama) in the Republic of Slovenia, Aggtelek Cave in the Republic of Hungary, Ochtinská aragonitová jaskyňa, Jasovská jaskyňa, Gombasecká jaskyňa, Krásnohorská jaskyňa and Dobšinská ľadová jaskyňa in the Slovak Republic, or Chauvet Cave, famous for its Palaeolithic paintings, in the French Republic. In the Palaeolithic age, human existence was largely dependent on the natural environment (Wieczorek, Zieliński 2020). Caves often provided people with shelter and increased their sense of security or comfort of life (Kowalski 2006, Andrejczuk, Kaźmierczak-Bereszka 2007). An important role is played by caves in functioning as places of religious worship, e.g. the grotto of Massabielle in Lourdes (Urban 2006a). One could also name a considerable number of caves used as shelters by hiding civilians or guerrillas during World War II, e.g. in the Świętokrzyskie Mountains (Urban 2008, Jan Urban – oral information 2021). There are also caves that were used for military or business purposes as late as World War II.

After that war, an increased interest in using caves as tourist attractions appeared. A number of actions were carried out to improve the attractiveness of cave surroundings and make better use of their existence for tourism. Sadly, despite caves being extremely valuable in terms of their natural, aesthetic, educational and scientific aspects, there are also instances of negative impact caused by anthropogenic factors.

According to Urban (2011), 40% of Polish caves were open to visitors in 2011, but only nine of them had a commercial character. Currently, there are 12 caves where an entrance fee is charged. Obviously, the system of three interconnected caves on Kadzielnia in Kielce is regarded as a single karst system, as these caves are linked by a common tourist route. At the same time, there are 19 show caves in the Slovak Republic (Čech et al. 2021), 14 in the Czech Republic (Marek, Olszak 2012) and 13 in the Republic of Croatia (Bočić et al. 2006).

At this point, it is worth noting the existence of caves with huge aesthetic and scientific values raising the value of anthropogenic underground show spaces, although they are not accessible to tourists. An example of such sites is Crystal Grottos in the Salt Mine in Wieliczka (Alexandrowicz, Urban 2015). Nevertheless, the subject of this analysis is show (commercial) caves adapted for unspecialised and mass tourism. These caves have appropriate infrastructure, making it possible to control tourist traffic. Such sites are concentrated in southern Poland and the southern part of central Poland (Fig. 1). The regions that are the most abundant in such geotourism attractions are the Lesser Poland (six caves), Lower-Silesian (two caves) and Świętokrzyskie

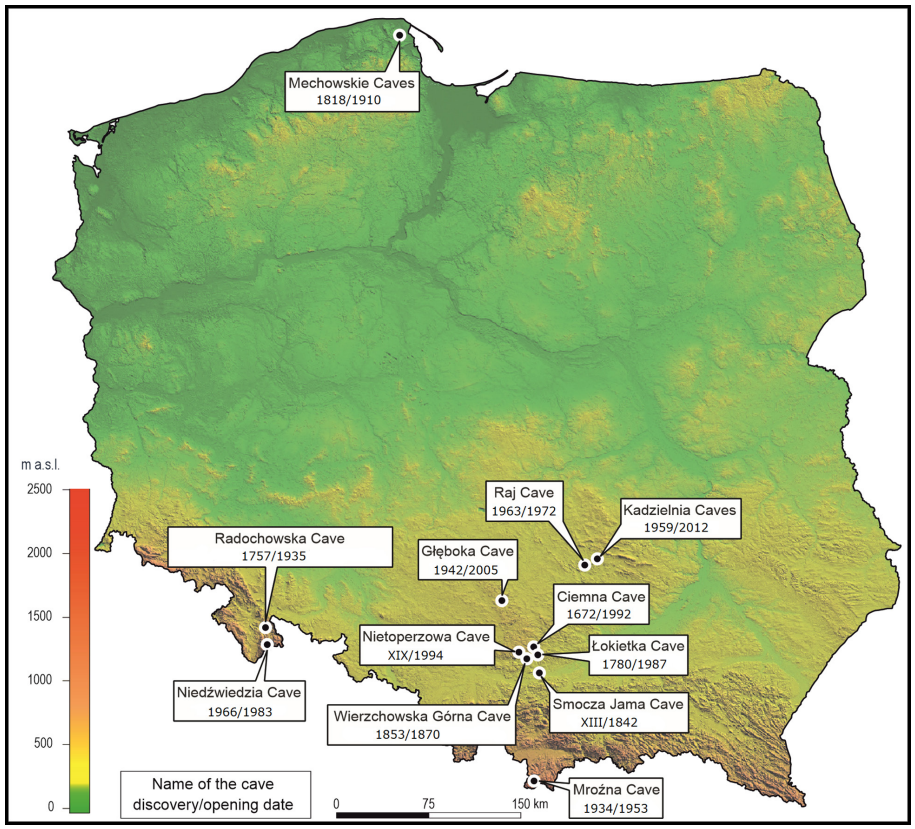


Fig. 1. Location of show caves on the digital elevation model of Poland.

(two caves) voivodeships. The Silesian and Pomeranian voivodeships have one cave each.

The current pandemic has revealed huge gaps in tourism operating systems, whose effects have unevenly burdened different groups and subsectors of this industry (Cave, Dredge 2020). This is the reason why cave tourism has also suffered considerably, not just in Poland, but worldwide.

The completion of this report was possible owing to the availability of access to statistics concerning numbers of visitors to particular sites. These data were obtained from institutions and businesses providing tourist access to the 12 sites analysed in the present study (Table 1). The study covers the period 2015–2020. Access to data from the 5-year period before the pandemic has made the obtained material more objective and has enabled a more reliable assessment of the potential of particular sites at the time preceding the pandemic.

Table 1. Show caves according to the order in which the caves are made available to tourists.

No.	Year of tourist availability	Cave name	Physiographic Region	Geographical coordinates
1	1842	Smocza Jama	Silesian-Kraków Upland	50°03'11.54", 19°56'01.36"
2	1870	Wierzchowska Górna Cave	Silesian-Kraków Upland	50°10'29.90", 19°48'24.30"
3	1910	Mechowo Cave	Polish Lowland	54°42'48.65", 18°17'04.80"
4	1935	Radochowska Cave	Sudetes Mts.	50°21'32.28", 16°49'03.86"
5	1953	Mroźna Cave	Tatry Mts.	49°14'58.90", 19°52'01.90"
6	1972	Raj Cave	Holy Cross Mts.	50°49'31.00", 20°29'57.00"
7	1983	Niedźwiedzia Cave	Sudetes Mts.	50°14'04.26", 16°50'36.65"
8	1987	Łokietek's Cave	Silesian-Kraków Upland	50°12'06.10", 19°49'07.56"
9	1992	Ciemna Cave	Silesian-Kraków Upland	50°11'48.95", 19°49'54.29"
10	1994	Nietoperzowa Cave	Silesian-Kraków Upland	50°11'38.33", 19°46'28.24"
11	2005	Głęboka Cave	Silesian-Kraków Upland	50°34'23.00", 19°31'44.00"
12	2012	Kadzielnia Cave	Holy Cross Mts.	50°51'42.00", 20°37'07.00"

Geomorphological and geotouristic settings of show caves

Poland's show (commercial) caves are characterised by a considerable variety of locations, physical parameters (e.g. elevation, length, depth, denivelation and aesthetic values. The highest-located show cave in Poland is Mroźna (Frosty) Cave, whose entrance hole lies at 1112 m a.m.s.l, while Mechowo Caves have the lowest location, at 60 m a.m.s.l. The biggest denivelation among the studied caves is characteristic of Niedźwiedzia (Bear) Cave (118 m), and the smallest, of Mechowo Caves. The longest cave is Bear Cave in Kletno (4 500 m), and the shortest, Mechowo Caves (61 m).

Mechowo Caves are among the best-known caves situated on the Polish Plain. They lie on the Gdańsk Littoral, in the village of Mechowo in Puck powiat (county). The caves evolved in coarse-grained Pleistocene sandstones and conglomerates varying in cementation degree, showing distinct bedding in dominant horizontal and also diagonal planes. Their uniqueness and distinctive character are also emphasised by cave formation in fluvioglacial sediments of the Weichselian glaciation (Zagożdżon, Zagożdżon 2016). The main attractions are rock columns supporting the roof (Fig. 2). Selective weathering and water and aeolian erosion contributed to the development of these forms. Since 1955, Mechowo Caves have been protected as a natural monument.

Kadzielnia[1] Caves are a complex of three interconnected caves: Odkrywców (Explorers'), Prochownia (Gunpowder Store) and Szczelina (Crevice), linked by a common route. They have a short history (Kasza 2009) and are a unique site, being located almost in the centre of Kielce, a city with a population of 200,000. Thus, they highlight the value of the geological capital of Poland, which this city, holding many more karst secrets, undoubtedly is (Zieliński et al. 2016). Kadzielnia is one of the best-known and most spectacular karst

[1] The name Kadzielnia comes from the juniper growing here and used for incense production, or according to another version, from the incense maker (churchman) who leased the area.

Fig. 2. Mechowo Caves' entrance hole is formed by characteristic columns (photo: A.Marek 2021).

sites of the Świętokrzyski region and of Poland. In Kadzielnia Caves there are large, coarse-crystalline stalagmites with an age of 150,000-300,000 years (Poros et al. 2021). Further, part of it is a nature reserve; the space comprising the underground tour route lies within the Kielce area of protected landscape, and part of Kadzielnia hill is also a nature reserve.

Raj (Paradise) Cave is also one of the biggest tourist attractions in the Świętokrzyski region (Zieliński, Janeczko 2016). It is situated on Malik hill in the Bolechowicki Range of the Świętokrzyskie Mountains. It was discovered in 1963 and opened for tourism in 1972 (Rubinowski 1977). The distinctive feature of Raj Cave is its rich and varied dripstone decoration. Typical dripstone formations of the Raj Cave are massively occurring tubular soda-straw stalactites called macaroni, rarer dripstone columns and large stalagmites at the bottom of the cave (Poros et al. 2021). During a speleothem inventory, 47,518 calcite speleothems were recorded, including 47,173 stalactites (Pater et al. 2003). The cave is a nature reserve.

Głęboka (Deep) Cave is the only publicly accessible site in the northern part of the Kraków-Częstochowa Upland. It is located within Góra Zborów, which is presently classified as a nature reserve. The cave is 170 m long and 12.5 m deep. Until the 1950s, there was a working quarry there, which contributed to a lot of damage in the cave and disturbing its environment: the mining activity aimed at the exploitation of Icelat spar, a variety of calcite (PIG-PIB 2021). After the sealing of anthropogenic openings in the cave floor, stable microclimate started to be recreated.

Ciemna (Dark) Cave is also situated in the Kraków-Częstochowa Upland, in the Góra Koronna massif within the area of Ojcowski National Park (ONP). It is located above the Prądnik valley. The cave is one of the most prominent archaeological sites in Poland (traces of Neanderthal presence). In 1924 the site was given legal protection (Zagożdżon, Zagożdżon 2016). According to Partyka (1997), in the 1990s, the cave was visited by every tenth visitor to the ONP.

Łokietek's[2] Cave is also situated in the Prądnik valley, in the ONP area. Similar to the former cave, it also developed in limestones (Fig. 3). It was Ojców's principal tourist attraction as early as the 18th century. Visitors used burning torches to light their way, which resulted in blackening the walls and denting the speleothems (Zagożdżon, Zagożdżon 2016). According to Partyka (1997), this cave was visited by every other visitor to ONP in the 1990s.

Wierzchowska[3] Górna (Upper Wierzchowska) Cave is located in the Kluczwoda valley in the Olkusz Upland. It developed in Upper Jurassic rock limestones. After World War II, it suffered a lot of damage because of unprotected cave openings. In 1966, the site was declared a natural monument.

Nietoperzowa (Bat) Cave lies in Będkowska Valley in the Olkusz Upland. It developed in Upper Jurassic rock limestones. In the 19th century, cave sediment was industrially exploited because of deposited bat droppings (Zelga-Szmidla, Gurgul 2007). It has been a nature reserve since 1997.

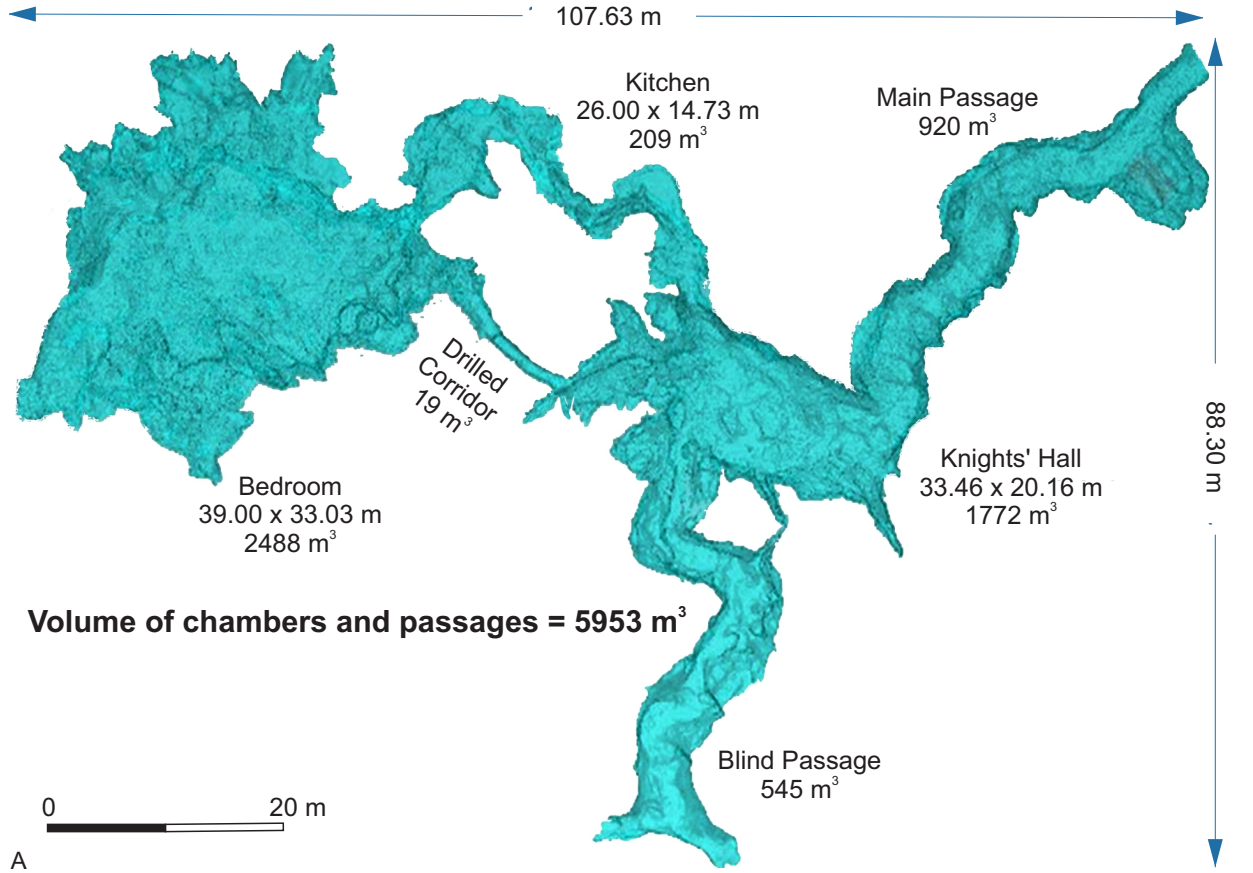
Smocza Jama (Dragon's Den) is located within Wawel hill in Kraków. A convenient location in the centre of an ancient settlement within one of the most attractive European tourist cities (Zieliński, Dziarmaga 2017), association with a popular legend and position on the shortest route from the castle courtyard to the bank of the Vistula make this cave widely popular. Moreover, Smocza Jama was the first Polish cave officially opened to the public and visitors have been admitted since 6 June 1842 (Mikoś et al. 2021). The cave consists of three chambers, the largest being 25 m long and 10 m high (Duda et al. 2010). The cave lacks speleothems, and some parts of walls and roofs are covered with brick casing (Zagożdżon, Zagożdżon 2016).

Radochowska[4] Cave is situated on the southern slope of Bzowiec hill (697 m a.s.l.) in the Złote (Golden) Mountains, a range in the eastern Sudetes. It developed in a marble lens within early Cambrian and early Palaeozoic crystalline rocks, including mica schists, paragneisses, quartzites and amphibolites (Bartuś 2012). Inside, the Gothic Chamber is particularly noteworthy. It contains a

[2] The cave is named after Władysław I Łokietek – King of Poland in 1320–1333.

[3] The name of the cave comes from the nearby village of Wierzchowie.

[4] The name of the cave comes from the nearby village of Radochów.



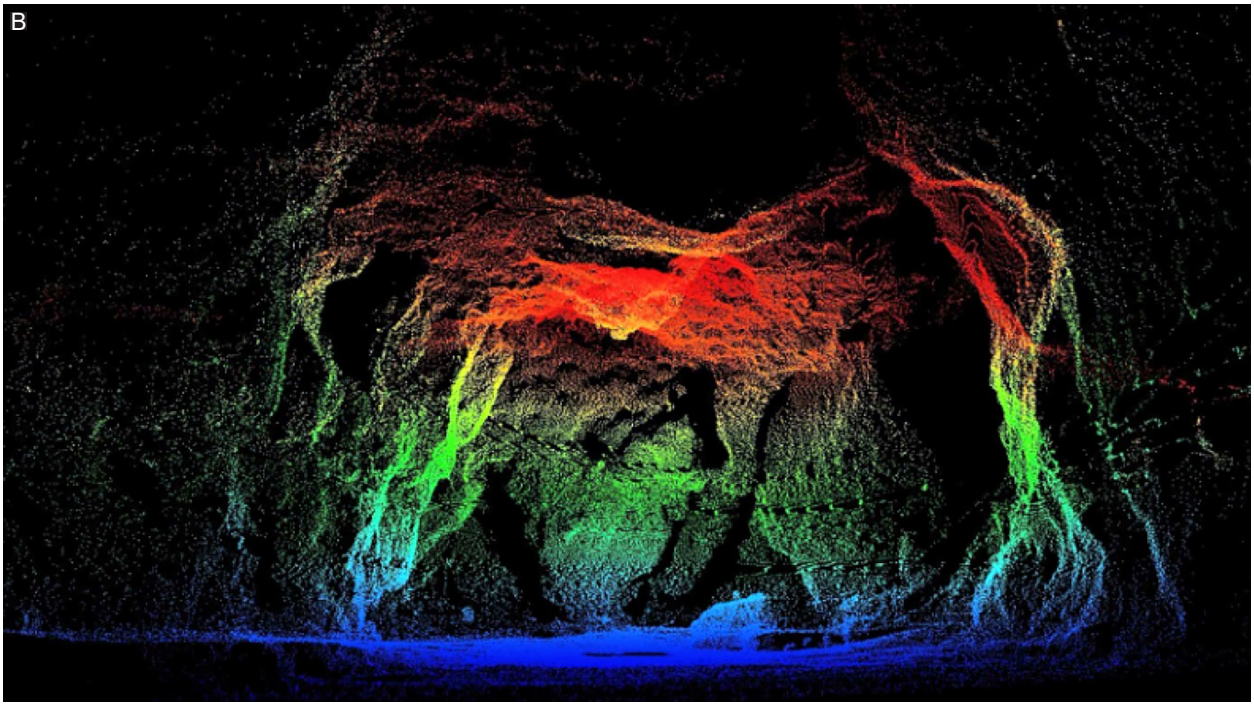


Fig. 3. The Łokietek's Cave. A – Model 3D and dimensions of chambers and passages; B – Isometric projection of a section of the Knights' Hall; projection composed of 357 terrestrial laser scanning (TLS) images; (Curtesy P. Wężyk – Laboratory of Geomatics, Faculty of Forestry, University of Agriculture in Kraków)

Fig. 4. Entrance pavilion of Bear Cave (photo A.Marek 2021).

lake with an area of 30 m². The cave was opened to the public in the interwar period. In front of the cave there stood a small building where paleontological findings were displayed. After World War II, the cave was left without protection, which contributed to the destruction of speleothems. Only small fragments of flowstone sheets have been preserved (Marek 2015). The cave has been protected as a natural monument since 2008.

Niedźwiedzia (Bear) Cave lies on the eastern slope of the Kleśnica valley, in the Śnieżnik massif, a part of the Eastern Sudetes (Fig. 4). It developed in a marble lens inside Stroma mountain (1166 m). It was discovered during routine operation work in a marble quarry in 1966 (PAN 1989). The tour route on the middle floor runs through varied spaces with distinguishable parts containing alluvial deposits and dripstone formations. Bear Cave, together with the surrounding forest rich in rare groundcover species, was declared a nature reserve in 1977 (Marek 2015).

Mroźna (Frosty) Cave is located on a slope of Kościeliska Valley, in the Organy massif, a part of the Western Tatras. It was formed in Middle Triassic limestones in the Pliocene (Fig. 5). It was discovered by S. Zwoliński in May 1934 (Lewkowicz 2010). Barely 63 m of corridors were discovered then.

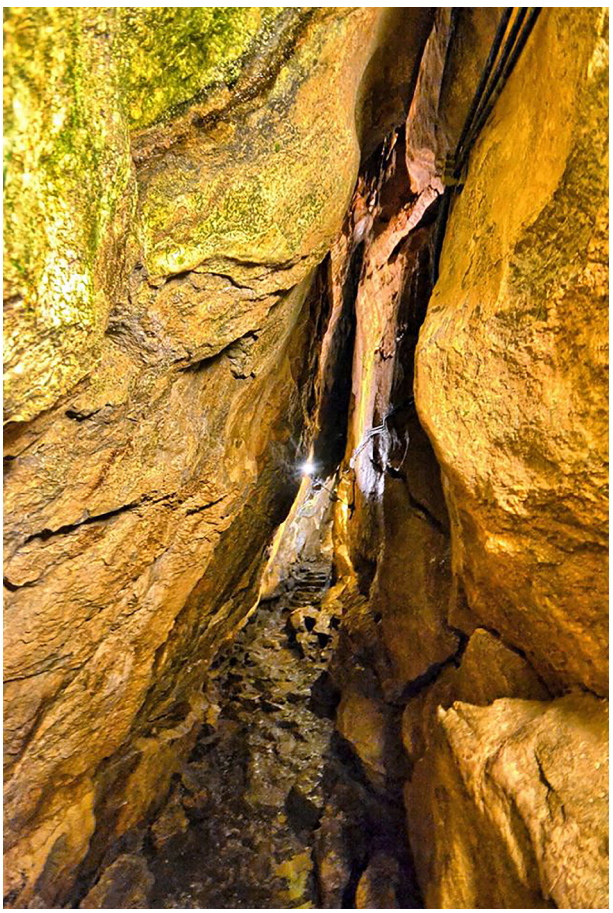


Fig. 5. White Passage (fractured corridor) in the Mroźna Cave (photo Zb.Zwoliński 2016).

Popularity of show caves

The studied show caves are characterised by considerable variety in terms of geographical position and form of protection. Three sites are situated within national parks (Ciemna Cave, Łokietek's Cave and Mroźna Cave). The utmost opposite of such a position is urban location. This concerns Kadzielnia Caves in Kielce and Dragon's Den in Kraków. The analysed caves also vary in terms of physical characteristics such as length, shape, capacity or denivelation, as well as aesthetic values shaping the assessment of the attractiveness of caves and their surroundings.

By far, the most popular and the most visited Polish cave is Smocza Jama (Dragon's Den). Its popularity with visitors is mostly due to the location in the centre of one of the most attractive Polish cities (Zieliński, Dziarmaga 2017). Smocza Jama is visited by more than 400,000 people annually (Fig. 6). The site also owes its success to a popular legend about the Wawel Dragon. It is also excellently advertised by the intriguing statue of a fire-breathing beast.

Commercial success has also been achieved by the only ticketed cave situated in an attractive valley in the Tatra National Park (TNP). Considering the fact that even with its 4 million visitors a year the TNP is one of the most popular national parks in Poland, it is not surprising that Mroźna Cave is also visited by a large number of tourists (Fig. 6). The popularity is also due to the physical character of the cave. It is visited along a one-way route, which does not loop. Moreover, the entrance and the exit are on different sides of the cave, which is very advantageous for organising tourist traffic. In 2018, the visitor attendance at this site was considerably lower in comparison with previous years, and this can be attributed to the fact the cave was closed for renovation works that were urgently required, owing to hazard caused by rockfalls off the roof sections and the need to secure these places, as well as to a need for modernisation of cave lighting. Unfortunately, because of the current and possible future rockfalls, Mroźna Cave is closed again to visitors in 2021.

A considerable number of tourists also visit Łokietek's Cave (Fig. 6), which is associated with a well-known legend about the Polish king Władysław Łokietek (to whom it owes its name). A commercial wonder among Polish caves is Raj (Paradise) Cave in Kielce region. The tour route in this cave is just 180 m long, but the dripstone decoration gives this space a unique character. Moreover, a big advantage is its location by the road from Kielce to Kraków. What is also very important is the catchy name with positive connotations – Paradise.

Great popularity is also enjoyed by Niedźwiedzia (Bear) Cave (Fig. 6). It is only for conservation reasons and to maintain the sustainability of the cave system that restrictive measures have been implemented to ensure that the per-annum number of visitors does not cross the advisable threshold limit, and this is why the number of visitors does not grow from one year to the next, although demand may be estimated as circa 50,000–60,000 more visits than the current number (Artur Sawicki – cave manager, oral information, 2021). Therefore, attempts are being made to create another independent tour route in the

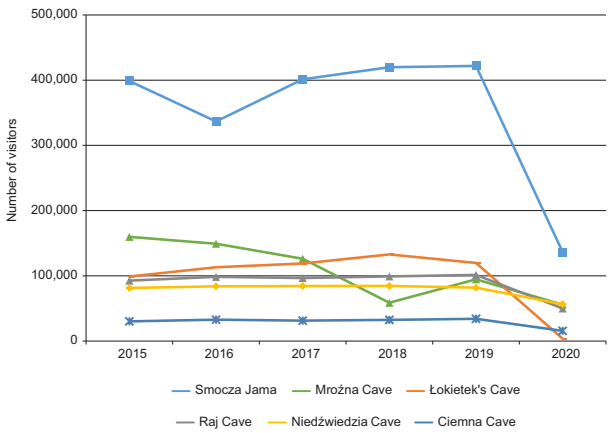


Fig. 6. Visitor numbers in six most popular Polish caves during 2015–2020.

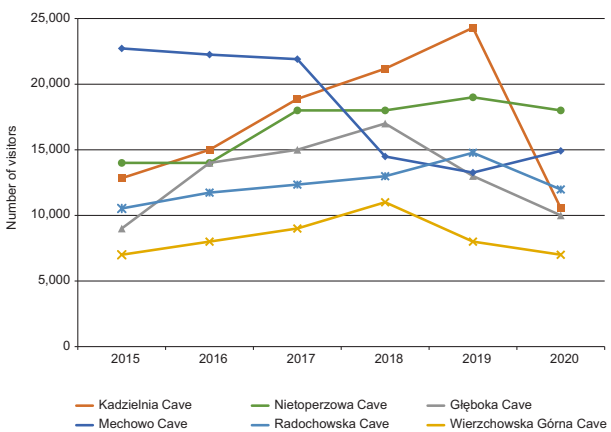


Fig. 7. Numbers of visitors to less popular Polish caves during 2015–2020.

currently inaccessible part. Its launch is planned for about 2025.

Although the remaining show caves do not have such large visitor figures (Fig. 7), they are still very important geotourism sites, significantly enhancing geodiversity. One should emphasise the value of Mechowo Caves, which are the smallest of the described sites. Despite its small size, the site is unique because of its development in Pleistocene fluvioglacial deposits and being the only publicly accessible site of this kind in Pomerania. Yearly, it may be visited by nearly 23,000 people (Fig. 7). Moreover, the admission fee is lower than those in the other commercial caves in Poland (Table 1). The most expensive Polish cave is Bear Cave. In high season (July and August), the full admission fee is 35 PLN, while the reduced one is not much less, at 30 PLN (Table 1). The admission fees are similar to those in the Slovak Republic (Čech et al. 2021). It is important to note that caves are a significant economic resource for the regions where they exist, and a direct and indirect source of income for many individuals.

It should be acknowledged that the geotourism potential of show caves in Poland is huge. In the analysed period, the highest total number of visitors (nearly 954,000) was recorded in 2017. It might be supposed that, had it not been for the considerable drop in visitor numbers to Mroźna Cave because of its temporary closure in 2018, the total number of visitors to show caves in Poland could have exceeded 1 million. An equally remarkable number of tourists visited caves in 2019. On average, show caves in Poland were visited by c. 932,000 people per annum during 2015–2019. In comparison, caves in the Czech Republic register c. 800,000 visitors a year, although the number of show sites is larger and the caves are generally more spacious (Marek, Olszak 2012).

The current epidemic has caused a significant drop in visitors' figures. In 2020, cave attendance was c. 42% of the mean from 2015 to 2019. The epidemic affected Łokietek's Cave the most. The 2020 attendance at this site was hardly 3% (just 3600 visitors) of that in 2019. It is noteworthy that Mechowo Caves recorded a 12.5% rise in interest

Table 2. Main attractive features of show caves in Poland.

Cave name	Environmental values (Representativeness, Rarity, Scenic-aesthetic)						Geohistorical–geoarcheological–geocultural values	Touristic values		
	Entrance altitude*	Total length	Denivelation	Clastic sediments	Speleothems	Fauna	Settlement, human presence	Accessible length	Artificial path	Entrance fee**
	[m a.s.l.]	[m]		[N – none, R – rare, S – small, M – moderate, B – big amount]				[m]	[N – no, P – partly, Y – yes]	[PLN]
Mechowo Caves	56	61	0	R	N	R	R	31	N	3/2
Kadzielnia Caves (Odkrywców, Prochownia, Szczelina)	257	392	23	S	S	M	N	140	Y	15/10
Raj Cave	250	240	9.5	M	B	B	B	180	Y	25/20
Głęboka Cave	365	190	16.5	M	S	M	N	170	Y	15/12
Ciemna Cave	372	209	10	S	S	M	B	130	P	14/7
Wierzchowska Górna Cave	390	975	25	M	M	M	B	700	P	20/16
Łokietek's Cave	453	320	7	B	N	M	B	270	N	26/13
Nietoperzowa Cave	439	891	52	B	N	M	B	300	P	15/10
Smocza Jama	205	270	15	N	N	R	M	81	Y	7
Radochowska Cave	453	501	30	S	R	M	N	300	P	25/20
Niedźwiedzia Cave	800	4500	118	M	B	B	R	700	Y	32/25
Mroźna Cave	1112	773	41.5	S	S	M	N	511	P	14/7

*According to different sources.
**Entrance fee: full/reduced.

Table 3. Assigned scores for cave attraction features.

Score	Environmental values (Representativeness, Rarity, Scenic-aesthetic)						Geohistorical–geoarcheological–geocultural values	Touristic values		
	Entrance altitude	Total length	Denivelation	Clastic sediments	Speleothems	Fauna	Settlement, human presence	Accessible length	Artificial path	Entrance fee*
	[m a.s.l.]	[m]		[N – none, R – rare, S – small, M – moderate, B – big amount]				[m]	[N – no, P – partly, Y – yes]	[PLN]
0	0–100	0	0–10	N	N	N	N	0	N	0
1	100–300	0–250	10–20	R	R	R	R	0–100	–	30–…
2	300–600	250–500	20–40	S	S	S	S	100–200	P	20–30
3	600–1000	500–1000	40–100	M	M	M	M	200–500	–	10–20
4	1000–…	1000–…	100–…	B	B	B	B	500–…	Y	0–10

compared to 2019. It should also be noted that these are the combined show caves located in the Kraków-Częstochowa Upland that have the biggest tourism potential. This area could even be referred to as a commercial cave district.

Show caves as geosites

In this paper, attempts were made to apply the Modified Geosite Assessment Model (M-GAM) method proposed by Tomić and Božić (2014) and Tomić et al. (2018). However, it turned out that at this stage of the research we do not have all the necessary data. Therefore, the method was significantly reduced and not fully applied. Hence, the presented results should be treated as preliminary.

Table 2 summarises the main attractiveness characteristics of the analysed caves. The characteristics of the caves' attractiveness can be classified into three categories of values: environmental, geohistorical–geoarcheological–geocultural and tourist. The assigned values of each characteristic are subject to the arbitrary judgement of the authors, apart from quantitative data, although these may also differ depending on the source of information. Table 3 presents the scores that were assigned to the individual values of the cave attractiveness features listed in Table 2. A 5-point Likert scale was used, from 0 to 4. The ranges for the values of the ratings were adopted based on the expert system. The results of assessments of the attractiveness of tourist caves in Poland are listed in Table 4.

Table 4. Results of the assessment of the attractiveness as geosites of show caves in Poland.

Rank	Cave name	Total score
1	Niedźwiedzia Cave	32
2	Wierzchowska Górna Cave	29
3	Nietoperzowa Cave	27
4	Mroźna Cave	26
5	Raj Cave	25
6	Łokietek's Cave	22
7	Głęboka Cave	21
8	Kadzielnia Caves	21
9	Ciemna Cave	20
10	Radochowska Cave	20
11	Smocza Jama	17
12	Mechowo Caves	9

The first five places on the list of the most attractive tourist caves are occupied by: Niedźwiedzia Cave (Fig. 8), Wierzchowska Górna Cave, Nietoperzowa Cave, Mroźna Cave and Raj Cave, which does not raise any objections to the generally accepted view of their high attractiveness, especially due to the speleothems. This is particularly true of the Niedźwiedzia Cave and Raj Cave, which is also confirmed by the visitation statistics for these caves. The penultimate position on the list of Smocza Jama, recognised as the most popular cave in terms of the number of visitors during the year, is no surprise, as its high popularity is evidenced not by its outstanding speleological features but by its very good and easy accessibility in a popular location in Kraków. In last place is Mechowo Caves, which owes its low rating to the very low values of speleological features, and above all to the non-karst genesis, which does not attract tourists' attention.

Fig. 8. Speleothems in the Niedźwiedzia Cave, the most attractive show cave in Poland (photo Zb.Zwoliński 2022).

Conclusions

The potential of show caves in Poland is very significant. Caves are visited by about 950,000 tourists a year. It is worth noting that public interest in visiting caves is much bigger than the physical or ecological possibilities of admitting visitors in the way that does not threaten the sustainability of the cave environment. Therefore, it is advisable to take further action aimed at adapting new caves for tourism. This will make it possible to equitably distribute the tourist population desiring to make trips to cave sites; to elaborate, by developing new caves in a way that tourists would find their interests sustained in visiting the prepared site, tourist traffic can be dispersed away from cave sites that are particularly heavily populated by tourists (such as Kadzielnia and Raj Caves), by incentivising them to visit similar neighbouring sites instead.

By far, the most visited cave in Poland is Smocza Jama. In 2019, the number of visitors to this small site exceeded 420,000. The commercial success of this site is influenced by its location in the centre of one of the most attractive Polish and European tourist cities, a well-known legend and its materialisation in the form of a popular sculpture. Another cave which stands out in terms of attendance is Mroźna Cave in the Tatras. However, its continuous operation as a tourist site is disturbed by problems related to ongoing karst processes and their consequences (rockfalls). Other popular sites are Łokietek's Cave in the Ojcowski National Park and Raj Cave in the Świętokrzyski region, characterised by beautiful dripstone formations. Raj Cave benefits from a very good location and an appealing name, too. Another very popular cave is Niedźwiedzia Cave, situated in the Eastern Sudetes. The number of visitors to this site usually reaches the tourism carrying capacity. However, another tour route at this site is planned to be launched around 2025.

The following caves were identified as the most attractive geosites: Niedźwiedzia Cave, Wierzchowska Górna Cave, Mroźna Cave, Raj Cave, Nietoperzowa Cave, and Ciemna Cave. The popularity of show caves does not necessarily reflect the attractiveness of caves as geosites. The environmental, geohistorical-geoarcheological-geocultural and tourist values used in the cave assessment are not perceived by tourists or taken into account when choosing caves to visit. Very often, the most important factor deciding about visiting a cave is its accessibility. This is the case of the Smocza Jama (Dragon's Den), which is located in an extremely popular place in Krakow, i.e. right next to the Wawel Castle. But in terms of value, it ranks penultimate in the ranking. Taking into account the analysed values of the caves, the Niedźwiedzia (Bear) Cave was considered the most attractive cave. The cave obtained 32 out of 40 possible scores. The total score was reduced by the high price of admission to the cave and the not very rich geohistorical-geoarcheological-geocultural traces. The last place in the ranking is occupied by Mechowo Caves, which are a kind of rarity among the analysed caves. It is not a karst cave, but is actually unique in the world due to its genesis in Quaternary deposits.

At the same time, it must be emphasised that commercial attendance success cannot always be directly translated into the popularity of individual sites, as they vary in the length and character of tour routes, visiting time, the number of visitors admitted in one group or the possibility of

admitting successive groups after one another. Therefore, one should also appreciate the tourism potential of small sites, such as Mechowo Caves. In spite of its tour route of just 31 m, this site can receive even c. 23,000 visitors a year. The authors of this report predict further growth of tourist caves' prosperity in Poland, stimulated by the International Year of Caves and Karst. Certainly, caves will be an even greater economic resource and a direct and indirect source of maintenance for an increasing number of people. Moreover, they have specific and unique value related to the possibility of paleoenvironmental reconstruction based on researching them. Consequently, caves are a priceless source of information. Therefore, they should be utilised in a sustainable way, making it possible to minimise and even eliminate any disturbance to their natural environment.

Acknowledgements

The authors would like to thank the management of all twelve analyzed caves for their kindness and valuable information. We would also like to thank Professors Tadeusz Mikoś (AGH University of Science and Technology in Kraków), Jan Urban (Institute of Nature Protection PAS in Cracow) and speleologists: Andrzej Kasza (Swiętokrzyski Speleoclub in Kielce) and Artur Komorowski (Beskidzki Speleoclub Association). Separate thanks go to the reviewers of the earlier version of the paper.

Author's contribution

AZ, AM and ZZ formulated the concept for the study; AZ and AM collected the data, performed statistical analysis and wrote the manuscript; and ZZ calculated the scores for geosites; AZ, AM, and ZZ read critically the whole text. All authors contributed equally towards conducting the research and revising an earlier draft of the manuscript critically for important intellectual content.

References

Alexandrowicz Z., Urban J., 2015. Crystal Caves in the Wieliczka Salt Mine – Unique cave site. In: Kicińska D., Stefaniak K., Szynkiewicz A. (eds), *Materiały 49 Sympozjum Speleologicznego* Sekcja Speleologiczna Polskiego Towarzystwa Przyrodników im. Kopernika, Załęcze Wielkie: 75–77.

Andrejczuk W., Kaźmierczak-Bereszka A., 2007. Jaskinie turystyczne Stanów Zjednoczonych. *Acta Geographica Silesiana* 2: 5–18.

Bartuś T., 2012. Jaskinia Radochowska. In: Słomka T. (ed.), *Katalog obiektów geoturystycznych w obrębie pomników i rezerwatów przyrody nieożywionej (A catalogue of geotourism sites within geological nature reserves and monuments)*. Wydawnictwo AGH, Kraków: 63–66.

Bočić N., Lukić A., Opačić V., 2006. Management models and development of show caves as tourist destinations Croatia. *Acta Carsologica* 35(2): 13–21. DOI 10.3986/ac.v35i2-3.224.

Cave J., Dredge D., 2020. Regenerative tourism needs diverse economic practices. *Tourism Geographies* 22(3): 503–513. DOI 10.1080/14616688.2020.1768434.

Čech V., Chrastina P., Gregorová B., Hronček P., Klamár R., Košová V., 2021. Analysis of attendance and speleotourism potential of accessible caves in karst landscape of Slovakia. *Sustainability* 13, 5881: 1–21. DOI 10.3390/su13115881.

Cigna A.A., 2010. Show cave development with special references to active caves. *Tourism and Karst Areas* 4(1): 7–16.

Cigna A.A., 2016. Tourism and show caves. *Zeitschrift für Geomorphologie* 60(2): 217–233. DOI 10.1127/zfg_suppl/2016/00305.

Cigna A.A., Forti P., 2013. Caves: The most important geotouristic feature in the world. *Tourism and Karst Areas* 6(1): 9–26.

Constantin S., Mirea I.C., Petculescu A., Arghir R.A., Măntoiu D.S., Kenesz M., Robu M., Moldovan O.T., 2021. Monitoring human impact in show caves. A study of four Romanian caves. *Sustainability* 13(4): 1619. DOI 10.3390/su13041619.

Crane R., Fletcher L., 2016. The speleotourist experience: Approaches to show cave operations in Australia and China. *Helictite* 42: 1–11.

Dowling K., Newsome D., 2017. Geotourism destinations – Visitor impacts and site management considerations. *Czech Journal of Tourism* 6(2): 111–129. DOI 10.1515/cjot-2017–0006.

Duda Z., Hydzik J., Wiśniewski M., 2010. Ocena stanu technicznego jaskini Smocza Jama na Wzgórzu Wawelskim w Krakowie. In: Zagożdżon P.P., Madziarz M. (eds), *Dzieje górnictwa – element europejskiego dziedzictwa kultury*. Oficyna Politechniki Wrocławskiej, Wrocław: 90–101.

Forti P., Pint J.J., Al-Shanti M.A., Al-Juaid A.J., Al-Amoudi S.A., Pint S.I., 2003. *The development of tourist caves in The Kingdom of Saudi Arabia.* Open-File Report SGS-OF-2003-6, Saudi Geological Survey, Jeddah.

Kambesis P., 2007. The importance of cave exploration to scientific research. *Journal of Caves and Karst Studies* 69(1): 46–58.

Kasza A., 2009. Nowe odkrycia w jaskiniach Kadzielni. *Jaskinie* 1(54): 30–31.

Kim S.S., Kim M., Park J., Guo Y., 2008. Cave tourism: Tourists' characteristics, motivations to visit, and the segmentation of their behavior. *Asia Pacific Journal of Tourism Research* 13(3): 299–318.

Kowalski S., 2006. Uwagi o osadnictwie paleolitycznym w Jaskini Ciemnej i Mamutowej w świetle badań z lat 1957–1974. In: Lech J., Partyka J. (eds), *Jura Ojcowska*

w pradziejach i początkach państwa polskiego. Ojcowski PN, Ojców: 335–354.
Kruczek Z., 2014. *Frekwencja w atrakcjach turystycznych*. Polska Organizacja Turystyczna, Kraków–Warszawa.
Lewkowicz Ł., 2010. Cave tourism in the Polish-Slovak transfrontier area. In: *6th Congress International Show Caves Association, Proceedings*, Liptovský Mikuláš: 100–107.
Lobo H.A.S., Moretti E.C., 2009. Tourism in caves and the conservation of the speleological heritage: The case of Serra Da Bodoquena (Mato Grosso Do Sul State, Brazil), *Acta Carsologica* 38(2–3): 265–276.
Lobo H.A.S., Perinotto J.A., De J., Boggiani P.C., 2008. Espeleoturismo no Brasil: panorama geral e perspectivas de sustentabilidade. *Revista Brasileira de Ecoturismo* l(l): 62–83.
Łyskowski M., Mazurek E., Ziętek J., 2014. Ground Penerating Radar investigation of limestone karst at the Odstrzelona Cave in Kowala, Świętokrzyskie Moutains, Poland. *Journal of Cave and Karst Studies* 76(3): 184–190.
Marciniak A., 2007. Walory decydujące o atrakcyjności obiektu geoturystycznego na przykładzie Dobszyńskiej jaskini lodowej – Słowacja. *Górnictwo i geologia* 2(1): 33–43.
Marciniak A., 2008. Percepcja walorów jako miara decydująca o atrakcyjności obiektu geoturystycznego, na przykładzie wybranych jaskiń słowackich. *Górnictwo i Geologia* 3(2): 43–51.
Marek A., 2015. *Geoturystyka Ziemi Kłodzkiej*. Wydawnictwo Silesia, Wrocław.
Marek A., Olszak I.J., 2012. Turystyczne jaskinie Czech i Moraw. *Słupskie Prace Geograficzne* 9: 61–78.
Mikoś T., Szumiński A., Tajduś A., Karczewski J., Kwiatkowska-Kopka B., 2021. *AGH na ratunek Smoczej Jamie. Udział Akademii Górniczo-Hutniczej w Krakowie w ratowaniu podziemnego zabytku*. Wydawnictwo AGH, Kraków.
Okonkwo E.E., Afoma E., Martha I., 2017. Cave tourism and its implications to tourism development in Nigeria: A case study of Agu-Owuru Cave in Ezeagu. *International Journal of Research in Tourism and Hospitality* 3(3): 16–24. DOI 10.20431/2455-0043.0303003.
Pachrová S., Chalupa P., Janoušková E., Šedivá-Neckářová A., Štefka L., 2020. Monitoring of visitors as a tool of protected areas management. *Academica Turistica* 13(1): 67–79. DOI 10.26493/2335-4194.13.67-79.
PAN [Polska Akademia Nauk]., 1989. *Jaskinia Niedźwiedzia w Kletnie. Badania i udostępnianie*. Zakład Narodowy im. Ossolińskich, Wrocław: 1–367.
Partyka J., 1997. Jaskinie Ojcowskiego Parku Narodowego udostępnienie dla ruchu turystycznego i problemy ochrony. *Materiały 31. Sympozjum Speleologicznego*, Sekcja Speleologiczna Polskiego Towarzystwa Przyrodników im. Kopernika, Ojców: 58–59.
Pater Ł., Wacławik Ł., Gubała J., 2003. Ocena stanu zachowania szaty naciekowej w Sali Stalaktytowej Jaskini Raj. In: Gradziński M., Szelerewicz M. (eds), *Materiały 37 Sympozjum Speleologicznego*, Sekcja Speleologiczna Polskiego Towarzystwa Przyrodników im. Kopernika, Wojcieszów: 51–53.
Pflitsch A., Piasecki J., Kleeberger M., 1999. Impact of tourists on the climate of static cave systems. *Proceedings of the 15th International Congress of Biometeorology & International Conference on Urban Climatology*, Sydney, 24: 1–8.
PIG-PIB [Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy]., 2021. *Jaskinie Polski*, Online: jaskiniepolski.pgi.gov.pl/Details/Information/3567 (accessed 2 September 2021).
Poros M., Urban J., Ludwikowska-Kędzia M., 2021. Dziedzictwo geomorfologiczne Geoparku Świętokrzyskiego i jego znaczenie dla geoturystyki. *Landform Analysis* 40: 71-107.
Rindam M., 2014. Cave tourism: The Potential of Asar Cave as a Natural Tourism Asset at Lenggong Valley, Perak. *SHS Web of Conferences* 12, 0101. DOI 10.1051/shsconf/20141201014.
Rubinowski Z., 1974. *Badania i udostępnienie jaskini Raj*. Wydawnictwa Geologiczne, Warszawa.
Rubinowski Z., 1977. Wpływ turystyki na stan zachowania jaskini Raj w Górach Świętokrzyskich. *Kras i speleologia* 1: 29–41.
Tičar J., Tomić N., Breg Valjavec M., Zorn M., Marković S.B., Gavrilov M.B., 2018. Speleotourism in Slovenia: balancing between mass tourism and geoheritage protection. *Open Geosciences* 10: 344–357. DOI 10.1515/geo-2018-0027.
Urban J., 1996. *Jaskinie regionu świętokrzyskiego*. Polskie Towarzystwo Przyjaciół Nauk o Ziemi, Warszawa.
Urban J., 2006a. Prawna i praktyczna ochrona jaskiń w Polsce. *Chrońmy Przyrodę Ojczystą* 1: 53–72.
Urban J., 2006b. Evaluation and protection of caves and karst sites on the state and international level – Polish example. In: Bella P. (ed.), *Výskum, využívanie a ochrana jaskýň* 5: 230–237.
Urban J., 2008. *Kras gipsowy w Nadnidziańskim i Szanieckim Parku Krajobrazowym*. Wydawnictwo Zespołu Nadnidziańskich i Świętokrzyskich Parków Kraiobrazowych.
Urban J., 2011. Tourist accessibility of caves in Poland – Description of the problems. In: Słomka T. (ed.), *Geoturism, A Variety of Aspects*. Wydawnictwo AGH, Kraków: 55–70.
Urban J., Kasza A., 2008. Genetical types of the caves in sandstones of the Swietokrzyskie (Holy Cross) Mountains, Central Poland. In: *Proceedings of the 10th International Symposium on Pseudokarst*, 29.04.2008–2.05.2008, Gorizia: 43–52.
Wieczorek D., Zieliński A., 2020. Uwarunkowania przyrodnicze życia ludów epoki kamienia w rejonie Dębowca i Osieka Jasielskiego. In: Gancarski J. (ed.), *Epoka Kamienia w Karpatach*. Wydawnictwo Muzeum Podkarpackiego, Krosno: 401–421.
Zagożdżon P.P., Zagożdżon K.D., 2016. Wybrane aspekty geoturystyki w Polsce – obiekty podziemne i geoturystyka miejska. *Przegląd Geologiczny* 64(9): 739–750.
Zelga-Szmidla A., Gurgul E., 2007. Speleologia na Jurze Krakowsko-Częstochowskiej. *Prace Naukowe Akademii im. Jana Długosza w Częstochowie, Kultura Fizyczna* 7: 225–229.
Zieliński A., 2010. Związek krajobrazu z rozwojem turystyki w rejonie Staszowa. *Prace Komisji Krajobrazu Kulturowego* 14: 274–283.
Zieliński A., 2013. *Rozwój jezior krasowych w Niecce Połanieckiej*. Wydawnictwo UJK, Kielce.
Zieliński A., Dziarmaga D., 2017. Atrakcyjność turystyczna miast w opinii turystów. *Zeszyty Naukowe. Turystyka i Rekreacja* 2(20): 131–139.
Zieliński A., Janeczko K., 2016. Największe atrakcje turystyczne w województwie świętokrzyskim w opinii turystów. *Ekonomiczne Problemy Turystyki* 2(34): 297–307. DOI 10.18276/ept.2016.2.34-25.
Zieliński A., Łyskowski M., Mazurkiewicz E., 2016. Ground penetrating radar investigation of limestone karst phenomena in the Botanical Garden in Kielce. *Geology, Geophysics & Environment* 42(1): 31–38. DOI 10.7494/geol.2016.42.1.31.
Zwoliński Zb., 2004. Geodiversity. In: A.S.Goudie (ed.), *Encyclopedia of Geomorphology, Vol. 1*. Routledge, London: 417–418.