Geotouristic attractiveness of the show caves of the Kraków-Częstochowa Upland area

Atrakcyjność geoturystyczna jaskiń udostępnionych do zwiedzania na terenie Wyżyny Krakowsko-Częstochowskiej

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Abstract: *In this paper, six scenic caves situated in the Kraków-Częstochowa Upland area were the subject for comparative research, considered as very essential examples of underground geotouristic attractions, displaying karst forms completely different from each other. These include: Smocza Jama Cave (Dragon's Den) in Kraków city, Łokietek and Ciemna (Dark) Cave at Ojców, Wierzchowska Górna Cave at Wierzchowie, Nietoperzowa-Zygmunta Cave at Jerzmanowice and Głęboka (Deep) Cave at Podlesice. The first five caves are situated in the southern part of the Kraków-Częstochowa Upland and the last one, in its northern part. All of them are situated in the Silesian-Kraków Monocline. These caves developed in the Upper Jurassic (Oxfordian) massive limestones. Their karst forms are various and picturesque. Numerous animal remnants and traces of different prehistorical cultures were discovered and collected by researchers within and around three caves situated within the Kraków-Częstochowa Upland area.*
The geotouristic attractiveness of all six caves was demonstrated by their comparative geotourism valorisation evaluation adapted to meet tourists', educators' and investors' expectations and needs. The statistical data of the annual number of visitors at these objects were also discussed. In general, interest in these caves as geotouristic abiotic nature objects has been growing regularly up until today. They have become very widely known in Poland. Moreover, the Smocza Jama Cave, associated with the Royal Castle on the Wawel Hill, and the Łokietek Cave have become very popular worldwide.

Keywords: *geotourism, Oxfordian limestones, karst, speleothems, animal bones*

Treść: *Artykuł został poświęcony analizie zróżnicowania podziemnych form krasowych na przykładzie sześciu jaskiń Wyżyny Krakowsko-Częstochowskiej dostępnych do zwiedzania, jako bardzo istotnych podziemnych atrakcji geoturystycznych. Należą do nich Smocza Jama w Krakowie, jaskinie Łokietka i Ciemna w Ojcowie, Jaskinia Wierzchowska Górna w Wierzchowiu, Jaskinia Nietoperzowa-Zygmunta w Jerzmanowicach, położone w południowej części Wyżyny Krakowsko-Częstochowskiej, i Jaskinia Głęboka, usytuowana w północnej części tej krainy. Poszczególne obiekty znajdują się na obszarze monokliny śląsko-krakowskiej. Powstały w oksfordzkich wapieniach skalistych. Ich szata naciekowa jest bardzo malownicza i zróżnicowana. Wewnątrz i/lub na zewnątrz trzech z nich wyeksponowano także skamieniałości, szczątki zwierząt oraz ślady prehistorycznej cywilizacji odkryte przez naukowców.*
Atrakcyjność geoturystyczna wymienionych jaskiń została określona na podstawie wyników waloryzacji geoturystycznej przeprowadzonej w przypadku każdej z nich, z uwzględnieniem potrzeb turystów, edukatorów i inwestorów. Wzięto pod uwagę także dane statystyczne dotyczące frekwencji turystów w określonych okresach w tych obiektach. Ogólnie rzecz biorąc, zainteresowanie opisywanymi jaskiniami systematycznie wzrasta do chwili obecnej. Stopniowo zyskują one na popularności w całej Polsce, a Smocza Jama (zwiedzana zwykle razem z Zamkiem Królewskim na Wawelu) oraz Jaskinia Łokietka są znane również na całym świecie.

Słowa kluczowe: *geoturystyka, wapienie oksfordu, kras, szata naciekowa, kości zwierząt*

Introduction

The Kraków-Częstochowa Upland area, situated in southern Poland (Kondracki, 2011; Fig. 1), is built mainly of Upper Jurassic (Oxfordian) deposits (Dadlez *et al.*, 2000; Gradziński, 2009; Figs. 2, 3). It represents one of the most typical karstlands in Poland. Over two thousand caves were developed within the Kraków-Częstochowa Upland area, six of which, open for tourism, were selected for the research due to the wide variety in their development and their picturesque karst forms. These include: Smocza Jama Cave (Dragon's Den) in Kraków city, Łokietek and Ciemna (Dark) Cave at Ojców, Wierzchowska Górna Cave at Wierzchowie, Nietoperzowa-Zygmunta Cave at Jerzmanowice situated in the southern part of the Kraków-Częstochowa Upland area and Głęboka (Deep) Cave at Podlesice in its northern part (Figs. 1, 2). They are all situated in the Silesian-Kraków Monocline (Dadlez *et al.*, 2000; Fig. 2). Up until today these caves have been inhabited by numerous bats and spiders. Lesser horseshoe bats are the dominating species (Nowak & Grzywiński, 2007, 2012, 2017). Their hibernation time lasts from autumn till spring, and therefore, the caves can operate for tourism only from April/May until September/October, depending on the number of bats in the cave (Dz.U. z 2016 r., poz. 2183).

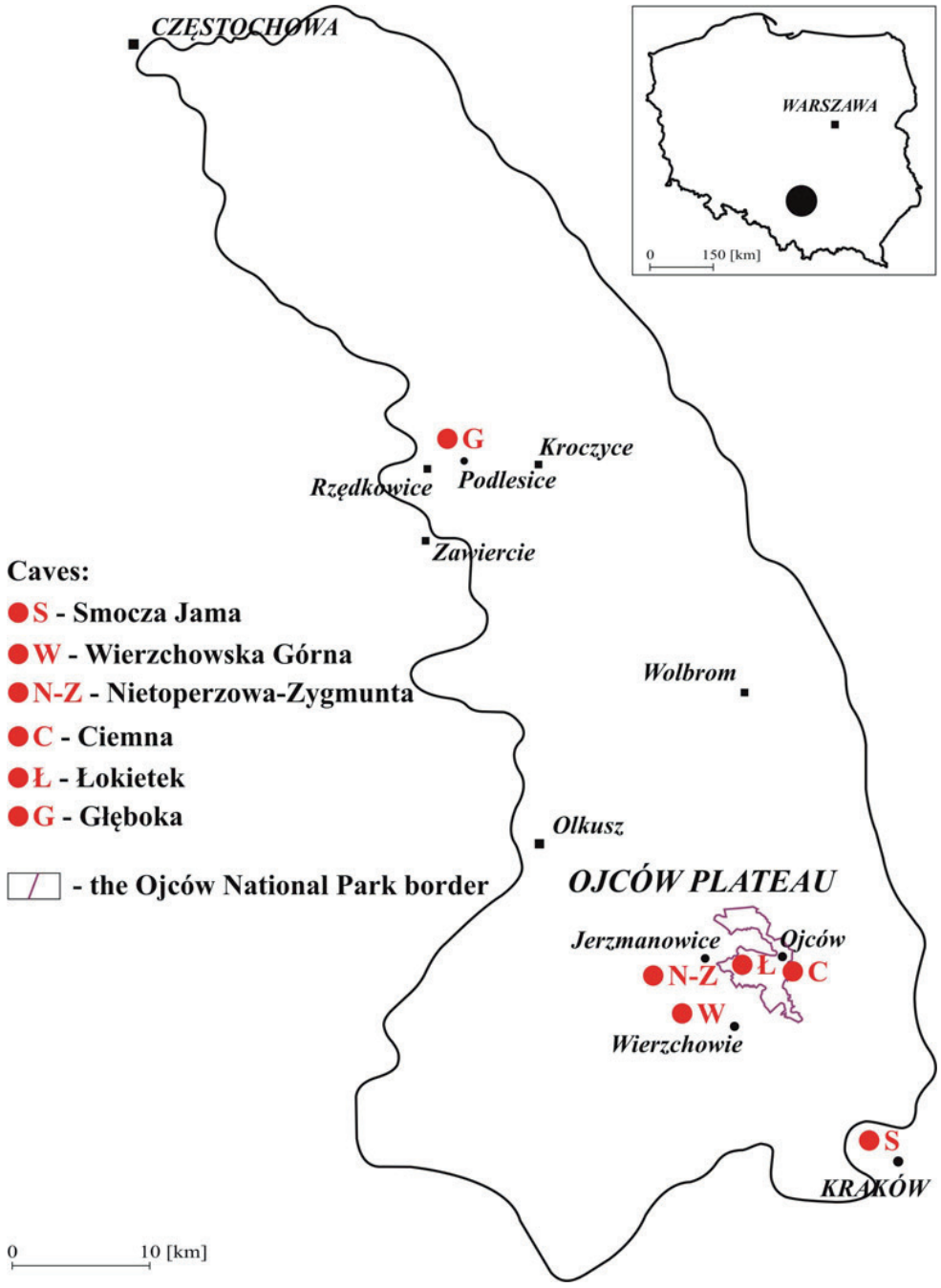

Fig. 1. Situation of selected caves within the Kraków-Częstochowa Upland area (after Kondracki, 2011)

Fig. 2. Situation of selected caves within the Silesian-Kraków Monocline area (after Dadlez *et al.*, 2000): 1 – Carboniferous; 2 – Triassic; 3 – Jurassic; 4 – Cretaceous; the other explanations – see Fig. 1

The aim of the paper is to demonstrate the geotouristic attractiveness of these caves, and compare their valorisation and evaluation (Tabs. 1–4) based on the statistical data of total annual visitors number during different time periods (Tab. 5).

Table 1. Size and distinguishing features of the caves open for tourism (after Szelerewicz & Górny, 1986, 2013; Górny & Szelerewicz, 1987; Krzemień & Partyka, 1987; Rotter & Szelerewicz, 1999; Gradziński & Partyka, 2004a, 2004b; Gradziński *et al.*, 2009, 2020; Sznober & Tyc, 2010; Polonius *et al.*, 2013, 2018; Gradziński & Michalska, 2020a, 2020b; Górny & Siwecki, 2020a, 2020b; Figs. 1–14)

Cave (date of its opening for tourism)	Length [m]	Vertical extent [m]	Distinguishing features	
			natural	anthropogenic
Smocza Jama (1976)	276	15	picturesque, wide, various cupolas, spacious chambers, water bodies	Dragon's sculpture outside cave
Łokietek (1910s)	320	7	picturesque various cupolas, moonmilk speleothems, short tubular stalactites, low stalagmites	entrance gate with lattice symbolizing cobweb motif
Ciemna (19th/20th century)	230	3	picturesque various cupolas, moonmilk speleothems, short stalactites, sediment profile outcropped in the archaeological excavation	Ogrójec viewing platform, former Neanderthal hunter encampment in Oborzysko Wielkie Tunnel
Wierzchowska Górna (1985)	975	25	tubular and spherical stalactites, moonmilk speleothems, stained with iron and manganese minerals, outcrops of cave sediment file, cupolas, sinter pools and rimstone dames	collection of: speleothems form kinds, Upper Jurassic fossils, Pleistocene fauna skeletal remnants, crystalline calcite specimen, Paleolithic flint products and Neolithic clay vessel remnants, primitive human model with his hearth within cave
Nietoperzowa--Zygmunta (1994)	891	52	moonmilk speleothems, outcrops of cave sediment file, wide and various cupolas, water bodies	collection of Pleistocene fauna skeletal remnants within cave and at its booking office, lapidary of Pleistocene fauna sculptures and rock boulders occurring around cave
Głęboka (2010)	190	22	crystalline calcite speleothems and short stalactites, flowstones stained with iron minerals, outcrops of sediment file, cupolas in ceiling	collection of crystalline calcite mining tools and speleothems form kinds within cave, lapidary of rock boulders occurring around cave, collection of Upper Jurassic fossils, Pleistocene fauna bones, minerals and rock specimens in Centre for Jurassic Natural and Cultural Heritage at Podlesice

Table 2. Evaluation range and estimate in cave geotourism valorisation (Alexandrowicz *et al*., 1992; Dmytrowski & Kicińska, 2011; Dryglas & Miśkiewicz, 2014; Doktor *et al.*, 2015)

Symbol	Criterion	Evaluated qualities	Points
Cave substantive value (SV)			
A	cave length [m]	<100	1
		100–300	2
		>300	3
B	cave vertical extent [m]	<10	1
		10–20	2
		>20	3
C	cave genesis indicating elements	few forms indicating the genesis	1
		several forms indicating the genesis	2
D	speleothems presence	no forms	0
		single forms	1
		several forms	2

Table 2 cont.

E	sediment presence	thin cave sediments	1
		thick cave sediments	2
F	water presence in the cave	dripping water	1
		watercourses / water bodies occurrence	2
Cave cultural value (CV) ("yes" = 1 pt; "no" = 0 pt)			
G	G_1	cave connection with regional history	0/1
	G_2	cave connection with mining history	0/1
	G_3	cave connection with regional legend	0/1
Cave location value (LV)			
H	distance from roadways	>3 km from a roadway	1
		1–3 km from a roadway	2
		<1 km from a roadway	3
I	distance from touristic routes	>200 m from a touristic route	1
		10–200 m from a touristic route	2
		<10 m from a touristic route	3
J	distance from touristic resorts (cities, spas)	>5 km from a touristic resort	1
		<5 km from a touristic resort	2
		in a touristic resort	3
The availability of the information on the cave (AIC)			
K	the availability of the information on the cave	hardly available guidebooks, no description on webpages	1
		few guidebooks, short information on webpages	2
		many guidebooks, detailed description on webpages	3
Cave geotouristic development level (V)			
L	cave management	cave accessible for tourism, no management	1
		cave accessible for tourism, good management	2
M	sightseeing way	individual	1
		with a guide	2
N	information panel around the cave	no information panel	0
		information panel describes the cave superficially	1
		information panel describes the cave in detail	2
O	exhibitions and lapidaries around the cave	no exhibition and lapidary	0
		small exhibition / lapidary	1
		big exhibition / lapidary	2
P	infrastructure development in the vicinity of the cave	no infrastructure	0
		partial and incomplete infrastructure	1
		technical and sanitation infrastructure, gastronomic facilities and accommodation (within 1 km distance) developed very well	2

Table 3. Marks and ranges points for different values (Tab. 2) of cave geotourism evaluation (after Alexandrowicz *et al.*, 1992; Dmytrowski & Kicińska, 2011; Dryglas & Miśkiewicz, 2014; Doktor *et al.*, 2015)

Cave value	High grade (>70%)	Average grade (69–40%)	Low grade (<40%)
Substantive value (SV = A + B + C + D + E + F)	>10	10–6	<6
Cultural value ($CV = G = G_1 + G_2 + G_3$)	3	3–2	<2
Locational value (LV = H + I + J)	>6	6–4	<4
The availability of the information on the cave (AIC = K)	3	3–2	<2
Cave geotouristic development level (V = L + M + N + O + P)	>7	7–4	<4
Cave geotouristic attractiveness (GA = SV + CV + LV + AIC + V)	**>25**	**25–14**	**<14**

Table 4. Results of caves geotourism evaluation (Tabs. 1–3; Figs. 1–14)

Criterion & value	Caves					
	Smocza Jama	Łokietek	Ciemna	Wierzchowska Górna	Nietoperzowa--Zygmunta	Głęboka
A	2	3	2	3	3	2
B	2	1	1	3	3	3
C	2	2	2	2	2	2
D	1	2	2	2	2	2
E	2	2	2	2	2	2
F	2	1	1	1	2	1
SV	11	11	10	13	14	12
G_1	1	1	1	1	1	1
G_2	0	0	0	0	0	0
G_3	1	1	1	1	1	1
CV	2	2	2	2	2	2
H	3	3	3	3	3	3
I	3	3	3	3	3	3
J	3	1	1	1	1	1
LV	9	7	7	7	7	7
K	3	3	3	3	3	3
AIC	3	3	3	3	3	3
L	2	2	2	2	2	2
M	1	2	2	2	2	2
N	0	0	1	1	1	2
O	0	0	1	2	2	2
P	2	1	0	1	1	2
V	5	5	6	8	8	10
GA	30/39	28/39	28/39	33/39	34/39	34/39
	77%	72%	72%	85%	87%	87%

Table 5. Total annual visitors number of the selected caves in Poland from the years 1993–2020

Year	a	b	c	d*	e*	f	g	h
1993	no data	132,523	19,556	21,000	closed	closed	no data	no data
1994	no data	128,283	19,042	21,000	16,500	closed	no data	no data
1995	no data	130,257	21,482	21,000	16,500	closed	no data	no data
1996	no data	123,313	24,469	21,000	16,500	closed	no data	no data
1997	no data	129,698	24,744	21,000	16,500	closed	no data	no data
1998	no data	136,120	22,924	21,000	16,500	closed	no data	no data
1999	no data	128,525	22,056	21,000	16,500	closed	no data	no data
2000	no data	107,241	21,139	21,000	16,500	closed	no data	no data
2001	no data	98,915	17,568	21,000	16,500	closed	no data	no data
2002	139,438	98,613	13,976	21,000	16,500	closed	no data	no data
2003	134,089	107,767	19,426	21,000	16,500	closed	no data	no data
2004	124,504	106,199	20,365	21,000	16,500	closed	no data	no data
2005	119,753	105,656	21,907	21,000	16,500	closed	no data	no data
2006	138,359	110,129	21,765	21,000	16,500	closed	no data	no data
2007	174,274	118,272	25,219	21,000	16,500	closed	no data	no data
2008	164,420	104,674	24,466	21,000	16,500	closed	no data	no data
2009	157,969	104,637	27,129	21,000	16,500	closed	no data	no data
2010	145,463	89,039	22,794	21,000	16,500	no data	no data	no data
2011	155,214	99,175	28,179	21,000	16,500	no data	no data	73,840
2012	152,903	95,393	26,332	21,000	16,500	no data	95,543	72,556
2013	153,712	92,302	25,470	21,000	16,500	no data	95,118	81,257
2014	356,088	96,998	26,969	21,000	16,500	12,654	94,939	84,332
2015	395,554	98,904	30,232	21,000	16,500	15,104	92,664	81,496
2016	336,776	113,155	32,829	21,000	16,500	17,000	98,477	no data
2017	401,440	118,893	31,504	21,000	16,500	15,000	96,687	no data
2018	419,941	132,868	32,474	21,000	16,500	17,000	99,146	no data
2019	421,802	119,802	34,150	21,000	16,500	no data	no data	no data
2020	136,220	3,500	15,682	21,000	16,500	no data	no data	no data

a – Smocza Jama Cave in Kraków city (data obtained from the Wawel Royal Castle management)
b – Łokietek Cave at Ojców (after www2)
c – Ciemna Cave at Ojców (after www2)
d – Wierzchowska Górna Cave at Wierzchowie (after www5)
e – Nietoperzowa-Zygmunta Cave at Jerzmanowice (P. Ferdek – oral information)
f – Głęboka Cave at Podlesice (after Kruczek, 2019)
g – Paradise Cave in Chęciny town (after Kruczek, 2019)
h – Bear Cave at Kletno (after Kruczek, 2019)
* – approximately; no data for individual years

Methodology

The research is based on personal direct field observations and photographic documentation of the described sites. Apart from that, older papers dealing with geotouristic valorisation and evaluation of these six caves were reviewed. These papers supplied the statistical data of the visitors' number of the described sites. Some information was also obtained from the cave guides and their management offices.

The described caves' geotourism valorisation evaluation was directed to tourists, educators and investors. It was assessed by using four principal categories of criteria: visual, cognitive, functional and investment (Tabs. 2–4). The cave values were assessed in the following way:

- the visual one by its substantive value, SV;
- the cognitive one by its cultural value, CV;
- the functional one by its location value, LV;
- the investment one by its geotouristic development level, V.

The availability of the information on the cave, AIC was also assessed. The geotouristic attractiveness, GA, was assessed as the score of all the above five values (Alexandrowicz *et al.*, 1992; Dmytrowski & Kicińska, 2011; Doktor *et al.*, 2015; Tabs. 2–3).

Geographical and geological settings of the Kraków-Częstochowa Upland area

The area of the Kraków-Częstochowa Upland is built mainly of Upper Jurassic (Oxfordian) massive limestones (Dżułyński, 1952; Kleczkowski, 1972; Gradziński, 1972, 2009; Matyszkiewicz, 1989, 2008; Krajewski & Matyszkiewicz, 2004; Matyszkiewicz *et al.*, 2006; Joniec & Słomka, 2012; Figs. 2, 3).

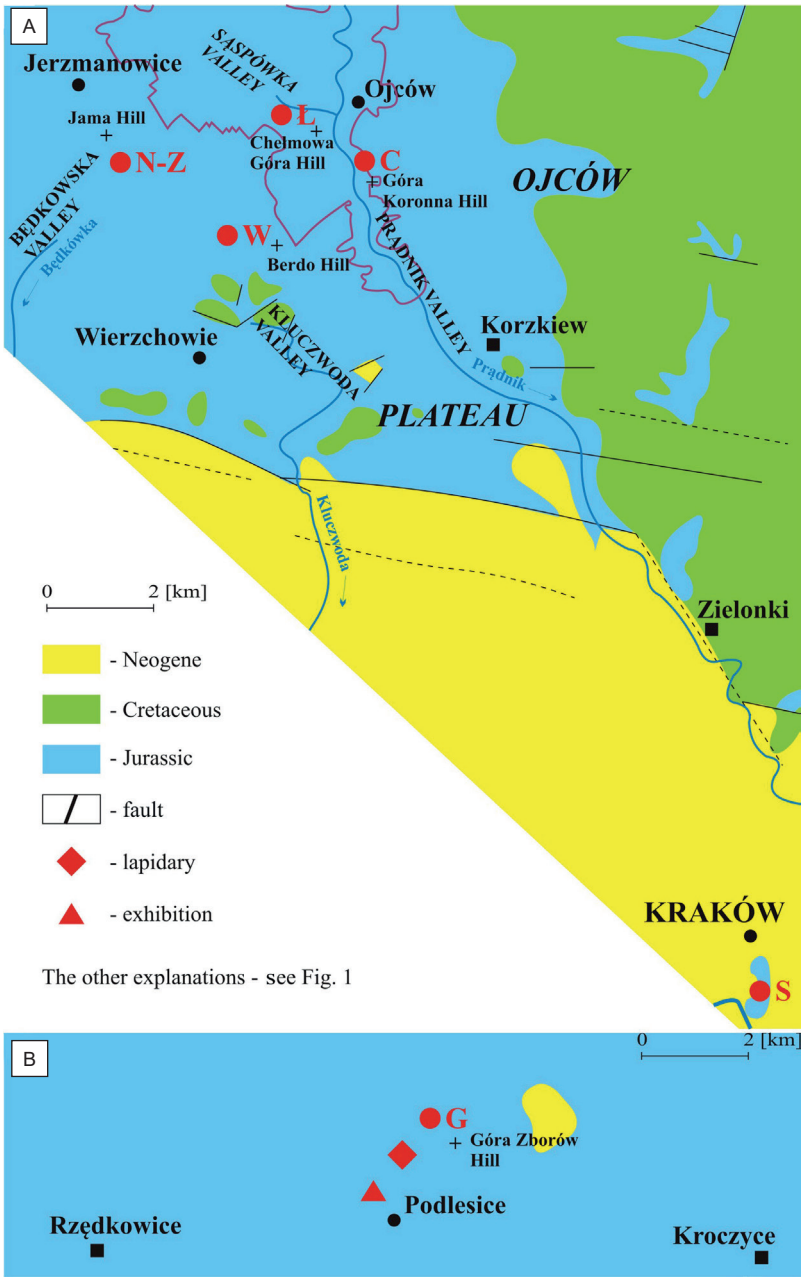

Fig. 3. Geological map of Kraków region without Quaternary and Neogene terrestrial deposits (A) (after Gradziński, 2009) and simplified geological sketch map of the area around Podlesice (B) (after Kaziuk, 1978)

In its southern part, it is partly covered by Cretaceous marls, limestones and sandy limestones, as well as by Miocene sediments (Gradziński, 1972, 2009; Fig. 3A), and in the northern part, by Paleogene sediments (Kaziuk, 1978; Kotlicki & Mojski, 1980; Fig. 3B).

Smocza Jama Cave

This cave is located in Kraków (Figs. 1, 2, 3A), within the Wawel Hill near its western slope, under the Royal Castle in the city centre on the Vistula River (Figs. 3A, 4A). This is one of the oldest known caves in Poland due to its location and well-known legend about the dragon who lived under the Wawel Hill. It was first mentioned in the 12th century in Wincenty Kadłubek's *Chronica Polonorum*, which is also the source of the first known version of the Wawel Dragon legend, later further developed by Jan Długosz and Marcin Bielski. The name of the cave was first given in 1551 in Marcin Bielski's *Kronika wszystkiego świata*. In the 16th and 17th century, an infamous whore house was operating at the entrance to the cave and within. It served as an inspiration for poets such as Jan Andrzej Morsztyn. In the 18th century, the Wawel Hill was fortified. Within the cave, supporting pillars were raised under the walls, and its main entrance was bricked up.

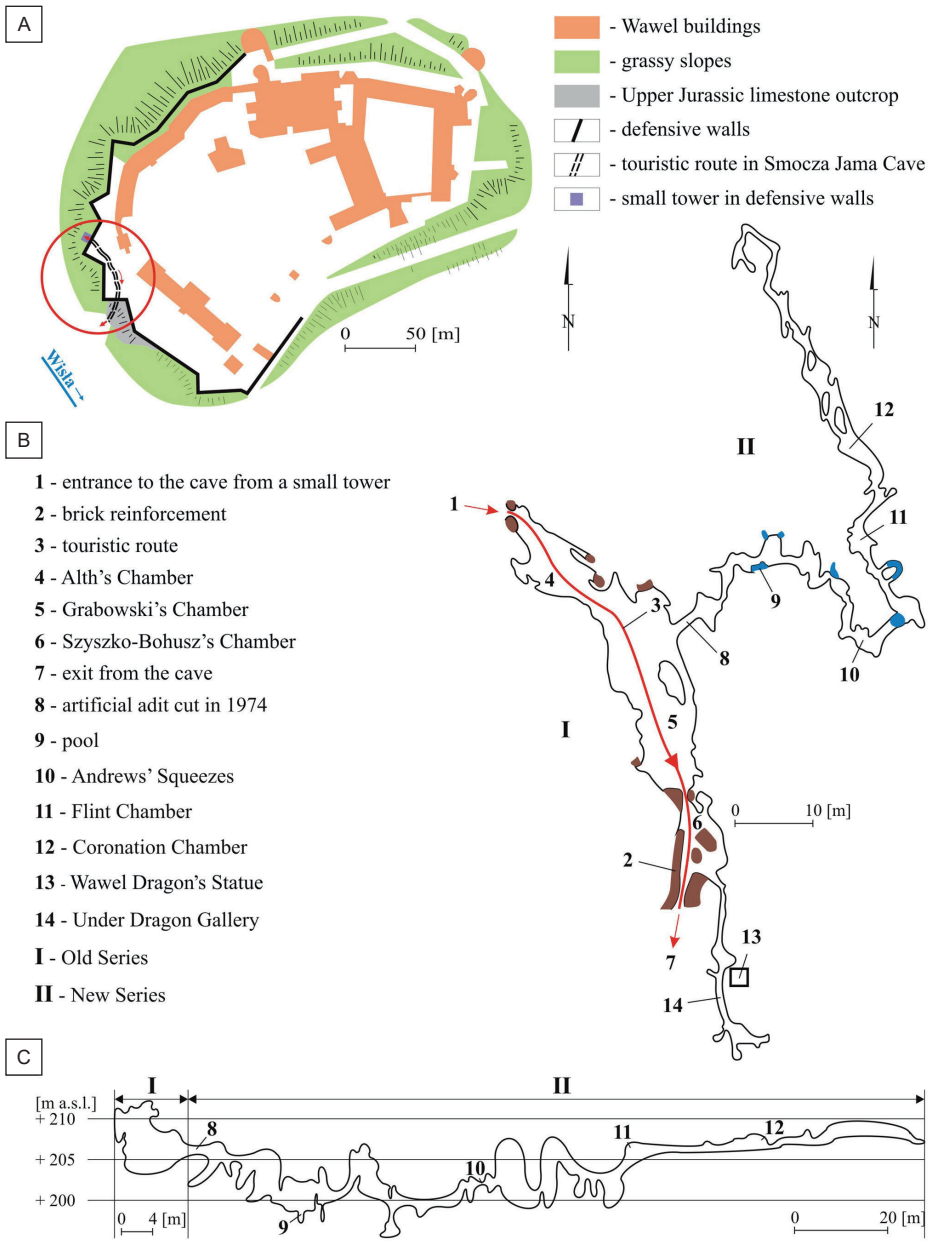

Fig. 4. Smocza Jama Cave: A – location within the map of the Wawel Hill (after www4); B – map (simplified); C – cross-section (simplified) (after Gradziński & Szelerewicz, 2004; Szelerewicz & Grodzicki, 2011; Szelerewicz & Górny, 2013)

Two other smaller openings were bricked up in 1830. Hence, the cave became open for tourism again in 1842. In the 19th century, it was visited by Alojzy Alth, a geologist, Ambroży Grabowski, a historian, and Adolf Szyszko-Bohusz, an architect. For their commemoration, all three cave chambers received their names (Fig. 4B). In 1945, after the Second World War, the southern opening of the cave, the current exit for visitors (Fig. 4B), was exposed. In 1972, a fire-breathing statue of the Wawel Dragon was erected by Bronisław Chromy. It is situated in front of the current exit from the cave (Fig. 4B). After renovation, the Smocza Jama Cave was opened for tourism again in 1976 (Kowalski, 1951; Firlet, 1996; Gradziński, 2006). The cave being situated within the Wawel Hill is associated with the Wawel Royal Castle, included as a part of the Kraków Old City into the UNESCO World Heritage List in 1978 (www6). This surely helped to make this geosite more recognizable and to achieve great success in its popularity in Poland and around the world.

Fig. 5. Photographs of Smocza Jama Cave (Fig. 4): A – view on the Wawel Hill with Smocza Jama Cave: 1 – entrance, 2 – exit; B – cupolas in the Grabowski Chamber and entrance into the "New Series" (Fig. 4B, C); C – brick reinforcements between Grabowski and Szyszko-Bohusz Chamber; D – cupolas in the Szyszko-Bohusz Chamber; E – exit from the cave; F – the sculpture of the Wawel Dragon. Photos M. Dzięgiel unless otherwise noted

Its total length is 276 m and vertical size 15 m (Kowalski, 1951; Gradziński & Szelerewicz, 2004; Szelerewicz & Górny, 2013). It consists of two primarily separated parts called in this paper: "Old series" and "New series" linked by an adit cut in 1974 during the works aimed at stabilization of the hill (Gradziński *et al.*, 2009; Fig. 4B, C).

The "Old series" of the cave acts as the part open for tourism (Fig. 4B, C). The touristic route is 81 m long (Gradziński & Szelerewicz, 2004; Radwanek-Bąk, 2011; Szelerewicz & Górny, 2013; Fig. 4A, B). The entrance into Smocza Jama Cave is situated at the top of a small tower in the castle defensive walls and its exit is at the boulevard of the Vistula River bank (Figs. 4A, 5A). The tourists go down the stairs in a small tower to the cave (Figs. 4A, 5A) and then pass through three spacious chambers named by turn: Alth, Grabowski and Szyszko-Bohusz ones (Fig. 4B). The touristic route is almost flat (Kowalski, 1951; Gradziński & Szelerewicz, 2004; Szelerewicz & Górny, 2013; Fig. 4C). The visitors can watch very picturesque corrosive forms as wide cupolas in the walls and ceiling (Tab. 1; Fig. 5B, D). They were developed in the phreatic and artesian condition. These chambers originated along joints and bedding planes. The cave is filled with an around 2 meters thick sediment file composed of the loam mixed with limestone debris (Szelerewicz & Górny, 1986; Heflik & Matl, 1991; Rotter & Szelerewicz, 1999; Motyka *et al*., 2005; Gradziński, 2006; Gradziński *et al.*, 2009; Szelerewicz & Górny, 2013; Tab. 1; Fig. 5C). There are also some brick reinforcements (Fig. 5C). In front of the exit from the cave (Fig. 5E), stands the dragon's sculpture, being its additional touristic attraction (Tab. 1; Fig. 5F).

The first section of the "New series" of the cave was discovered in the 1970s. Further ones were discovered in 1983 and explored in 1995 and 1996 by some speleologists (Motyka *et al.*, 2005). The "New series" comprises some small chambers linked by extremely narrow squeezes, among others "Andrews' Squeezes" and small pools (Fig. 4B, C). It starts from the Grabowski Chamber (Figs. 4B, 5B) and continues as narrow fissures, down to the depth of about 4 m (Fig. 4C). The surface of the pools is situated at the level around 199 m a.s.l. (Fig. 4C), thus, at the similar level as the Vistula (Wisła) River flowing around 60 m from the cave pools (Motyka *et al.*, 2005; Fig. 4A, B).

Speleothems are very rare in the cave. Some of them occur only in the Grabowski Chamber and around the "Andrews' Squeezes" (Gradziński *et al.*, 2009; Szelerewicz & Górny, 2013; Fig. 4B, C). They are dated at 1700 ±70 BP and exhibited in the Geological Museum of the University of Science and Technology in Kraków (Szelerewicz & Górny, 2013). The Under Dragon Gallery, the second lateral one, is more than 20 m long and starts from the Szyszko-Bohusz Chamber (Fig. 4B). It was discovered in 1983 and explored again by some speleologists in 1996. It is also extremely narrow and low (Szelerewicz & Górny, 2013; Fig. 4B).

The geotouristic attractiveness of Smocza Jama Cave is of high grade, as estimated at 77% (Tabs. 1–4). The interest in the cave was always very high. In the years 2002–2013, the total number of its visitors varied from 119,753 up to 174,274. Since 2014, it has risen noticeably from 356,088 up to 421,802 in 2019. However, in 2020, it dropped down to 136,220 (Tab. 5), due to pandemia.

Łokietek Cave

This cave is located at Ojców, on the right side of the Sąspówka Valley, in the northwestern slope of the Góra Chełmowa Hill, in the central part of the Ojców Plateau, and within the Ojców National Park (ONP) area (Figs. 1, 2, 3A). According to the legend, Władysław Łokietek, a future Polish king, was hiding in the cave after he escaped from Krakow from the troops of the Czech king Wacław II in the 14th century. His life was saved by a spider which blocked the cave entrance opening with its cobweb, and thus, it discouraged the Czech troops from invading the cave. Hence, the cave has got its "Łokietek" name (Sukertowa, 1928; Partyka, 2006; Gradziński *et al.*, 2020; Gradziński & Michalska, 2020b). Using the cave for hiding by people in the medieval times was documented by numerous archaeological finds (Wojenka, 2012, 2018b). However, Łokietek's hiding in the cave seems to be a questionable event up until today (Samsonowicz, 2000). The cave was used by local people for hiding also during the First and the Second World Wars (Wojenka, 2018a; Gradziński *et al.*, 2020).

The Łokietek Cave was developed due to the karst underground water flow, along vertical joints, and therefore is a part of the large karst system. Its galleries' shape indicates that it was developed in phreatic conditions and subsequently remodelled in a vadose zone (Gradziński, 1962). Due to the cave hypsometric position, it was found that it was developed in the late Pliocene or early Quaternary (Madeyska, 1977).

The cave was described for the first time probably by Sebastian Piskorski in 1691. Later descriptions were made by Rzączyński (1721), Karpiński (1788), Staszic (1815) and Krasiński (1821) among others. Since the end of the 18th century, it has been regularly visited by naturalists groups (Wiaziemski, 1980). Since the 1870s, cave sediment files have been researched by scientists including two archaeologists: Jan Zawisza, in 1871 and Stanisław Czarnowski, in 1886 and 1899. This research has been continued up until today. Hence, some remnants of Pleistocene bear bones, the Palaeolithic flint tools, Neolithic ceramics and Jerzmanowice tool blades as the traces of the prehistorical culture were found (Olszyński, 1871; Czarnowski, 1914a; Rook, 1980; Szelerewicz & Górny, 1986; Partyka, 2006; Wyżga, 2016; Kot *et al.*, 2019; Gradziński & Michalska, 2020b). Some remnants of tools from medieval and modern times were also found there (Gradziński *et al.*, 1998; 2003; Sobczyk & Sitlivy, 2001; Rodzińska-Nowak *et al.*, 2001–2002; Partyka, 2006; Wyżga, 2016; Kot *et al.*, 2019).

At the turn of the 19th and 20th century, the Łokietek Cave became one of the most popular caves at Ojców. In

the 1910s, just before the First World War, it was opened for tourism (Tab. 1). Up until today, this is one of the most popular caves in Poland and the longest one within the ONP area. Its touristic route is 320 m long and vertical size is 7 m (Kowalski, 1951; Gradziński, 1972; Krzemień & Partyka, 1990; Gradziński & Partyka, 2004b; Gradziński *et al.*, 2008, 2020; Partyka, 2006; Radwanek-Bąk, 2011; Żarski et al., 2013; Gradziński & Michalska, 2020b; Tab. 1). Most of its galleries were developed along joints. The cave starts with a very narrow gallery developed in a relic of a fractured fissure, whose ceiling collapsed probably before the glacial period (Gradziński, 1962). It leads to the entrance gate with a metal lattice symbolizing the cobweb motif, according to the legend about Władysław Łokietek (Tab. 1; Figs. 6A, 7A). The visitors pass through the Main Underground Gallery where they can watch very picturesque cupolas (Tab. 1; Figs. 6A, 7B). The gallery is filled with an around 5 m thick sediment file, consisting of the loam mixed with limestone debris (Sobczyk & Sitlivy, 2001). Then, they reach the Knightly Chamber, a very spacious one (Fig. 6A), where speleothems covered with moonmilk in the walls can be observed.

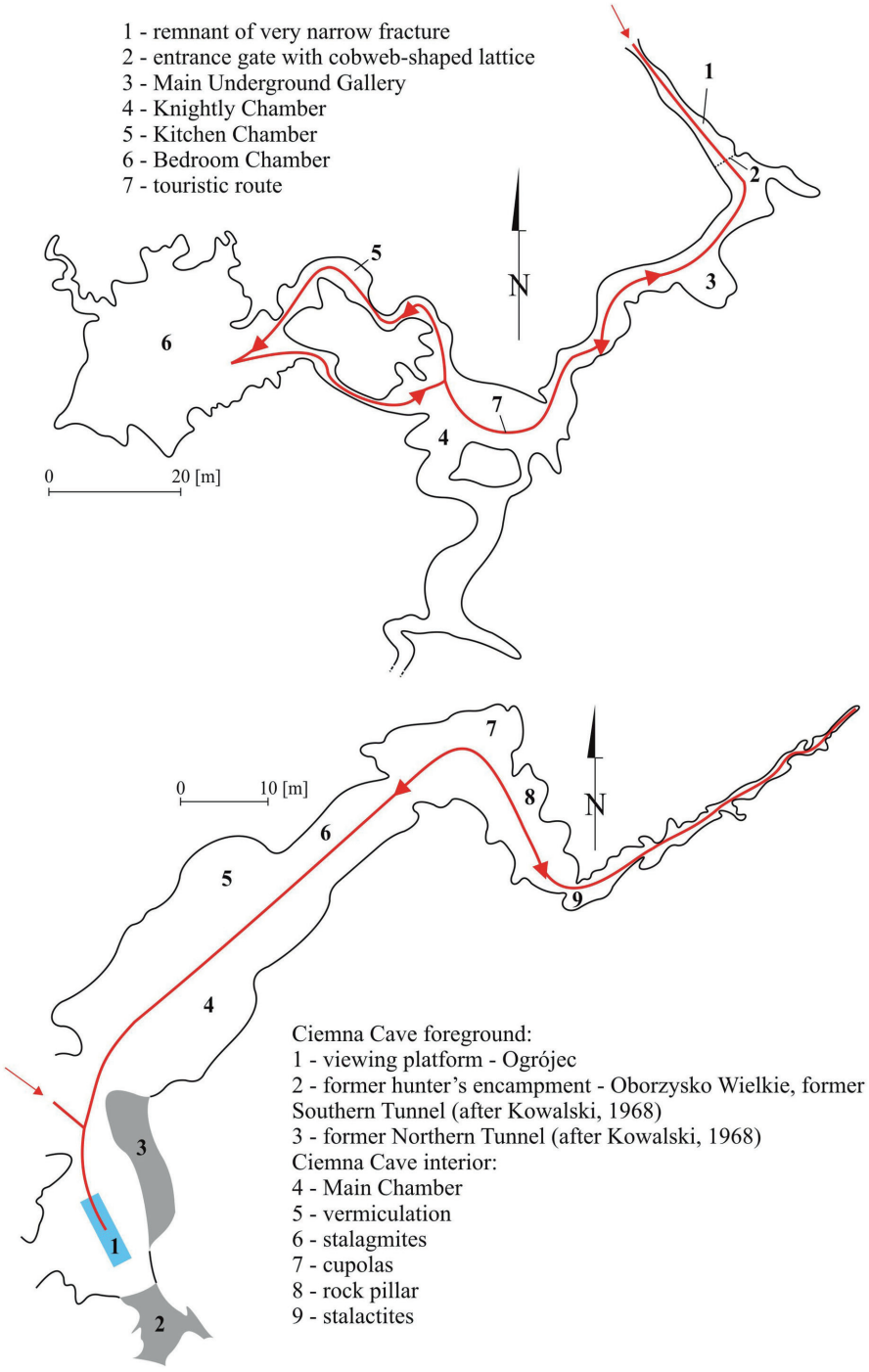

Fig. 6. Map of Łokietek (A) and Ciemna (Dark) cave systems (B) (after Gradziński *et al.*, 2020; Gradziński & Michalska, 2020a, 2020b)

Fig. 7. Photographs of Łokietek and Ciemna Cave (Figs. 1–3, 6). Łokietek Cave: A – entrance into the cave; B – cupolas in the Main Underground Gallery; C – speleothems in the Kitchen Chamber; D – tubular stalactites and speleothems in the Bedroom Chamber; Ciemna Cave: E – the Ogrójec viewing platform (Fig. 6B); F – former Neanderthal hunters encampment in the Oborzysko Wielkie Tunnel (Fig. 6B); G – stalagmites; H – tubular stalactites

Then, the visitors go up the steps to the Kitchen Chamber, a small one, located on the highest level of the cave. There, they can also watch picturesque speleothems covered with moonmilk (Tab. 1, Figs. 6A, 7C). Then, the visitors go down the steps to the Bedroom Chamber, a very spacious one, where they can see some short tubular stalactites (Tab. 1; Figs. 6A, 7D). Some parts of the bottom of the Bedroom Chamber are covered with speleothems around 20 centimetres thick. Their older generation was radiocarbon dated at 20,500 BP and younger during the Holocene. The Holocene speleothems contain dark-coloured laminae associated with activity of humans within the cave. Some low stalagmites in the Bedroom Chamber can be observed there too (Gradziński *et al.*, 1998, 2003; Gradziński & Michalska, 2020b; Tab. 1). From there, the tourists come back to the Knightly Chamber through another gallery, cut in 1974, and then, to the exit (Fig. 6A).

The Łokietek Cave is inhabited mainly by bats. Among their eleven species, lesser horseshoe and big night bats dominate there (Nowak & Grzywiński, 2017). Apart from bats, some spiders inhabit the cave too (Sanocka, 1990; Rozwałka, 2008).

The geotouristic attractiveness of Łokietek Cave is of high grade, as estimated at 72% (Tabs. 1–4). The interest in the cave was always very high. In the Interwar time, the annual average total number of visitors was only around a few thousands, but since the post-war years it has increased noticeably (Gradziński & Partyka, 1997). In the years 1993–2019 it varied from 104,637 up to 136,120, with an exception of the years 2001–2002 when it decreased to the values from 98,613 up to 98,915 and 2010–2015 when they varied from 89,039 up to 99,175. However, in 2020, it dropped down to 3,500 (Tab. 5), due to pandemia.

Ciemna Cave

This cave is also located at Ojców, on the left side of the Prądnik Valley, 65 m above its bottom, in the northwestern slope of the Góra Koronna Hill, in the central part of the Ojców Plateau and also within the ONP area (Figs. 1, 2, 3A). The cave is a part of the large karst system comprising two rocky tunnels: northern, being the cave entrance at present, and southern, named "Oborzysko Wielkie", and the rocky courtyard named "Ogrójec", with a metal viewing platform between them (Figs. 6B, 7E). The Ogrójec rocky courtyard is a relic of the former cave chamber linking these tunnels. It was dissected by erosion before the Late Pleistocene (Gradziński *et al.*, 2020).

Ciemna Cave was developed due to the karst underground water flow, before the Pleistocene. Its galleries' shape and numerous cupolas on its ceiling indicate that it was made in phreatic conditions and subsequently remodelled in a vadose zone (Gradziński, 1962; Gradziński & Michalska, 2020a).

Ciemna Cave has also been researched by scientists since the 1870s. At the beginning, subsurface sediments at Ogrójec and Oborzysko Wielkie were researched by four archaeologists: Jan Zawisza in 1871 (Olszyński, 1871; Zawisza, 1871), Stanisław Czarnowski in the years 1898–1912 (Czarnowski, 1914b), Stefan Krukowski: 1918–1919 (Krukowski, 1939) and Stanisław Kowalski: 1963–1968 (Kowalski, 1971, 2006; Madeyska, 1982; Kot *et al.*, 2019). Since 2007, the cave sediment files have been researched again (Valde-Nowak *et al.*, 2014, 2016a, 2016b; Valde-Nowak, 2015; Alex *et al.*, 2017; Willman *et al.*, 2019).

Owing to large number of finds from numerous Palaeolithic, Neolithic and younger cultural levels, Ciemna Cave has been one of the most famous archaeological sites in Poland. Not only the remnants of numerous animal bones were found there, mainly bear and wolverine, but also Palaeolithic flint tools, mainly knives and combs, used for woodworking and skewing of the hunted animals. In addition, the very spectacular, 115,000 years old remnants of the Neanderthal tooth and child finger bones were discovered there (Nadachowski *et al.*, 2015; Valde-Nowak *et al.*, 2018; Willman *et al.*, 2019). This is one of the most important archaeological sites documenting Neanderthal settlements in Central Europe, 115,000–120,000 years ago. These settlements are believed to represent Micoquien, Mousterian and Taubachian cultures, typical of the late Middle Palaeolithic period in Central and Eastern Europe. This conclusion is based upon the remnants of the most characteristic flint tools of this period, the "Prądnik" knife (Valde-Nowak *et al.*, 2014). Apart from that, there were some finds of Neolithic ceramic and the medieval artifacts, including iron tinder and silver coins from the 14th century (Kowalski, 1971, 2006; Rook, 1980; Szelerewicz & Górny, 1986; Chochorowska & Dagnan-Ginter, 1995; Gradziński & Partyka, 2004a, 2004b; Partyka, 2006; Gradziński *et al.*, 2008; Sobczyk, 2011; Cyrek & Madeyska, 2016; Rydzewski, 2016; Wojenka, 2018a, 2018b; Gradziński *et al.*, 2020; Gradziński & Michalska, 2020a).

Ciemna Cave was used by local people for hiding in the historical periods (Wojenka, 2018a). In 1787, it was visited by the king Stanisław August Poniatowski (Falniowska-Gradowska, 1995; Kozibąk, 2015; Wyżga, 2016). At the turn of the 19th and 20th century, Ciemna Cave became one of the most popular geosites at Ojców. The cave was equipped with electricity, supplied from a small water power plant at the Prądnik River. However, it was destroyed during the Second World War and has not yet been repaired, leaving only electrical installation remains inside the cave (Gradziński, 2018; Gradziński *et al.*, 2020). As a result, it was named "Ciemna" and its sightseeing has been held with torches. After the Second World War, the cave was closed for tourism for its protection, due to the establishment of the Ojców National Park area in 1956, within which it is situated (Figs. 1, 2, 3A). However, since 1992, the cave has become open for tourism, when a marked touristic and educational path linking the bottom of the Prądnik Valley with the peak of the Góra Koronna Hill, running around the cave was created (Kowalski & Partyka, 1997; Tab. 1). In 2004, a metal viewing platform with information boards was built at Ogrójec (Figs. 6B, 7E) and a former Neanderthal hunters encampment was reconstructed within the Oborzysko Wielkie Tunnel (Figs. 6B, 7F). The visitors can watch them

from Ogrójec. This site also provides an excellent view of the Prądnik Valley.

Ciemna Cave (Fig. 3A) is one of the longest caves within the ONP. Most of its galleries were developed along joints (Gradziński, 1962). Its touristic route is horizontal, 230 m long together with the Northern and Oborzysko Wielkie Tunnel and Ogrójec viewing platform. Its underground section is only 150 m long (Kowalski, 1951; Gradziński, 1972; Partyka, 2006; Gradziński *et al.*, 2007, 2008, 2020; Radwanek-Bąk, 2011; Sobczyk, 2011; Żarski *et al.*, 2013; Gradziński, 2018; Gradziński & Michalska, 2020a; Fig. 6B). The touristic route starts from the Ogrójec viewing platform (Figs. 6B, 7E). The visitors enter the Main Chamber which is very spacious. It is filled with a 2 m to 7 m thick sediment file, composed of loam mixed with limestone debris (Gradziński *et al.*, 2020). The visitors can see some moonmilk speleothems and very wide low stalagmites (Figs. 6B, 7G). They are radiocarbon dated as the Holocene (Pazdur *et al.*, 1994; Gradziński *et al.*, 2003). These stalagmites contain dark-coloured laminae associated with activity of humans within the cave (Gradziński *et al.*, 1998; 2003; Gradziński & Michalska, 2020a). Afterwards, the Main Chamber turns into a narrowing and descending gallery, where the visitors can see some cupolas on the ceiling and a rock pillar on the gallery's right bend (Fig. 6B). Behind the pillar, they can observe some short stalactites (Figs. 6B, 7H). Then, the gallery turns left. In its last section, the visitors can observe some more cupolas and stalactites and return the same way (Fig. 6B).

Ciemna Cave is inhabited by seven bat species dominated by lesser horseshoe bats (Nowak & Grzywiński, 2007, 2012). Their number in winter 2017 was 383, and therefore Ciemna Cave is one of the most important winter sites of this species in Poland (Nowak & Grzywiński, 2017). Bats colonie gather in the Main Chamber ceiling (Fig. 6B). Apart from bats, troblogiontic spiders also inhabit the cave (Rozwałka, 2008).

The geotouristic attractiveness of Ciemna Cave is of high grade, as estimated at 72% (Tabs. 1–4). Even though the touristic route within the cave is much shorter than within Łokietek one, the interest in this facility was always very high. In the years 1993–2004, the total number of visitors to the cave varied from 19,024 to 24,744, with an exception of the years 2001–2002, when it decreased to the values from 13,976 up to 17,568 (Tab. 5). When a metal viewing platform with information boards at Ogrójec and a reconstructed former Neanderthal hunters encampment in the Oborzysko Wielkie Tunnel were created, in 2004, a noticeable increase in the total number of tourists visiting the cave was observed: from 21,765 up to 34,150. However, in 2020, the number decreased to 15,682 (Tab. 5), due to pandemia.

Wierzchowska Górna Cave

This cave is located at Wierzchowie, about 16 km northwest from Kraków in the Kluczwoda Valley, in the northwestern slope of the Berdo Hill, on the southwestern margin of the Ojców Plateau (Figs. 1, 2, 3A). Wierzchowska Górna Cave is also a part of the large karst system and was developed due to the karst underground water flow. Its galleries' shape indicates that it was developed in phreatic conditions and subsequently remodelled in a vadose zone (Kowalski, 1951; Gradziński, 1962; Górny & Szelerewicz, 1987; Krzemień & Partyka, 1987; Polonius *et al.*, 2018). Most of its galleries were developed along joints (Gradziński, 1962). The exceptional position of this cave is due to its numerous excellent, various and very well-preserved karst features and abundant speleothems, as well as the cave's history recorded in its sediment files, which have been researched by scientists. Apart from them, some Late Jurassic fossils, Pleistocene fauna bones, and the model of the primitive human with his hearth have been collected there (Tab. 1).

Wierzchowska Górna Cave was discovered in 1853. Its sediment file was researched, and as a result, a large number of fossils, animal bones and traces of the prehistorical culture were found within. Two archaeologists, Jan Zawisza and Godfryd Ossowski cut some galleries in the cave sediment file, behind the entrance opening no. 1 (Fig. 8) in the late 19th century. They found a large number of vessel remnants, some flint tools and Pleistocene fauna skeletal remnants, which proved of high scientific value for the cave and its attractiveness as tourist destination. Hence, at the end of the 19th century, Wierzchowska Górna Cave started to be visited by tourists, mainly by spa guests from Ojców, around 6 km northeast from Wierzchowie (Fig. 3A). In the mid-20th century, it was closed for renovation, but since 1985, the cave has become open for tourism again (Górny & Szelerewicz, 1987; Krzemień & Partyka, 1987; Polonius *et al*., 2018). In 1997, there was a massive rock fall, due to which, the previous entrance opening no. 1 was obstructed by massive rock blocks. Therefore, since that time, the tourist route starts at the entrance opening no. 2 (Fig. 8).

Wierzchowska Górna Cave is one of the largest known caves open for tourism in the Kraków-Częstochowa Upland area and Poland. Its total length is 975 m and vertical size 25 m (Tab. 1). Its tourist route is 370 m long. It passes through the Lower Small Chamber, at the crossing with the Gothic Gallery and reaches the Przesmyk Długi Gallery (Fig. 8), cut in its sediment file. The visitors can see its outcrop there, consisted of limestone debris (Fig. 9A). Then, they go to the Cupolas Chamber, karst forms observed on its ceiling (Fig. 8). Further, the gallery leads to the Hotelik Chamber, with its speleothems radiocarbon dated between 44,000–13,700 ±200 BP (Pazdur *et al.*, 1994, Fig. 8). They are very picturesque and stained with iron and manganese minerals and moonmilk (Tab. 1). That chamber was named "Hotelik" as former cave researchers used to sleep on the rock shell over the speleothems there. Then, the visitors move into the Throne Chamber, called "Dancing Hall" (Fig. 8), the largest one in the cave part open for tourism. There one can see speleothems and tubular stalactites (soda straws) in the wall and ceiling. They contain dark-coloured laminae associated with activity of humans within the cave (Gradziński *et al.*, 2003; Polonius *et al.*, 2018; Tab. 1; Fig. 9B).

In the Throne Chamber, the visitors can also examine the big collection of speleothems forms, Late Jurassic fossils, Pleistocene fauna bones and skeletal remnants. Among the fossils are ammonites, belemnites, crinoids and sponges. Among the Pleistocene fauna, skeletal remnants are mostly bones of cave bear, hairy rhinoceros, lion, hyena and mammoth tooth (Tab. 1; Fig. 9C). All these exhibits were taken from the outcrops in the vicinity of the cave. Apart from the exhibition, some conglomerates were found in the sediment file in the chamber. They are matrix-supported and consist of dark grains, quartz grains, clasts of Upper Jurassic limestones, ferruginous clay matrix and carbonate cement. The dark grains, characteristic of the conglomerates, were developed in oxisols in tropical or subtropical climates. These soils were developed and eroded during the Palaeogene or Neogene, and thus, their physically resistant components were redeposited into caves, developing the conglomerates. Due to erosion, only small parts of them are preserved up until today (Gradziński, 1999).

From the Throne Chamber, the visitors come back to the Hotelik one (Fig. 8) and can watch small sinter pools and rimstone dams located a little further on from the crossing of two galleries (Fig. 8). Then, they walk to the exposing of a big specimen of the crystalline calcite (Tab. 1; Fig. 8), demonstrating that "spar hunters" explored the cave to extract this mineral resource for glass production before the cave was open for tourism. The crystalline calcite occurs as stalactites and some veinlets protruding into the cave joints. But due to its extraction, numerous stalactites and stalagmites in the cave were deeply destroyed.

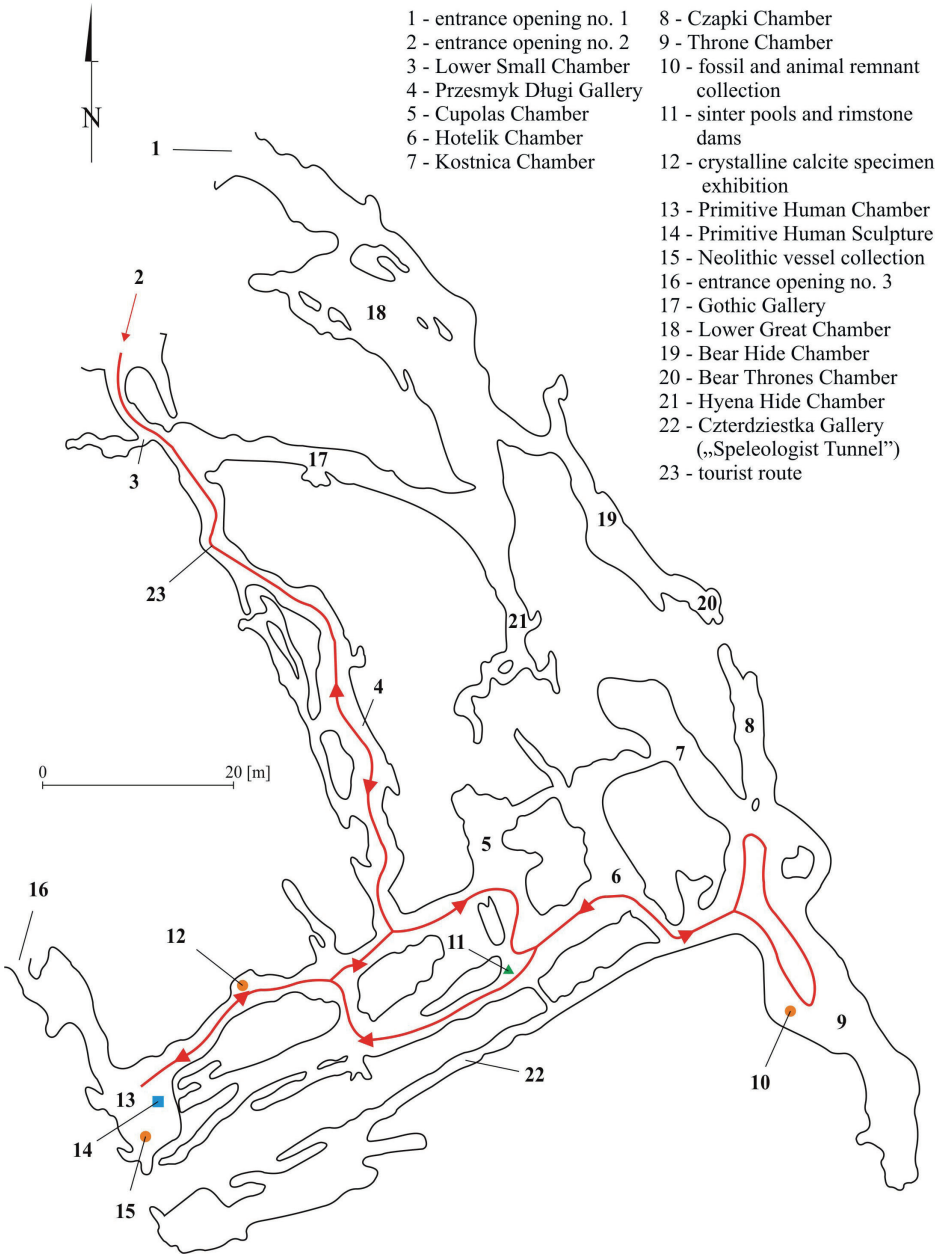

Fig. 8. Map of Wierzchowska Górna Cave system (after Górny & Szelerewicz, 1987; Polonius *et al.*, 2018)

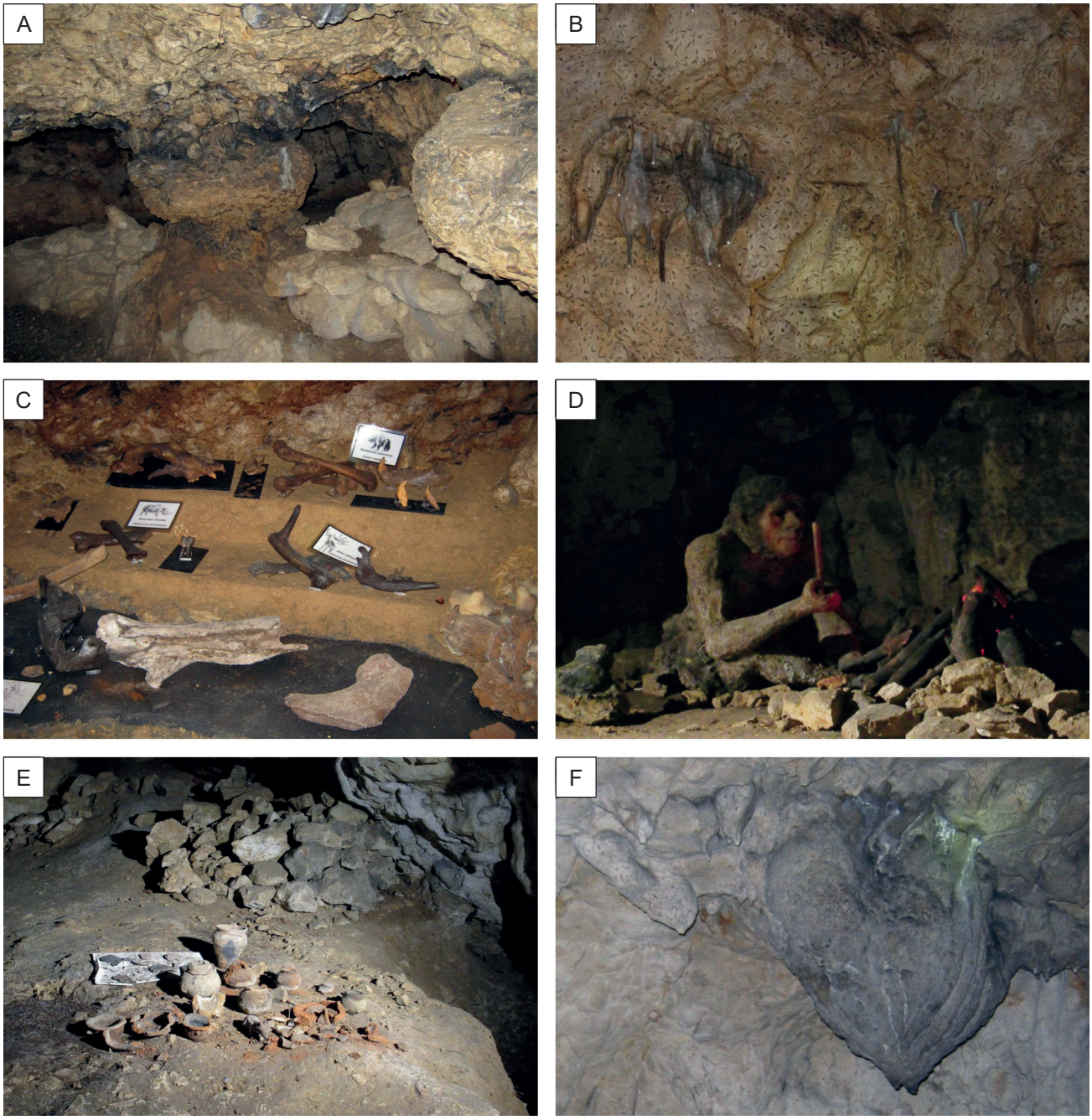

Fig. 9. Photographs of Wierzchowska Górna Cave (Fig. 8): A – outcrop of cave sediment file in the Przesmyk Długi Gallery; The Throne Chamber: B – tubular stalactites and speleothems; C – Pleistocene fauna bones collection; The Primitive Human Chamber: D – its sculpture and hearth model; E – Palaeolithic flint products and Neolithic clay vessel remnants; F – spherical stalactites

In the Primitive Human Chamber (Fig. 8), the visitors examine traces of the prehistorical culture: the model of the Primitive Human with his hearth (Fig. 9D) and the collection of the remnants of some Palaeolithic flint tools and Neolithic clay vessels (Tab. 1; Fig. 9E). Archaeological research of the cave sediment file revealed two layers representing human settlements: Palaeolithic and Neolithic. In the Primitive Human Chamber, the visitors can also watch spherical stalactites (Fig. 9F). They were probably developed due to warm air flowing upwards through the entrance opening no. 3 (Kowalski, 1951; Górny & Szelerewicz, 1987; Krzemień & Partyka, 1987; Fig. 8). Then, the visitors come back to the Przesmyk Długi Gallery and the entrance opening no. 2 (Fig. 8).

Wierzchowska Górna Cave is inhabited by numerous bats, mainly lesser horseshoe ones and *Meta menardi* spiders (Polonius *et al.*, 2018).

The geotouristic attractiveness of Wierzchowska Górna Cave is of high grade, estimated at 85% (Tabs. 1–4). Up until today, annually around 21,000 people on average visit the cave (www5; Tab. 5).

Nietoperzowa-Zygmunta Cave

This cave is located at Jerzmanowice, in the Będkowska Valley, in the southwestern slope of the Jama Hill, on the southwestern margin of the Ojców Plateau (Figs. 1, 2, 3A). Nietoperzowa and Zygmunta Cave are linked into one system (Figs. 10, 11). This is also a part of the large karst system and was developed due to the karst underground water flow. Its shape indicates that it was made in phreatic conditions and subsequently remodelled in a vadose zone. Large number of fossil and current bat bones and their guano deposits found within the cave sediment file proved that large number of bats inhabited this cave. Hence, it was named "Nietoperzowa" Cave (Gradziński, 1962; Gradziński & Partyka, 2004a; Górny, 2010a; Górny & Siwecki, 2020a; 2020b).

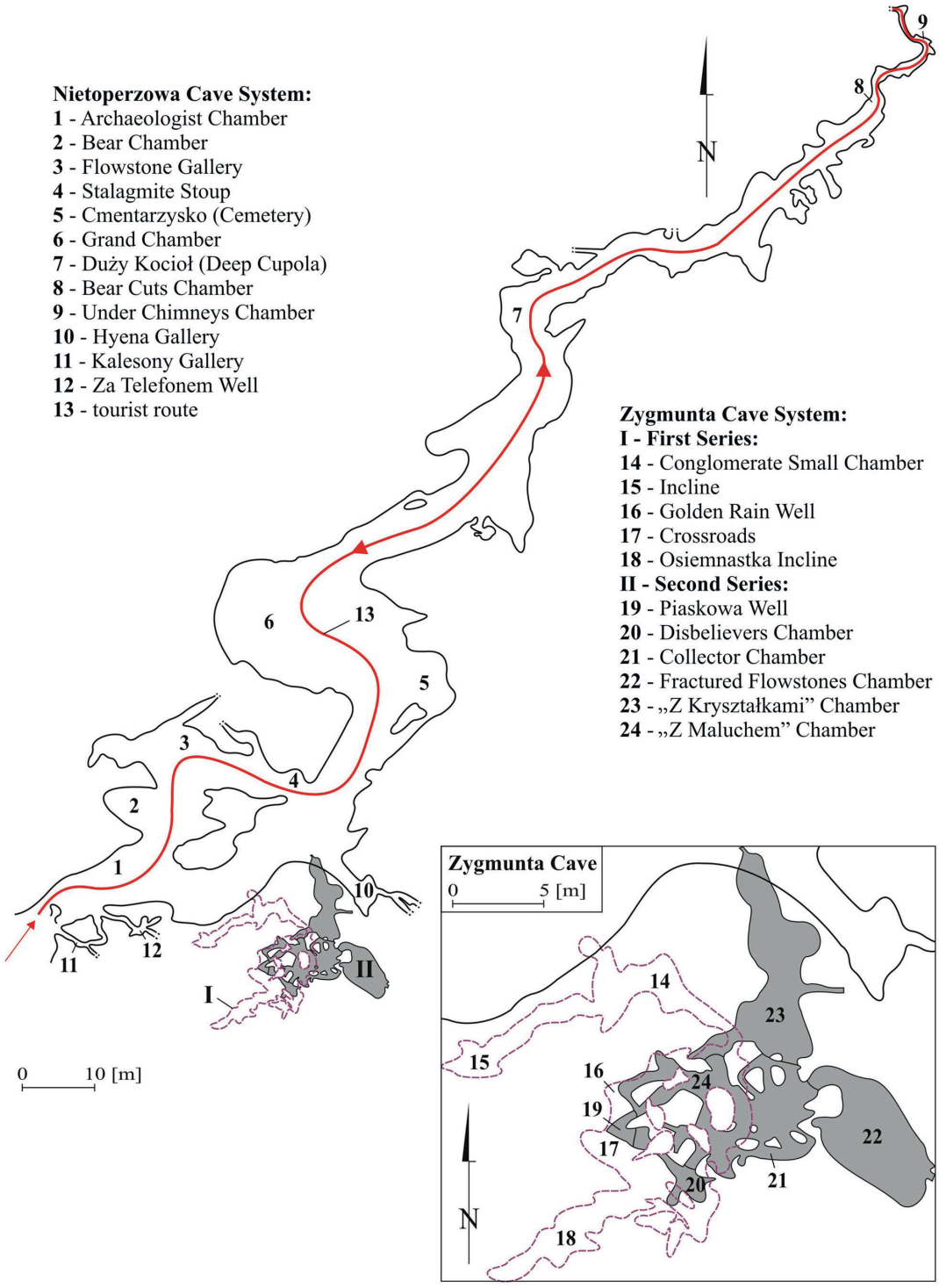

Fig. 10. Map of Nietoperzowa-Zygmunta Cave (after Górny & Siwecki, 2020a, 2020b)

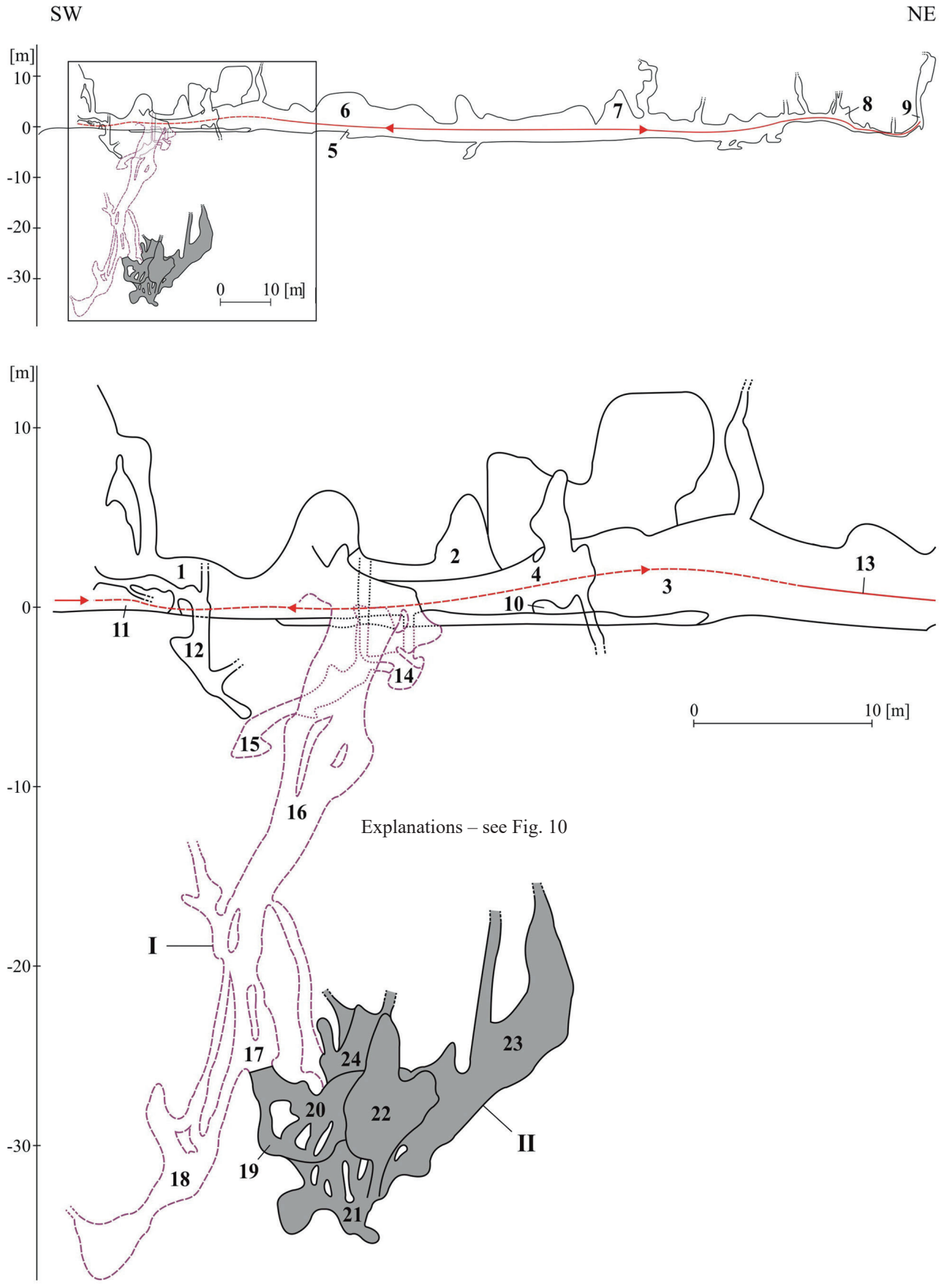

Fig. 11. Cross-section through Nietoperzowa-Zygmunta Cave (after Górny & Siwecki, 2020a, 2020b; Fig. 10)

Nietoperzowa Cave is a horizontal one (Figs. 10, 11). Its galleries were formerly filled with a thick layer of its sediment file. The trace of their upper limit level can be observed in the cave walls (Fig. 12A). Large parts of these sediment file and bat guano deposits were dug out of the cave to be used for phosphorus fertilizer production by O. Grube in the 1870s. Currently, the cave galleries are filled with sediment divided into seventeen layers. The oldest one consisted of sands and muds and the loams mixed with limestone debris. Their total thickness is around 10 m (Madeyska, 1997; Górny, 2010a; Górny & Siwecki, 2020a, 2020b). This is also a unique example of the underground geosite due to its very well-preserved numerous speleothems, open for tourism in the Kraków-Częstochowa Upland (Gradziński & Partyka, 2004a; Górny, 2010a; Górny & Siwecki, 2020a, 2020b; Tab. 1).

Nietoperzowa Cave was discovered in the 1840s. Its scientific research was initiated by an archaeologist, Jan Zawisza, in 1871 and continued by Ferdinand Roemer, a German palaeontologist, who discovered a large number of the Pleistocene fauna skeletal remnants in the sediment file.

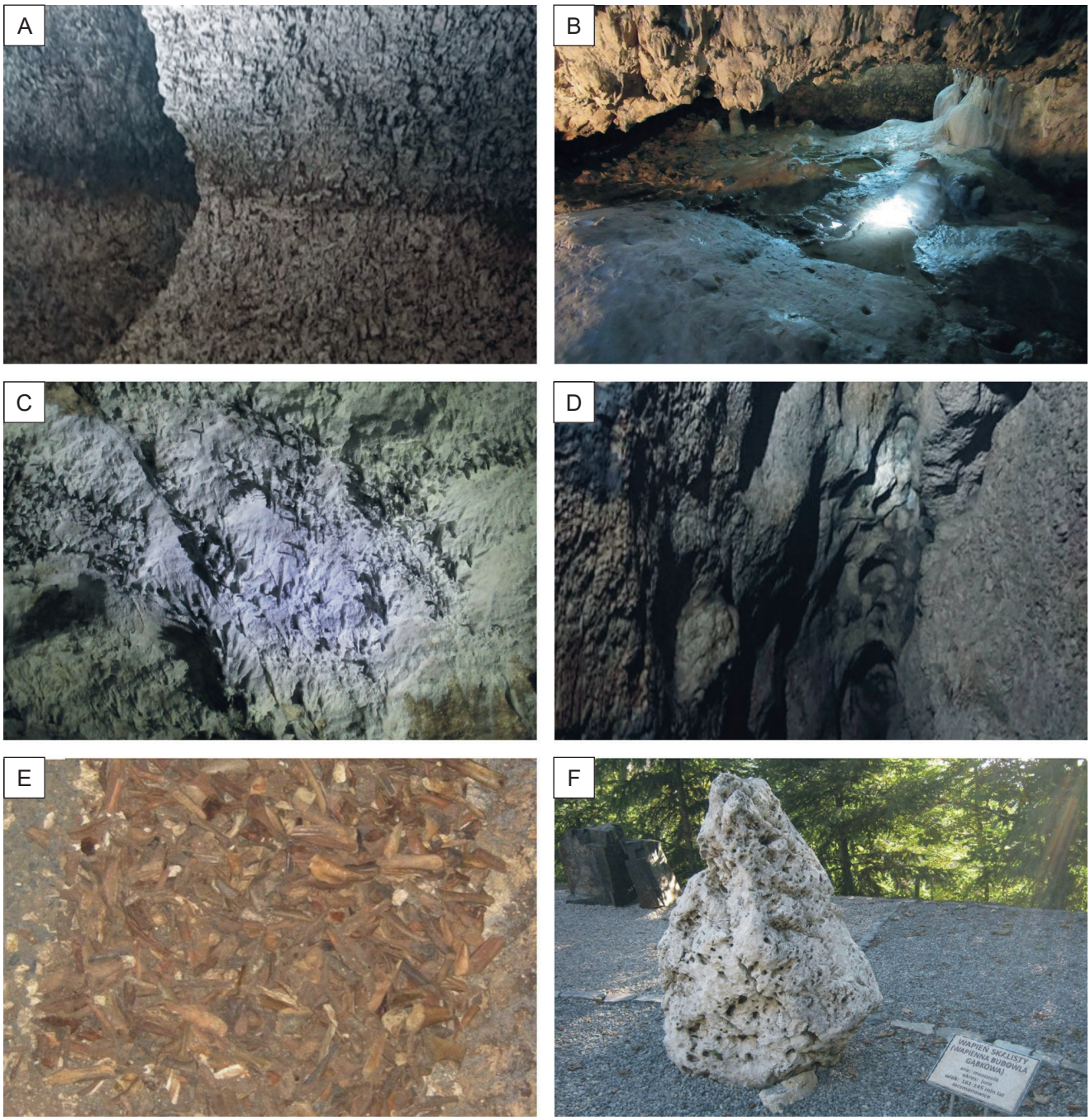

Fig. 12. Photographs of Nietoperzowa-Zygmunta Cave (Figs. 10, 11): A – upper limit for the former level of the sediment file dug out of the cave around the Wide Cupola section; B – wide stalagmite, sinter pools, rimstone dams and speleothems stained with minerals and moonmilk in the Flowstone Chamber; C – moonmilk stalactites in the Grand Chamber; D – deep cupolas in Wide Cupola section; E – collection of fauna bones in Cemetery; F – Upper Jurassic (Oxfordian) karstified limestone rock boulder in the lapidary around the cave

Dominating were cave bear and mammoth bones. Around 4,000 bear fangs were also found there (Chochorowska & Dagnan-Ginter, 1995; Gradziński & Partyka, 2004a). Scientific research was continued by next two archaeologists, Leon Kozłowski, in 1918, and Waldemar Chmielewski, in the years 1956–1962, who discovered around a thousand cave bear fangs in the area of 125 m^2. Apart from them, Waldemar Chmielewski found some traces of the Palaeolithic Human's hearth. Scientific research of the cave sediment file revealed one layer, named "Jerzmanowice culture" representing Upper Palaeolithic human settlements, as demonstrated by Palaeolithic flint tools, with leaf-shaped knife blades (Chmielewski, 1961, 1970). The oldest culture band was dated radiocarbon at 36,550 ±140 BC (Chochorowska & Dagnan-Ginter, 1995; Górny & Siwecki, 2020a, 2020b). However, the latest attempts, set the archaeological record of the "Jerzmanowice culture" from Nietoperzowa Cave in an accurate chronological framework, based on Bayesian statistical processing of radiocarbon dates. This analysis showed that the lower boundary of layer no. 6 in Nietoperzowa Cave could be statistically located in the range 44,000–42,000 BC and the upper limit for the "Jerzmanowice culture" was estimated at 31,000 BC (Krajcarz *et al.*, 2018). What is more, it was proved that Polish in-cave loess layers were significant clastic cave deposits considered as correlative horizons. They can be also very useful as lithostratigraphic markers for archaeology and palaeontology (Krajcarz *et al.*, 2016). Subsequent research made in the Archaeologist Chamber (Figs. 10, 11) proved high scientific value of the cave and its geotouristic attractiveness. Hence, the works to prepare the cave to be open for tourism started. This opening took place in 1994 (P. Ferdek – oral information; Tab. 1).

In 2008, the first section of Zygmunt Cave (Figs. 10, 11), as the 17 m long narrow gallery, was discovered by Zygmunt Ferdek, the manager of Nietoperzowa Cave (Górny, 2010b; Górny & Siwecki, 2020a, 2020b). It is situated in the joint of the southwestern rocky slope of the Jama Hill (Fig. 3A) just before the entrance opening of Nietoperzowa Cave. Since 2016, the exploration of Zygmunta Cave has been continued by the speleologists from the cave-building company (www1). It is mainly a vertical one. It comprises a large number of karst wells and chimneys (Górny & Siwecki, 2020a; 2020b; Figs. 10, 11). In 2019, the karst squeeze linking Zygmunta with Nietoperzowa Cave into one system (Figs. 10, 11) was discovered. In 2020, the Under Chimneys Chamber was discovered at the end of the main gallery of Nietoperzowa Cave (Górny & Siwecki, 2020a, 2020b; Figs. 10, 11).

The total length of the Nietoperzowa-Zygmunta Cave System is 891 m and vertical size 52 m (Tab. 1; Figs. 10, 11). That newly discovered cave system is one of the longest and deepest within the Kraków-Częstochowa Upland area. The Nietoperzowa Cave is a horizontal part of the system. Most of its galleries were developed along joints (Gradziński, 1962). The touristic route is 306 m long (Gradziński & Partyka, 2004a; Górny, 2010a; Radwanek-Bąk, 2011; Górny & Siwecki, 2020a, 2020b; Figs. 10, 11). It starts with the Archaeologist Chamber and passes through the Bear to Flowstone Gallery (Figs. 10, 11). The visitors can observe the outcrop of the sediment file, composed of cemented limestone debris (Tab. 1). A little further on, the abundant speleothems, the most spectacular part of the cave is found (Tab. 1). There are also very picturesque speleothems, cupolas and low stalagmites, some of which are of the spherical shape and also wide (Fig. 12B). Speleothems radiocarbon dated as the Holocene (Gradziński *et al.*, 2003) contain dark-coloured laminae associated with activity of human within the cave. One can also observe there sinter pools and rimstone dams, periodically filled with autochthonous water and moonmilk speleothems (Tab. 1; Fig. 12B). Then, the visitors walk to the Grand Chamber (Figs. 10, 11), the only spacious one in the cave. It is filled with the limestone debris and some rock blocks, probably dropped from the ceiling. The moonmilk stalactites also occur on its walls and ceiling (Tab. 1; Fig. 12C).

Further, numerous cupolas occur on the ceiling and walls in the Deep Cupola (Figs. 10, 11, 12D). In the Under Chimneys Chamber, the gallery narrows and ends as the karst chimney partly filled with cave sediment (Tab. 1; Fig. 11). Tourists can also examine some bones of the Pleistocene fauna collected in the rock niche of the Cemetery, close to the Grand Chamber (Tab. 1; Figs. 10, 11, 12E). They return the same way to the entrance opening (Figs. 10, 11).

The entrance opening into Zygmunt Cave is situated between the Za Telefonem Well and Hiena Gallery (Figs. 10, 11). It is divided into two series: upper and lower in this paper. Numerous picturesque speleothems, stalactites, stalagmites and cupolas are also developed in the cave. However, some parts of them have been destroyed probably due to tectonic processes (Górny & Siwecki, 2020a, 2020b).

In Zygmunta Cave the co-occurrence of interlayering various generations of speleothems and clastic cave sediments was already researched. The clastic sediments include specific black-coloured pisoids, composed of iron or manganese minerals. Regardless of the age of the deposits, they indicate the multistage filling of the cave in changing palaeoenvironmental conditions (Sala *et al.*, 2018).

Nietoperzowa-Zygmunta Cave has been inhabited by numerous bats for thousands of years. Up until today, lesser horseshoe and night bats have dominated there. Apart from them, *Meta menardi* and *Porrhomma egeria* spiders inhabit the cave as well (Górny & Siwecki, 2020a, 2020b).

Some Pleistocene fauna bones are also collected in the glass-case at the cave booking-office (Tab. 1). In the vicinity of the cave, there is the lapidary of the rock boulders occurring around the Nietoperzowa Cave and Pleistocene fauna sculptures (Tab. 1; Fig. 12F).

The geotouristic attractiveness of Nietoperzowa-Zygmunta Cave is of very high grade, estimated at 87% (Tabs. 1–4). Up until today, around 16,500 people a year on average visit the cave (P. Ferdek – oral information; Tab. 5).

Głęboka Cave

This cave is located at Podlesice, around 30 km south-east from Częstochowa, in the northwestern slope the Góra Zborów Hill (Figs. 1, 2, 3B), in the Raven Rocks (Joniec & Słomka, 2012; Fig. 13). This is also a very important example of an underground geotouristic attraction in the Kraków-Częstochowa Upland area with its various, numerous and very picturesque karst features and speleothems. The cave was developed in the phreatic water circulation (Sznober & Tyc, 2010; Polonius *et al.*, 2013; Tab. 1).

The cave was discovered in 1942 when the Oxfordian limestones of the Raven Rocks started to be extracted. Hence, some part of its Northern Chamber (Fig. 13) cut in the cave sediment file was outcropped. This quarry stopped operating in 1949. The cave was frequently explored by "spar hunters" for crystalline calcite extraction for glass production after the Second World War until the 1950s, and therefore was deeply destroyed. The outcropped part of the Northern Chamber was bricked up when the cave was renovated in the 1970s. Its renovation was continued in the years 2006–2008. It was opened for tourism since 2010 (Sznober & Tyc, 2010; Polonius *et al.*, 2013; Tab. 1).

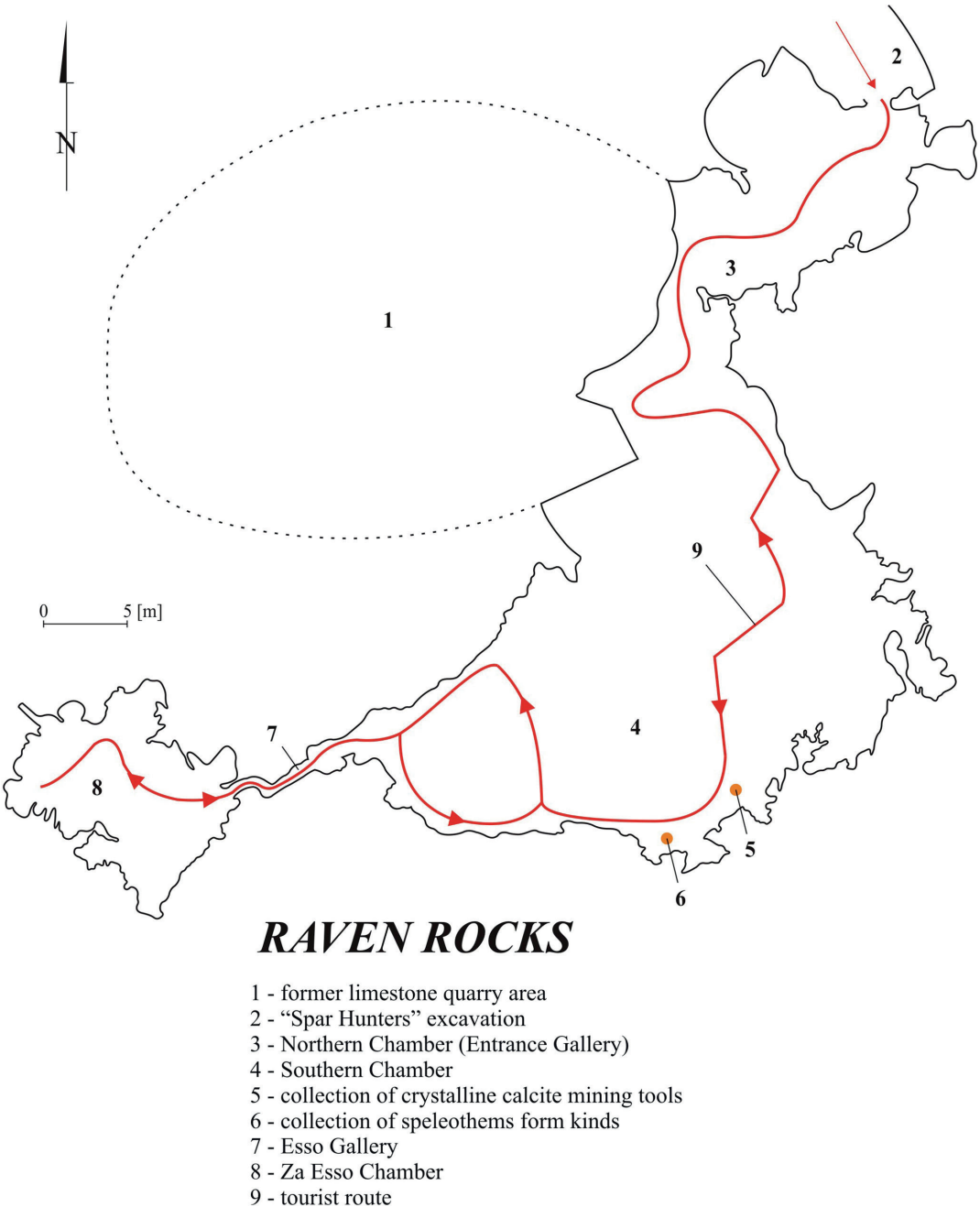

Fig. 13. Map of Głęboka Cave System (after Sznober & Tyc, 2010)

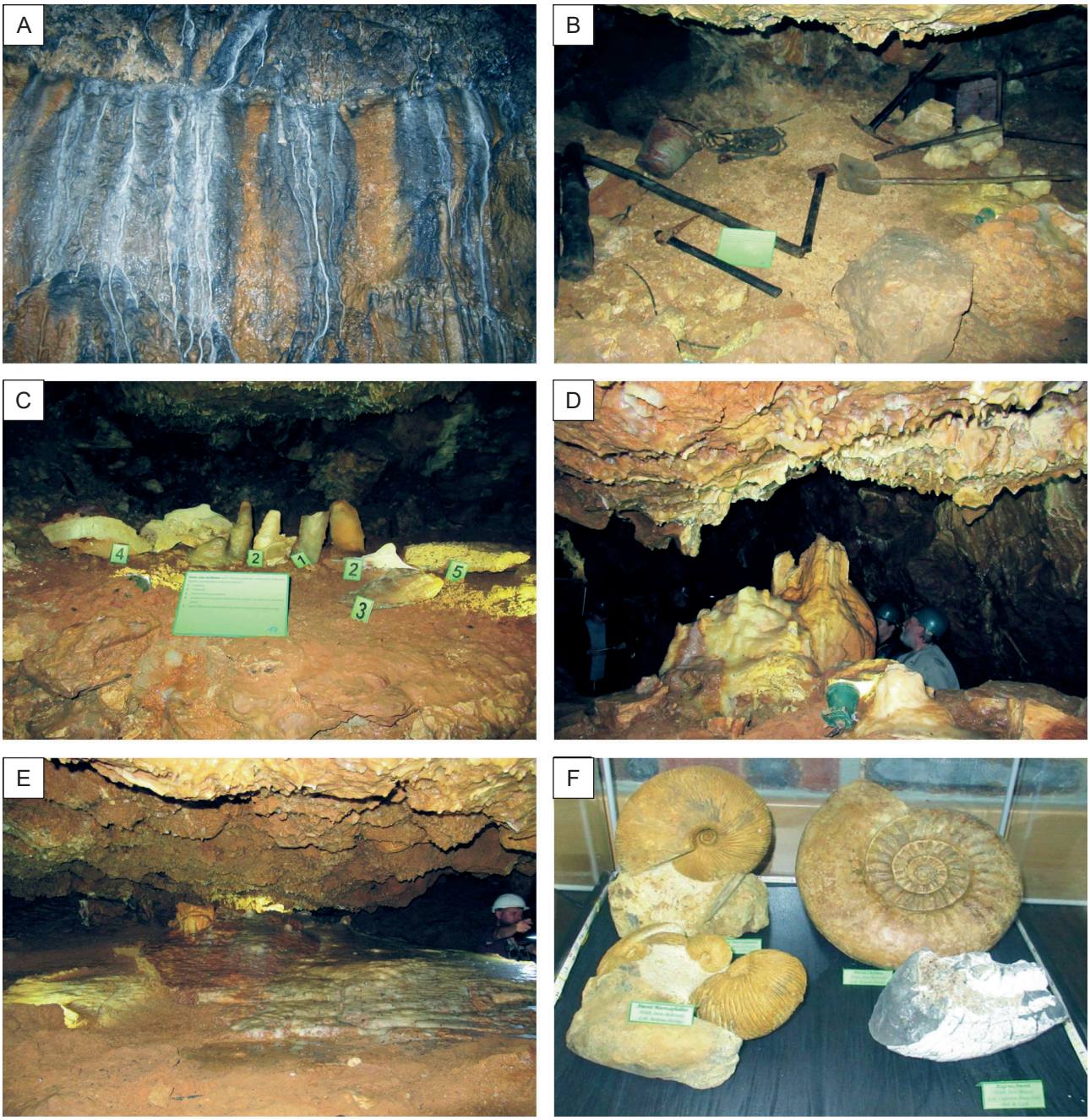

Fig. 14. Photographs of Głęboka Cave (Fig. 13): A – rillenkarren; exhibitions of: B – crystalline calcite mining tools; C – speleothems form kinds: 1 – stalactite, 2 – stalagmite, 3 – flowstone part, 4 – recrystallized calcite flowstone in the sediment file layer, 5 – wavy calcite sheets crystalized in cave lake water; Za Esso Chamber: D – crystalline calcite stalactites and moonmilk thick stalagmite; E – rimstone dams; F – Middle and Late Jurassic ammonites exhibited in the Centre for Jurassic Natural and Cultural Heritage at Podlesice

The total length of Głęboka Cave and its touristic route is 190 m and its vertical size 22 m (Tab. 1). The entrance opening is located in the place of "Spar Hunters" crystalline calcite extraction (Fig. 13). In the Northern Chamber, is the outcrop of limestone debris of the cave sediment file and numerous limestone rock blocks occur there. Some parts of them could drop down from the ceiling and the others could be the rock output remnants from the former quarry (Figs. 13). They can include numerous calcite crystals (Sznober & Tyc, 2010; Polonius *et al.*, 2013). There are also some cupolas in the ceiling. In addition, the artificial wall bricks the primarily outcropped part of the Northern Chamber on its western side (Fig. 13). Its ceiling is protected by metal mesh and anchors.

From the Northern Chamber, the visitors go down the steps to the Southern one (Fig. 13) situated at the level around 20 m lower. It is a very spacious chamber with a very picturesque calcite flowstones stained with iron minerals (Tab. 1).

In the walls and ceiling, there are observed very short crystalline calcite stalactites and speleothems (Fig. 14A). In the Southern Chamber, the tourists can also examine the collection of crystalline calcite mining tools (Fig. 14B) and speleothems forms: stalactite, stalagmite, flowstone part, recrystallized calcite flowstone in the cave sediment layer, and wavy calcite sheets crystalized in cave lake water (Sznober & Tyc, 2010; Polonius *et al.*, 2013; Tab. 1; Fig. 14C).

In the last section of the tourist route, the visitors pass through the Esso Gallery, a very narrow one, to the Za Esso Chamber (Fig. 13). This gallery is shaped in an S-letter, and hence it was named "Esso". In that chamber, very interesting speleothems occur, especially a crystalline calcite stalactites, thick moonmilk stalagmite (Fig. 14D) and some rimestone dams (Fig. 14E). Almost all lower levels of the cave are filled with fine-grained and sandy sediment, covered with a thick layer of flowstone in places. The thickest and most intact flowstone occurs in the southern part of the Southern Chamber (Figs. 13, 14C, D). By using oxygen isotope stratigraphy (OIS) method, it was found that this flowstone crystallizing process was dated between 935 ±5 ka – 470 ±5 ka with three major discontinuities. The observed isotopic variability was also consistent and confirmed with the petrographic observations of the flowstone (Błaszczyk *et al.,* 2018). The visitors come back to the entrance opening by the same way (Fig. 13).

Głęboka Cave is inhabited by single bats. Lesser horseshoe and night ones dominate there (Polonius *et al.*, 2013).

In the vicinity of the cave entrance opening is also the lapidary consisting of the boulders of the rocks occurring in the Kraków-Częstochowa Upland area (Tab. 1; Fig. 3B). Apart from that, the tourists can also examine the collection of Oxfordian fossils, Pleistocene fauna bones, and numerous minerals and rock specimens carried from the other places in Poland and from abroad exhibited in the glass-cases in the Centre for Jurassic Natural and Cultural Heritage at Podlesice (Tab. 1; Fig. 3B). An example is the group of the Oxfordian ammonites (Fig. 14F).

The geotouristic attractiveness of Głęboka Cave is of high grade, estimated at 87% (Tabs. 1–4). Statistical data obtained only for the years 2014–2018 indicate that the interest on the cave was also very high. During this time, total number of visitors to the cave for that period varied from 12,654 up to 17,000 (Tab. 5).

Discussion

All six described caves open for tourism, situated within the Kraków-Częstochowa Upland area are very picturesque ones. Their distinguishing features are very essential and various (Tab. 1).

Karst relief is well developed within each of them (Tab. 1). Speleothems are particularly picturesque in Łokietek, Ciemna, Wierzchowska Górna, Nietoperzowa-Zygmunta and Głęboka Cave, and corrosive forms in Smocza Jama one (Tab. 1), as the example of specific karst developed in isolated horst massif, which is perfectly illustrated by the morphology of the cave walls. Such cave karst features are exceptional in Poland and Europe (Gradziński & Urban, 2018). The specific ones of Głęboka Cave are its crystalline calcite speleothems and short stalactites (Tab. 1). Three of the described caves: Ciemna, Wierzchowska Górna and Nietoperzowa-Zygmunta are also very important archaeological and palaeontological sites in Poland. Particularly Ciemna Cave, where the traces of the Neanderthal settlements known from 115,000–120,000 years ago were discovered. Smocza Jama and Łokietek Cave are also significant elements of Polish legendary and real history. All the above advantages constitute the geological heritage of all six caves described in the paper.

Therefore, the geotouristic attractiveness values assessed for all six caves indicate their high grade for all of them, as they vary from 72% to 87% (Tabs. 1–4). The highest ones are: 87% for Nietoperzowa-Zygmunta and Głęboka Cave and 85% for Wierzchowska Górna Cave, and the lowest ones: 77% for Smocza Jama Cave and 72% for Łokietek and Ciemna Cave (Tab. 4). Lower values for Smocza Jama and Łokietek Cave are due to the lack of boards with information about their origin and features for tourists and no rocky and fossil specimen collection or lapidary around them. For Ciemna Cave, the lower grade is due to the lack of infrastructure in its vicinity (Tabs. 2, 4). The other three ones, apart from the excellent development of their karstic forms, are equipped with big exhibitions of rocky and fossil specimen collections and two of them, additionally with lapidaries. These are, as a result, considered to be the most attractive ones (Tabs. 2–4).

Statistical data analysis of tourist flow in the touristic routes within Smocza Jama and Łokietek Cave reflects their geotouristic attractiveness of high grade very much and makes them very popular. Smocza Jama Cave is a particularly famous and well-known geosite owing to its association with the Royal Castle on the Wawel Hill (Fig. 4) known all over the world, which could be also related to its entering the UNESCO World Heritage List in 1978 (www6). Currently, the number of tourist visits to these facilities is higher than of those to the also popular Paradise Cave in Chęciny and Bear Cave at Kletno (Tab. 5). This perfectly demonstrates the increasing dynamics of the tourist flow in the best known caves open for tourism in Poland and in the world. These two geotouristic attractions were the first underground geological heritage geosites within the Kraków-Częstochowa Upland area open for tourism in the 1920s and in 1976 (Tab. 1). Hence, up until today, they have been visited much more frequently than the other four described ones (Tab. 5). As the interest in Łokietek Cave is also very high, the local authorities, in cooperation with the Ojców National Park management, Jurassic Communes Union and numerous foreign organizations associated with the geological heritage protection and

some other European international institutions, should make an effort to include also this object into the UNESCO World Heritage List. This may help to make this geosite more recognizable and achieve additional success.

However, despite the fact that the other four described caves: Ciemna, Wierzchowska Górna, Nietoperzowa-Zygmunta and Głęboka have also high grades of their geotouristic attractiveness (Tabs. 1–4), they are still much less known as a geotouristic attractions than the two objects described above (Tab. 5). They have been the latest objects open for tourism in: 1985, 1992, 1994 and 2010 (Tab. 1). As such, they could not be effectively promoted yet. However, when local authorities attempt to create the Jurassic Geopark extended over the entire area of the Kraków-Częstochowa Upland, these latter four caves will gain potential to be much more popular in Poland and around the world. Owing to that, Smocza Jama and Łokietek Cave could become even more widely recognised all over the world. As a result of the creation of the Jurassic Geopark, some exchange of experiences and information concerning the restoration and modernization of the geosites among local authorities is much easier. This could lead to an increase of their global rank and reputation (Alexandrowicz, 2006). The perspectives of geotourism development in the Kraków-Częstochowa Upland area, based upon its geoheritage attractions seem to be very optimistic.

The idea of the Jurassic Geopark creation was already initiated in 2000. Until early 2022, it was decided that its area would comprise the northern part of the Kraków-Częstochowa Upland area (www3). However, in the future, the Jurassic Geopark area may be extended on its southern part as well.

Conclusions

As the caves described in the paper are so well known and popular, they should be particularly taken care of and managed. First of all, they should be regularly renovated.

Smocza Jama, Łokietek and Ciemna Cave should be modernised in the future to improve their geotouristic attractiveness and recognition. The first two of them, should provide some information about their origin and features, and rocky and fossil specimen collection or lapidary around them. Around Ciemna Cave, some technical, sanitation and gastronomical infrastructure should be developed at the bottom of the Prądnik Valley (Fig. 3A), close to the touristic path leading to that facility.

When some further speleological investigation of still unknown caves within the Kraków-Częstochowa Upland area is developed, there could be established some new underground touristic routes in some parts of them in the future, as their galleries and chambers are spacious enough for smooth tourist movement along them. The above enterprise could be made particularly in the northern part of the Kraków-Częstochowa Upland area, as only its one cave, Głęboka one, has been opened for tourism, in contrast to the southern part of the upland. It could make this area much more popular in the future.

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