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Stratigraphy of Biśnik Cave: New data and interpretations

Aleksandra Kropczyk[1], Adrian Marciszak[1] and Andrea Pereswiet-Soltan[2]

[1]Department of Paleozoology, University of Wrocław, Poland and [2]Institute of Systematics and Evolution of Animals, Polish Academy of Sciences Cracow Branch, Poland
Corresponding author: Adrian Marciszak; Email: adrian.marciszak@uwr.edu.pl

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Abstract

A new series of 11 radiocarbon (AMS) dates were obtained to the Biśnik Cave, one of the most important Central European sites. New AMS dates contributed to a more precise stratigraphic model for the complex sequence of sediments in this site. Received results showed that layer 1a is younger than 15 kyr, and layers 1b, 1 and 2 are dated on 25–15 kyr. Layers 4–3 were dated on 40–35 kyr, while layers 7–5 on 70-40 kyr. Layer 7 is the first and the uppermost strata in the whole profile out of the radiocarbon method. The new re-examination of chronology and fauna shed new light on the history of Biśnik fauna. The obtained UTh date of an age of 225 ± 27 kyr confirmed assignation layer 18 to MIS 7. Results of AMS dating were compared with optically stimulated luminescence (OSL), thermoluminescence (TL) and uranium-thorium dates as well as with results of biostratigraphic analysis. Results of data received from different direct dating methods (AMS, UTh, OSL, and TL) are confirmed also by data obtained from the biostratigraphic analysis. Only the maximum age of the lowermost sediments is still debatable. The whole, exceptionally abundant fauna, documented last ~340 kyr, roughly between MIS 10/9-1. Among mammals, ancient species, early and mid-Middle Pleistocene faunal markers are absent.

Introduction

The stratigraphic sequence of sediments in Biśnik Cave is one of the longest from Central European sites. In an up to 10-m thick set of sediments, 22 horizons were distinguished, covered the last ~350 kyr (Cyrek et al. 2010). So long period of a relatively complete stratigraphic record is unique in Polish geology, even if the recording sediments sequence is not fully continuous and contains some hiatuses. The extraordinary abundance of archaeological and paleontological finds makes this locality so unique in the Eurasian scale (Cyrek et al. 2009, 2010; Krajcarz and Cyrek 2011; Krajcarz and Madeyska 2012; Krajcarz et al. 2010; Mirosław-Grabowska 1998, 2002a, 2002b). There are subjects of numerous studies, which together make it possible to reconstruct the dynamic changes that have taken place during this time. An indispensable tool in this type of analysis and reconstruction is direct dating, which allows you to place a given event or remain at a specific time. The juxtaposition of various methods of direct and indirect dating allowed us to verify the current state of knowledge and clarify the hitherto unclear issues. The main subject of this paper is summary of the current state of knowledge and confronting the results obtained from different methods. The new radiocarbon dating of the 7–5 layers that have been poorly recognized so far has allowed them to be shifted in time and showed that they are older than previously thought.

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Site

Biśnik Cave (50°25'35"N 19°39'56"E; 406–410 m a.s.l.) is a multi-layered site, located in the central part of Kraków-Częstochowa Upland (Cyrek et al. 2010; Kowalski 1951). The site is known long ago and was excavated between 1991–2019. The cave is formed by several interconnected chambers and rock shelters, originally almost filled with deposits. The layers in the locality are numbered downwards, and covered timespan of the last ~350 kyr (Cyrek et al. 2010; Krajcarz 2012; Krajcarz et al. 2014a; Marciszak et al. 2011a, 2011b, 2019a, 2019b; Stefaniak et al. 2020). Artefacts and bone marks documented frequent human presence and settlement of the locality from the Middle Palaeolithic (Cyrek et al. 2010, 2014; Krajcarz and Cyrek 2011; Krajcarz et al. 2014a; Cyrek 2021). Known so far fauna consists 104 bird and 144 mammal species, dated in the range MIS 10/9-1 (Bocheński et al. 2012; Cyrek et al. 2010; Gąsiorowski et al. 2014; Klimowicz et al. 2016; Krajcarz and Krajcarz 2013, 2019; Krajcarz et al. 2010, 2014a, 2014b, 2016; Marciszak 2012, 2014; Marciszak & Lipecki, 2021; Marciszak and Socha 2014; Marciszak and Stefaniak 2010; Marciszak et al. 2011a, 2011b, 2014, 2019a, b, 2021a, 2021b; Mazza et al. 2021; Piskorska and Stefaniak 2014; Piskorska et al. 2015; Rzebik-Kowalska 2009; Socha 2009, 2014; Stefaniak 2015; Stefaniak and Marciszak 2009; Stefaniak et al. 2020; Tomek et al. 2012; Van Asperen and Stefaniak 2011).

Methodology

The new 11 radiocarbon dates (AMS) were made in Poznań Radiocarbon Laboratory (Table 1), following their pre-treatment protocol for the extraction of collagen (Longin 1971; Piotrowska and Goslar 2002). Before extraction, degree of collagen degradation is checked by measuring content of nitrogen and carbon in bone, using analyser Flash EA 1112 Series (ThermoScientific). The samples are regarded suitable for collagen dating, if nitrogen content in bone is not lower than 0.6%, and ratio C/N is not higher than 5 (Brock et al. 2012; Guiry and Szpak 2020). Suitable bones are crushed mechanically to granulation <0.3 mm, the bone powder is then treated with 2M HCl (room temp., 20 min), and 0.1M NaOH (room temp., 1 hr). After each step of treatment, the sample is centrifuged and the residuum is collected. Extraction of collagen is processed in HCl (pH = 3, 80 °C, 10 hr), and after centrifugation, residuum is removed. The extracted collagen is then ultra-filtered on pre-cleaned Vivaspin 15 MWCO 30 kD filters. Quality of the collagen is ultimately assessed basing on C/N atomic ratio (interval of acceptance: 2.7–3.5) and collagen extraction yield (acceptance threshold: 0.5%). On demand, carbon and nitrogen stable isotopic composition of the collagen can be determined (Bronk Ramsey et al. 2004). All new dates were calibrated using program IntCal20, according to Reimer et al. (2020).

Results

Obtained results of numerical dating are coherent, and older layers usually gave older dates (Supplemental Appendix; Table 1). We do not used a series of 15 UTh dates made by Hercman and Górka (2002), since most of them are not reliable and do not fit neither other dates nor to correlated ages based on climatostratigraphy. During that time UTh was not a well-established dating method and faced many difficulties. Published TL dates (Supplemental Appendix 1; Cyrek et al. 2009, 2010) correspond well with the new dating and climatostratigraphic scheme. The only exceptions are layers 19 and 15, which according to Krajcarz et al. (2014a) seem to be too old.

Undoubtedly Holocene age of the layer 1a was confirmed by 4 AMS dates, which calibrated age ranged between ~6.9–1.4 kyr. The presence of Neolithic and younger like Middle Ages artifacts (Cyrek 2021; Cyrek et al. 2010) and lack of Late Pleistocene faunal elements additionally confirmed this attribution. Layer 1b, in the light of AMS dates previously attributed also to the Holocene (Cyrek et al. 2010; Mirosław-Grabowska 2002a, 2002b), should be correlated rather to the Late Pleistocene, mostly with MIS 2. Ultimately, the uppermost part may represent the earliest part of the Holocene (Supplemental Appendix; Table 1). Similarly, the age of the latest part of MIS 2 and the earliest part of

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Table 1. *New radiocarbon and uranium-thorium dates from Biśnik Cave. The table reports,, and collagen quality indicators (total nitrogen and carbon contents, and collagen yields). Calibrations were performed using the appropriate IntCal20 calibration curve (Reimer et al. 2020) in OxCal 4.5 (Ramsey 2009). Abbreviations and table captions:* ***layer*** *– particular layers from Biśnik Cave, numbered increasing from the bottom to the surface,* ***14C age*** *- uncalibrated radiocarbon ages (^{14}C BP ± 1σ),* ***cal. BP 95.4%*** *- calibrated age ranges at 95.4% probability (cal. BP),* ***lab. code*** *- laboratory codes,* ***method*** *– dating method,* ***AMS*** *- Accelerator Mass Spectrometry (AMS) radiocarbon dating method measuring carbon-14 content up to ~ 50 kyr,* ***UTh*** *- Uranium-Thorium dating, determines the age of calcium carbonate ($CaCo_3$) by measuring the ratio of radioactive daughter isotopes (like ^{230}Th) to their parent isotopes (like ^{234}U or ^{238}U) up to ~ 500 kyr,* ***taxonomy*** *- taxonomic determination of the remains that were used in dating,* ***specimen*** *- skeletal elements analysed,* ***N %*** *- N percentage measured in the raw bone, represent elemental composition measured on bulk bone before extraction,* ***C %*** *- C percentage measured in the raw bone, represent elemental composition measured on bulk bone before extraction,* ***col. %*** *- collagen percentage measured in the raw bone,* ***C col. %*** *- C percentage measured after collagen extraction,* ***N col. %*** *- N percentage measured after collagen extraction,* ***C/N at col.*** *- the C:N content measured after collagen extraction.*

							N %	C %	col. %	C col. %	N col. %	C:N at col.
							Before collagen extraction			After collagen extraction		
Layer	14C age	Cal. BP 95.4%	Lab. code	Method	Taxonomy	Specimen						
1a	6020 ± 34	6952-6781	Poz-116067	AMS	Mammalia indet.		1.6	7.6	3.9	51.4	18.7	3.2
1a	3030 ± 35	3355-3147	Poz-89021	AMS	*Ursus arctos arctos*	scapula	2.7	11.7	17.8	51.0	18.4	3.2
1a	1625 ± 30	1549-1406	Poz-111564	AMS	Rodentia		3.1	9.0	11.4	48.1	17.4	3.2
1a	4960 ± 30	5745-5599	Poz-116069	AMS	Mammalia indet.		1.4	6.4	2.1	50.0	18.0	3.2
1b	10340 ± 60	12479-11936	Poz-111589	AMS	Rodentia		2.0	7.3	3.5	46.1	16.6	3.2
1b	29980 ± 330	35216-33901	Poz-116066	AMS	Mammalia indet.		0.6	5.3	1.7	43.1	16.9	3.0
2	11550 ± 60	13510-13307	Poz-114081	AMS	Rodentia		2.2	7.7	3.3			
2	12970 ± 60	15713-15298	Poz-116068	AMS	Mammalia indet.		1.5	5.7	11.8	52.1	18.9	3.2
3	32900 ± 470	37577-36996	Poz-89058	AMS	*Ursus arctos taubachensis*	metatarsal 2	1.5	7.3	1.7	45.6	16.1	3.3
4	33200 ± 400	38369-37347	Poz-86888	AMS	*Ursus arctos taubachensis*	femur	2.5	8.1	2.7	44.6	15.9	3.3
7	>50000		Poz-86838	AMS	*Ursus arctos taubachensis*	humerus	2.8	8.4	4.7	50.0	18.3	3.2
18	225000 ± 27000		IGS-507	UTh	*Ursus arctos taubachensis*	metacarpal 5						

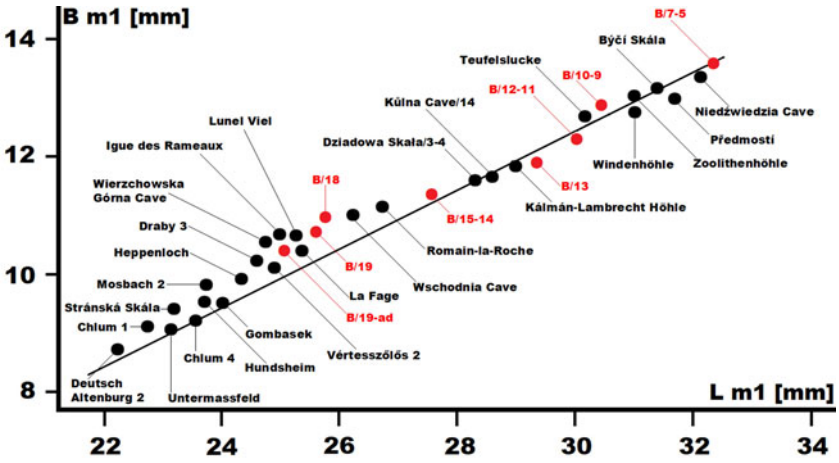


Figure 1. *Graph showing the relationship between the m1 mean length (L m1) and the trigonid mean breadth (B tr m1) in Canis lupus evolutionary lineage. For references see Table 2.*

MIS 1 was obtained for layer 1 (Gąsiorowski et al. 2014). An apparent discrepancy exists between the OSL and AMS dates for layers 1, 1a and 1b, where the OSL dates are much older than the AMS dates. It should be mentioned however, that the OSL method was used to date the grains of sediments, which may be older than the bone deposited later into the sediment.

For layer 2 two dates showed variable values, and their calibrated age ranged between 15.7–13.3 kyr cal BP. In general overview, this layer was accumulated between 25–15 kyr. Such considerable variation may testify to the admixture of this layer. It is especially since paleontological material noted dominance of Late Pleistocene species, with a slight admixture of Holocene elements. Two AMS dates assigned layers 4–3 to the late part of MIS 3 (38.4–37.0 kyr cal BP). The TL dates showed similar values and ranged between 58-25 kyr (Supplemental Appendix; Cyrek et al. 2009, 2010). Layers 7–5 were accumulated in several phases, with layer 6–5 related to ~ 60–40 kyr. Layer 7 seems to be of the range of the method, and the new AMS date obtained for this layer was also older than 50 kyr. The OSL and TL dates from sediments suggested an age between 70–60 kyr for the layer 7. All three layers, 7, 6 and 5 are also regarded as the coolest in the whole profile, which was confirmed by paleoecological analysis (Marciszak and Socha 2014; Socha 2009, 2014). Also, remains of many species e.g. *Canis lupus spelaeus* or *Ursus arctos taubachensis* Rode, 1935 reached those layers maximum size, according to the Bergman rule. The OSL, TL and UTh dates indicate that layer 8 was dated on 80–70 kyr, layers 10–9 on 100–80 kyr, and layers 12–11 were dated on 115–90 kyr (Supplemental Appendix; Krajcarz et al. 2014a).

Some earlier papers e.g. Mirosław-Grabowska (1998, 2002a, 2002b), Cyrek et al. (2010) related layer 13–12 to the Eemian, even if position of these deposits dated on the last interglacial are still highly disputed problem (Cyrek et al. 2010; Krajcarz et al. 2014a). Recently layer 13 and some part of layer 14 was assigned to MIS 5e, while the rest part of layer 14 and upper part of layer 15 is correlated with MIS 6 (Krajcarz et al. 2014a; Marciszak et al. 2021a, 2021b). Older papers e.g. Hercman and Gorka (2002), or Cyrek et al. (2009, 2010) correlated lower part of layer 15. According to Gąsiorowski et al. (2014) and Krajcarz et al. (2014a) these results are not reliable in the light of OSL and UTh dating results, which indicated an age between 170–130 kyr (MIS 6) (Supplemental Appendix 1). In contrast with these dates stated data obtained from biochronological analysis, like those from abundant material of speleoid bears. The morphodynamic analysis showed evolutionary level comparable with bears dated on MIS 7, like those from Hunas (Hilpert 2005), and lower to those from MIS 6. The age of layers 16, 17 and 18 was generally correlated with MIS 7, with the lower part of layer 18 might be assigned to late MIS 8, a was obtained from biochronological analysis and some TL dates (Supplemental Appendix).

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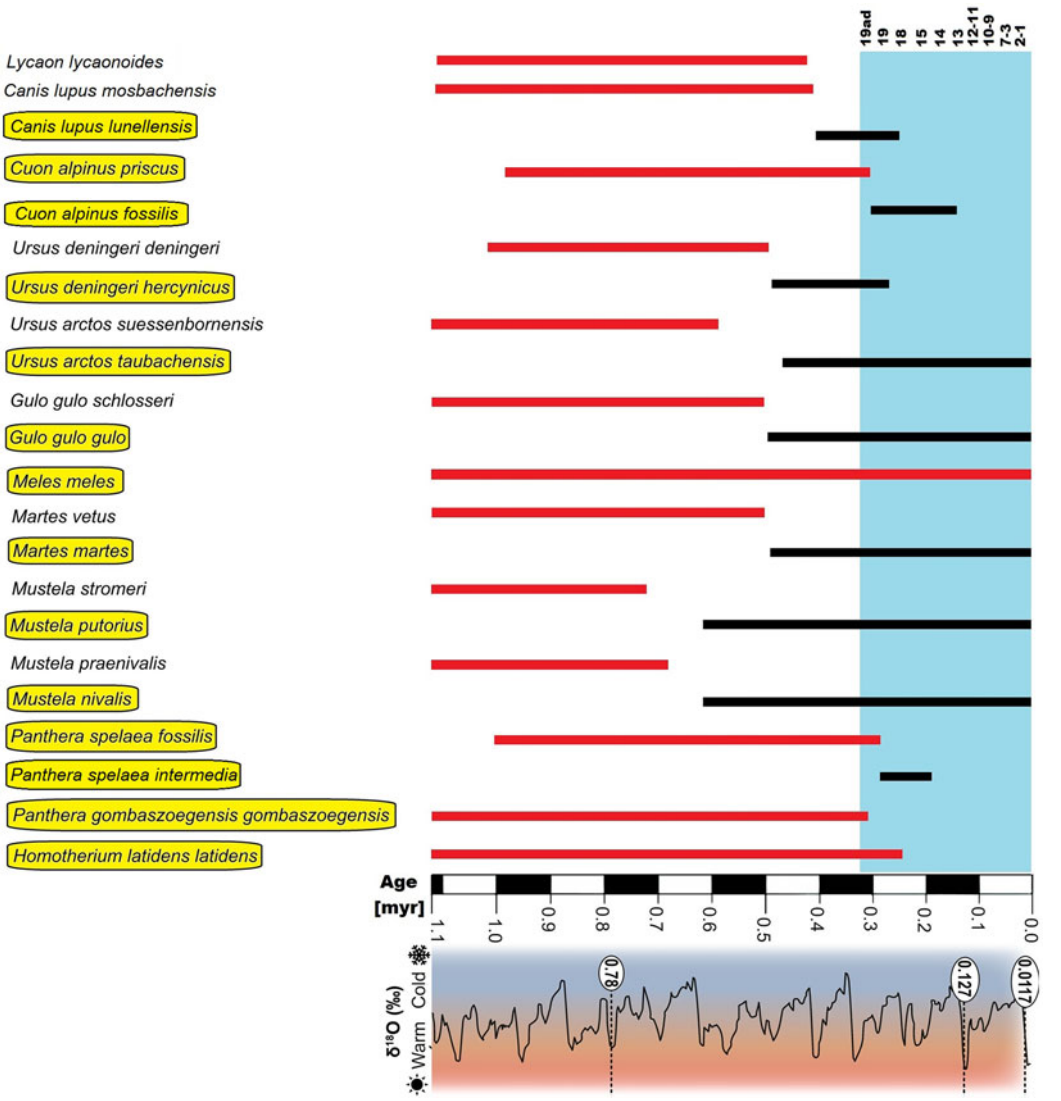


Figure 2. *Reconstructed chronology of some carnivores from Biśnik Cave and some closely related forms. The red lines refer to the occurrence of the ancient species of the Early Pleistocene origin. Black lines refer to the more recent species of the mid-late Middle Pleistocene origin, belonged to the core of the extant carnivore fauna. Carnivores found in Biśnik Cave are marked in yellow. The blue bar indicates the most probable chronology of the Biśnik Cave.*

The dating of layer 18 on MIS 7 was recently also additionally confirmed by one UTh date from bone of *U. a. taubachensis*, which gave an age of 225 ± 27 kyr.

Layer 19 was also assigned to MIS 7 by Krajcarz and Cyrek (2011), while complex layers of 19ad was correlated with MIS 8. Received TL dates showed much older age (MIS 15-12) than this obtained from biochronological analysis (MIS 9, and probably some part of MIS 10). The frequent, deningeroid bears represented advanced form, evolutionary higher evolved, than those from MSI 11, known from e.g. from Za Hájovnou Cave (Musil 2014; Wagner 2014) or Draby. Analysis of wolf and lion material from Biśnik Cave showed, that immense individuals of *Panthera spelaea fossilis* from layer 19ad of this site morphometrically related to the period dated on MIS 11-9 (Figure 1; Marciszak et al. 2019a). They

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Table 2. *The mean values of the m1 length (L m1) and the trigonid breadth (B tr m1) in Canis lupus evolutionary lineage. For references see the Materials and Methods section.*

Locality	Country	Source	MIS	L m1	B tr	N
Canis lupus spelaeus						
Predmosti	Czech Republic	this paper	2	31.74	13.08	47
Niedźwiedzia Cave	Poland	this paper	3-2	32.29	13.24	25
Biśnik Cave, layers 7-3	Poland	this paper	3	32.78	13.64	11
Býčí Skála Jeskyně	Czech Republic	this paper	3	31.56	13.27	6
Zoolithenhöhle	Germany	this paper	3-2	31.37	13.14	54
Windenhöhle	Austria	this paper	3	31.27	12.74	11
Teufelslucke	Austria	this paper	3	30.41	12.56	6
Biśnik Cave, layers 10-9	Poland	this paper	5b-a	30.68	12.89	7
Canis lupus lupus						
Biśnik Cave, layers 12-11	Poland	this paper	5d-c	30.29	12.27	7
Biśnik Cave, layer 13	Poland	this paper	5e	29.32	11.78	10
Kálmán Lambrecht Cave	Hungary	this paper	5e	29.14	11.66	8
Kůlna Cave, layer 14	Czech Republic	this paper	5e	28.68	11.69	5
Dziadowa Skała, layers 3-4	Poland	this paper	5e	28.22	11.47	4
Biśnik Cave, layers 15-14	Poland	this paper	6	27.39	11.34	8
Romain-la-Roche	France	Argant 2010	6	27.18	10.67	49
Wschodnia Cave	Poland	this paper	7	26.49	10.87	7
Canis lupus lunellensis						
Biśnik Cave, layer 18	Poland	this paper	7	25.64	10.78	5
Wierzchowska Górna Cave	Poland	this paper	8	24.52	10.35	4
Igue des Rameaux	France	Boudadi-Maligne 2010	9-8	25.27	10.34	82
La Fage, aven 1	France	Boudadi-Maligne 2010	9-8	25.49	10.12	7
Lunel Viel 1	France	Boudadi-Maligne 2010	9	25.05	10.21	24
Biśnik Cave, layer 19	Poland	this paper	9	25.87	10.44	7
Biśnik Cave, layers 19ad	Poland	this paper	10-9	25.22	10.27	6
Canis lupus mosbachensis						
Heppenloch	Germany	Adam 1959	11	24.85	9.84	7
Draby 3	Poland	this paper	11	24.78	9.97	5
Vértesszőlős 2	Hungary	this paper	11	24.84	9.78	10
Hundsheim	Austria	this paper	15-13	23.48	9.26	5
Mosbach 2	Germany	this paper	15-13	24.05	9.68	7
Gombasek	Slovakia	this paper	19-17	24.27	9.34	19
Stránská Skála	Czech Republic	this paper	19-17	23.27	8.99	68
Chlum 1	Czech Republic	this paper	23-21	23.32	9.44	27
Chlum 4	Czech Republic	this paper	23-21	23.91	9.25	10
Untermassfeld	Germany	Sotnikova 2001	1.1-1.0	24.45	9.12	16
Deutsch Altenburg 4B	Austria	this paper	1.1-1.0	22.61	9.28	5

represent form more evolved than those from MIS 15-12, known, among others from Mauer, Mosbach 2, Château or Południowa Cave. Also, other carnivores confirmed dating these layers on MIS 9, and partially maybe also on MIS 10 (Figure 1, Table 2).

In layers 19ad of Biśnik Cave we do not have mid Middle Pleistocene faunal elements, known from other Central European sites. Species like *Lycaon lycaonoides* Kretzoi, 1938, *Canis lupus mosbachensis*

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Soergel, 1925, *Gulo gulo schlosseri* Kormos, 1914, *Martes vetus* Kretzoi, 1942, *Mustela strandi* Kormos, 1934, *Mustela palerminea* Petényi, 1864, *Mustela praenivalis* Kormos, 1934, *Acinonyx pardinensis* Croizet and Jobert, 1828 or *Pachycrocuta brevirostris* Gervais, 1850, are missing here (Figure 2). Instead, we have forms like a gracile and small wolf *Canis lupus lunellensis* Bonifay, 1971, very characteristic faunal element of MIS 10–8 in Europe, robust *Cuon alpinus priscus* Thenius, 1954, small *Gulo gulo gulo* Linnaeus, 1758, large and robust *Martes martes martes* Linnaeus, 1758, *Mustela erminea aestiva* Kerr, 1792 and *Mustela nivalis boccamela* Bechstein, 1800, which morphology still hold some primitive features (Marciszak 2012; Marciszak and Socha 2014; Marciszak et al. 2021a, 2021b).

Also, analysis of faunal lists of other mammals, like insectivores, rodents or ungulates supported this assignation. Among rodents so far, any ancient species from genus *Pliomys* were found, also *Arvicola* species is represented by *Arvicola amphibious*, not by *Arvicola mosbachensis* Schmidtgen, 1911 (Berto et al. 2021; Socha 2014). Among ungulates, characteristic for this period is occurrence of a large red deer *Cervus elaphus spelaeus* Owen, 1846, an early *Megaloceros giganteus antecendens* Berckhemer, 1937 and/or *Megaloceros giganteus germaniae* Pohlig, 1892, *Cervalces* sp. and *Capreolus capreolus priscus* Soergel, 1914 (Croitor et al. 2014; Stefaniak et al. 2020; van der Made et al. 2014). Most of these forms do not occur in the younger layers or evolve into other, younger chronosubspecies. Scare material of *Panthera gombaszoegensis* or *Cervalces* sp. was interpreted as one of the latest, relics occurrences of both species (Marciszak 2014; Stefaniak 2015; Stefaniak et al. 2020; Marciszak & Lipecki, 2021, 2021b). Krajcarz et al. (2014a) claimed that the age of layers complex 19ad is difficult to establish. The OSL dates indicate that the accumulation had to represent younger episode at ∼370–280 kyr. It cannot be however entirely ruled out, that the re-deposited sediments could be also much older. So far, the mandible of ancient, small polecat *Mustela stromeri* Kormos, 1934 from layer 20 is the only Early Pleistocene of even Pliocene faunal element recorded from Biśnik Cave. But this accidental find cannot of course give any reliable data about the stratigraphy of the site.

Conclusions

A set of new AMS and UTh dates contributed to a more precise stratigraphic model for the complex sequence of sediments in Biśnik Cave, when compared with previous interpretations. The profile of this site is well-stratified, with some hiatuses, with sign of re-deposition. Our new dates generally agree with those obtained by previous authors, where particular layers are dated as follows: (a) 1a is younger than 15 kyr, (b) 1b, 1 and 2 are dated on 25–15 kyr, (c) layers 4–3 are dated on 40–35 kyr, (d) layers 7–5 on 70–40 kyr, where layer 7 is the first and the uppermost strata in the whole profile out of the radiocarbon method, (e) layer 8 was dated on 80–70 kyr, layers 10–9 on 100–80 kyr, and layers 12–11 were dated on 115–90 kyr, (f) layer 13 and upper part of layer 14 was assigned to MIS 5e, while the lower part of layer 14 and upper part of layer 15 is correlated with MIS 6; (g) lower part of layer 15 and layers 16, 17 and 18 were dated on MIS 7 (one UTh date of an age of 225 ± 27 kyr confirmed assignation layer 18 to MIS 7), (h) layer 19 was also assigned to MIS 7/8, and complex layers of 19ad was correlated with MIS 9/10. Dates received from different dating methods (AMS, UTh, OSL, and TL) are confirmed also by data obtained from the biostratigraphic analysis. Only the maximum age of the lowermost sediments are still debatable. The whole, exceptionally abundant fauna, documented last ∼350 kyr, roughly between MIS 10/9-1. Among mammals, ancient species, early and mid-Middle Pleistocene faunal markers are absent. The new re-examination of chronology and fauna shed new light on the history of Biśnik fauna.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/RDC.2026.10243

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References

Asperen ENv and Stefaniak K (2011) Biśnik Cave and its biostratigraphical position based on equid remains. *Acta Zoologica Cracoviensia* **54A**(1–2), 55–76.

Berto C, Nadachowski A, Pereswiet-Soltan A, Lemanik A and Kot M (2021) The Middle Pleistocene small mammals from the lower layers of Tunel Wielki Cave (Kraków-Częstochowa Upland): An Early Toringian assemblage in Poland. *Quaternary International* **577**, 52–70.

Bocheński Z, Bocheński ZM and Tomek T (2012) *A History of Polish Birds*. Cracow: Institute of Systematics and Evolution of Animals, Polish Academy of Sciences.

Brock F, Bronk Ramsey C and Higham T (2007) Quality assurance of ultra-filtered bone dating. *Radiocarbon* **49**, 187–192.

Brock F, Wood R, Higham TFG, Ditchfield P, Bayliss A and Ramsey CB (2012) Reliability of nitrogen content (%N) and carbon: nitrogen atomic ratios (C:N) as indicators of collagen preservation suitable for radiocarbon dating. *Radiocarbon* **54**(3–4), 879–886.

Bronk Ramsey CH, Higham T, Bowles A and Hedges R (2004) Improvements to the pre-treatment of bone at Oxford. *Radiocarbon* **46**(1), 155–163.

Brown TA, Nelson DE, Vogel JS and Southon JR (1988) Improved collagen extraction by modified Longin method. *Radiocarbon* **30**, 171–177.

Croitor R, Stefaniak K, Pawłowska K, Ridush B, Wojtal P and Stach M (2014) Giant deer *Megaloceros giganteus* Blumenbach, 1799 (Cervidae, Mammalia) from Palaeolithic of eastern Europe. *Quaternary International* **326–327**, 91–104.

Cyrek K (2021) The oldest phases of the Levallois method and the beginnings of the Middle Palaeolithic at the northern foreland of the Carpathians. *Quaternary International* **595**, 12–29.

Cyrek K, Mirosław-Grabowska J, Stefaniak K and Socha P (2009) Archaeology, stratigraphy and paleoecology of Biśnik Cave. *Studies of the Faculty of Earth Sciences, University of Silesia* **56**, 191–214.

Cyrek K, Socha P, Stefaniak K, Madeyska T, Mirosław-Grabowska J, Sudoł M and Czyżewski Ł (2010) The Palaeolithic of Biśnik Cave (Southern Poland) against the environmental background. *Quaternary International* **220**, 5–30.

Cyrek K, Sudoł M, Czyżewski Ł, Osipowicz G and Grelowska M (2014) Middle Palaeolithic cultural levels from Middle and Late Pleistocene sediments of Biśnik Cave, Poland. *Quaternary International* **326–327**, 20–63.

Gąsiorowski M, Hercman H and Socha P (2014) Isotopic analysis (C, N) and species composition of rodent assemblage as a tool for reconstruction of climate and environment evolution during Late Quaternary: A case study from Biśnik Cave (Częstochowa Upland, Poland). *Quaternary International* **339–340**, 139–147.

Guiry EJ and Szpak P (2020) Quality control for modern bone collagen stable carbon and nitrogen isotope measurements. *Methods in Ecology and Evolution* **11**(9), 1049–1060.

Hercman H and Górka P (2002) Analizy metodą uranowo-torową kości kopalnych z Jaskini Biśnik. In Cyrek K (ed), *Jaskinia Biśnik: Rekonstrukcja zasiedlenia jaskini na tle zmian środowiska przyrodniczego*, pp. 181–192. Toruń: Wydawnictwo Uniwersytetu Mikołaja Kopernika.

Higham TFG, Jacobi RM and Bronk Ramsey C (2006) AMS radiocarbon dating of ancient bone using ultrafiltration. *Radiocarbon* **48**, 179–195.

Hilpert B (2005) *Die Ursiden aus Hunas: Revision und Neubearbeitung der Bärenfunde aus der Steinberg-Höhlenruine bei Hunas (Gde. Pommelsbrunn, Mittelfranken, Bayem)*. Unpublished dissertation, Erlangen.

Klimowicz M, Nadachowski A, Lemanik A and Socha P (2016) Is the enamel differentiation quotient (SDQ) of the narrow-headed vole (*Microtus gregalis*) useful for Pleistocene biostratigraphy? *Quaternary International* **420**, 348–356.

Kowalski K (1951) *Jaskinie Polski, Tom 1*. Warszawa: Wiedza Powszechna.

Krajcarz MT (2012) Geology of the Biśnik Cave. In Cyrek K, Czyżewski AŁ and Krajcarz MT (eds), *Guidebook and Book of Abstracts of International Conference "European Middle Palaeolithic during MIS 8–MIS 3 Cultures–Environment–Chronology"*, Wolbrom, Poland, 25–28 September 2012, p. 14. Toruń: Nicolaus Copernicus University Press.

Krajcarz MT, Bosák P, Šlechta S, Pruner P, Komar M, Dresler J and Madeyska T (2014a) Sediments of Biśnik Cave (Poland): Lithology and stratigraphy of the Middle Palaeolithic site. *Quaternary International* **326–327**, 6–19.

Krajcarz MT and Cyrek K (2011) The age of the oldest Palaeolithic assemblages from Biśnik Cave (southern Poland) in the light of geological data. *Przegląd Archeologiczny* **59**, 55–74.

Krajcarz MT, Gola MR and Cyrek K (2010) Preliminary suggestions on the Pleistocene palaeovegetation around Biśnik Cave (Częstochowa Upland, Poland) based on studies of molecular fossils from cave sediments. *Studia Quaternaria* **27**, 55–61.

Krajcarz MT and Krajcarz M (2013) The 200000-year long record of stable isotopes ($\delta^{18}O$, $\delta^{13}C$) from cave bear (*Ursus spelaeus*) teeth from Biśnik Cave, Poland. *Quaternary International* **339–340**, 119–130.

Krajcarz M and Krajcarz MT (2019) Post-depositional bone destruction in cave sediments: A micromorphological study of the MIS 5a–d cave bear strata of Biśnik Cave, Poland. *Journal of Quaternary Science* **34**(2), 138–152.

Krajcarz MT, Krajcarz M and Marciszak A (2014b) Paleoecology of bears from MIS 8–MIS 3 deposits of Biśnik Cave based on stable isotopes ($\delta^{13}C$, $\delta^{18}O$) and dental cementum analysis. *Quaternary International* **326–327**, 114–124.

https://doi.org/10.1017/RDC.2026.10243 Published online by Cambridge University Press

Krajcarz MT and Madeyska T (2012) Geology and chronostratigraphy of sediments from Biśnik Cave. In Cyrek K, Czyżewski AŁ and Krajcarz MT (eds), *Guidebook and Book of Abstracts of International Conference "European Middle Palaeolithic during MIS 8–MIS 3 Cultures–Environment–Chronology"*, Wolbrom, Poland, 25–28 September 2012, pp. 56–58. Toruń: Nicolaus Copernicus University Press.

Krajcarz M, Pacher M, Krajcarz MT, Laughlan L, Rabeder G, Sabol M, Wojtal P and Bocherens H (2016) Isotopic variability of cave bears (δ15N, δ13C) across Europe during MIS 3. *Quaternary Science Reviews* **131**, 51–72.

Kromer B, Lindauer S, Synal H-A and Wacker L (2013) MAMS: A new AMS facility at the Curt-Engelhorn-Centre for archaeometry, Mannheim, Germany. *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* **294**, 11–13.

Longin R (1971) New method of collagen extraction for radiocarbon dating. *Nature* **230**, 241–242.

Made Jvd, Marciszak A and Stefaniak K (2014) The Polish fossil record of the wolf *Canis* and the deer *Alces*, *Capreolus*, *Megaloceros*, *Dama* and *Cervus* in an evolutionary perspective. *Quaternary International* **326–327**, 406–430.

Marciszak A (2012) *Ssaki łasicowate (Mustelidae, Carnivora, Mammalia) z plejstocenu Polski*. Unpublished PhD thesis, University of Wrocław, Wrocław.

Marciszak A (2014) Presence of *Panthera gombaszoegensis* (Kretzoi, 1938) in the late Middle Pleistocene of Biśnik Cave, Poland, with an overview of Eurasian jaguar size variability. *Quaternary International* **326–327**, 104–113.

Marciszak A, Krajcarz MT, Krajcarz M and Stefaniak K (2011a) The first record of leopard *Panthera pardus* Linnaeus, 1758 from the Pleistocene of Poland. *Acta Zoologica Cracoviensia* **54A**(1–2), 39–46.

Marciszak A, Kropczyk A and Lipecki G (2021a) The first record of *Cuon alpinus* (Pallas, 1811) from Poland and the possible impact of other large canids on the evolution of the species. *Journal of Quaternary Science* **36**(6), 1101–1121.

Marciszak A and Lipecki G (2020) The history of bears (Ursidae, Carnivora, Mammalia) from Silesia (southern Poland) and the neighboring areas. *Geological Quarterly* **64**(4), 876–897.

Marciszak A and Lipecki G (2021) *Panthera gombaszoegensis* (Kretzoi, 1938) from Poland in the scope of the species evolution. *Quaternary International* **633**, 36–51.

Marciszak A, Lipecki G, Pawłowska K, Jakubowski G, Ratajczak-Skrzatek U and Nadachowski A (2021b) The Pleistocene lion *Panthera spelaea* (Goldfuss, 1810) from Poland: A review. *Quaternary International* **605–606**, 213–240.

Marciszak A, Schouwenburg C and Darga R (2014) Decreasing size process in the cave (Pleistocene) lion *Panthera spelaea* (Goldfuss, 1810) evolution: A review. *Quaternary International* **339–340**, 245–257.

Marciszak A, Schouwenburg Ch, Gornig W, Lipecki G and Mackiewicz P (2019a) Morphometric comparison of *Panthera spelaea* (Goldfuss, 1810) from Poland with the lion remains from Eurasia over the last 700 ka. *Quaternary Science Reviews* **223**, 105950.

Marciszak A, Schouwenburg Ch, Lipecki G, Talamo S, Shpansky A, Malikov D and Gornig W (2019b) Steppe brown bear *Ursus arctos* "*priscus*" from the Late Pleistocene of Europe. *Quaternary International* **534**, 158–170.

Marciszak A and Socha P (2014) Stoat *Mustela erminea* Linnaeus, 1758 and weasel *Mustela nivalis* Linnaeus, 1766 in palaeoecological analysis: A case study of Biśnik Cave. *Quaternary International* **339–340**, 258–265.

Marciszak A, Socha P, Nadachowski A and Stefaniak K (2011b) Carnivores from Biśnik Cave. *Quaternaire, Hors-série* **4**, 101–106.

Marciszak A and Stefaniak K (2010) Two forms of cave lion: Middle Pleistocene *Panthera spelaea fossilis* Reichenau, 1906 and Upper Pleistocene *Panthera spelaea spelaea* Goldfuss, 1810 from the Biśnik Cave. *Neues Jahrbuch für Geologie und Paläontologie Abhandlungen* **258**(3), 339–351.

Mazza PPA, Stefaniak K, Capalbo Ch, Cyrek K, Czyżewski Ł, Kotowski A, Orłowska J, Marciszak A, Ratajczak-Skrzatek U, Savorelli A and Sudoł-Procyk M (2021) Taphonomic analysis of the MIS 4–3 (Late Pleistocene) faunal assemblage of Biśnik Cave, Southern Poland: Signs of a human-generated depot of naturally shed cervid antlers? *Quaternary International* **633**, 52–79.

Mirosław-Grabowska J (1998) Quaternary stratigraphy in the eastern part of Smoleń-Niegowonice Range (Kraków-Częstochowa Upland). *Studia Geologica Polonica* **113**, 105–119.

Mirosław-Grabowska J (2002a) Geological value of Biśnik Cave sediments (Cracow-Częstochowa Upland). *Acta Geologica Polonica* **52**(1), 97–110.

Mirosław-Grabowska J (2002b) Lithology and stratigraphy of sediments from Biśnik Cave. In Cyrek K (ed), *Jaskinia Biśnik: Rekonstrukcja zasiedlenia jaskini na tle zmian środowiska przyrodniczego*, pp. 143–179. Toruń: Wydawnictwo Uniwersytetu Mikołaja Kopernika.

Musil R (2014) The unique record of Za Hájovnou Cave. *Sborník Národního Muzea Řada B Přírodní Vědy* **70**(1–2), 7–26.

Piskorska T and Stefaniak K (2014) Middle Palaeolithic remains of reindeer (*Rangifer tarandus* Linnaeus, 1758) from Biśnik Cave and other cave localities from Poland. *Quaternary International* **326–327**, 82–90.

Piskorska T, Stefaniak K, Krajcarz M and Krajcarz MT (2015) Reindeer during the Upper Palaeolithic in Poland: Aspects of variability and paleoecology. *Quaternary International* **359–360**, 157–177.

Piotrowska N and Goslar T (2002) Preparation of bone samples in the Gliwice radiocarbon laboratory for AMS radiocarbon dating. *Isotopes in Environmental and Health Studies* **38**, 1–9.

Reimer PJ, Austin WEN, Bard E, Bayliss A, Blackwell PG, Bronk Ramsey C, Butzin M, Cheng H, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Hajdas I, Heaton TJ, Hogg AG, Hughen KA, Kromer B, Manning SW, Muscheler R, Palmer JG, Pearson C, van der Plicht J, Reimer RW, Scott EM, Southon JR, Turney CSM, Wacker L, Adolphi F, Büntgen U, Capano M, Fahrni S, Fogtmann-Schulz A, Friedrich R, Köhler P, Kudsk S, Miyake F, Olsen J, Reining F, Sakamoto M, Sookdeo A and

https://doi.org/10.1017/RDC.2026.10243 Published online by Cambridge University Press

Talamo S (2020) The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* **62**(4), 725–757.

Rzebik-Kowalska B (2009) *Biodiversity of Polish Fossil Insectivores (Erinaceomorpha, Soricomorpha, Insectivora, Mammalia) Compared to the European and Global Faunas*. Kraków: Institute of Systematics and Evolution of Animals, Polish Academy of Sciences.

Socha P (2009) Small mammals (Erinaceomorpha, Soricomorpha, Chiroptera, Lagomorpha, Rodentia) from Pleistocene deposits of the Biśnik Cave. *Studies of the Faculty of Earth Sciences, University of Silesia* **56**, 215–224.

Socha P (2014) Rodent palaeofaunas from Biśnik Cave (Kraków-Częstochowa Upland, Poland): Palaeoecological, palaeoclimatic and biostratigraphic reconstruction. *Quaternary International* **326–327**, 64–81.

Stefaniak K (2015) *Neogene and Quaternary Cervidae from Poland*. Kraków: Institute of Systematics and Evolution of Animals, Polish Academy of Sciences.

Stefaniak K and Marciszak A (2009) Large mammals (Carnivora, Ungulata) from Pleistocene sediments of the Biśnik Cave. *Studies of the Faculty of Earth Sciences* **56**, 225–254.

Stefaniak K, Ratajczak U, Kotowski A, Kozłowska M and Mackiewicz P (2020) Polish Pliocene and Quaternary deer and their biochronological implications. *Quaternary International* **546**, 64–83.

Talamo S and Richards M (2011) A comparison of bone pre-treatment methods for AMS dating of samples >30,000 BP. *Radiocarbon* **53**, 443–449.

Tomek T, Bocheński ZM, Socha P and Stefaniak K (2012) Continuous 300,000-year fossil record: Changes in the ornithofauna of Biśnik Cave, Poland. *Palaeontologia Electronica* **15** (1, 2A), 1–20.

van Klinken GJ (1999) Bone collagen quality indicators for palaeodietary and radiocarbon measurements. *Journal of Archaeological Science* **26**, 687–695.

Wagner J (2014) Metric characteristics of ursid cheek teeth from Za Hájovnou Cave (Javoříčko Karst, the Czech Republic) and its taxonomical implication. *Sborník Národního Muzea Řada B Přírodní Vědy* **10**(1–2), 71–90.

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