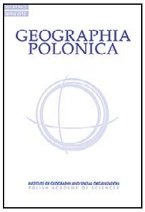


Geographia Polonica
2024, Volume 97, Issue 3, pp. 295-325
https://doi.org/10.7163/GPol.0281

INSTITUTE OF GEOGRAPHY AND SPATIAL ORGANIZATION
POLISH ACADEMY OF SCIENCES
www.igipz.pan.pl

www.geographiapolonica.pl

LATE MIDDLE PALAEOLITHIC AND EARLY UPPER PALAEOLITHIC IN POLAND IN THE LIGHT OF NEW NUMERICAL DATING

Andrzej Wiśniewski[1] • Dariusz Bobak[2] • Marta Połtowicz-Bobak[2] • Piotr Moska[3]

[1] Institute of Archaeology
University of Wrocław
Szewska 48, 50-139 Wrocław: Poland
e-mail: andrzej.wisniewski@uwr.edu.pl (corresponding author)

[2] Institute of Archaeology
University of Rzeszów
Hoffmanowej 8, 35-016 Rzeszów: Poland

[3] Institute of Physics
Silesian University of Technology
Konarskiego 22B, 44-100 Gliwice: Poland

Abstract

Although the first numerical dating of Middle and Upper Palaeolithic sites in Poland was applied at the beginning of the second half of the 20th century, it has only been in the last two decades that a data increase has been recorded, making it possible to discuss both the development of human behaviour and cultural phenomena in time perspective. This paper aims to show the chronological diversity of sites dating from the beginning of the Weichselian glaciation (MIS 5a – MIS 5d, GI-19 – GI-23, Greenland Interstadials) to the middle part of MIS 3 (GI-8 – GI-10). We considered sites dated mainly by thermoluminescence dating (OSL) and radiocarbon dating. We relied on a series of recent datings. We attempted to analyse the stratigraphic integrity, the archaeological finds and the numerical dating results. Through OSL dating, we could establish the chronology of Micoquian sites, previously regarded as middle Pleistocene, to the last glaciation. The dating compilation also shows that the Late Middle Palaeolithic and Early Upper Palaeolithic (EUP) sites are unlikely to overlap, or if they do, it is only over a small period. Unfortunately, this period is poorly interpreted because it spans the limit of the radiocarbon dating reliability and goes beyond the bounds of the calibration curve. Confronting the datings of the Lincombian-Ranisian-Jerzmanowician (LRJ) complex and the oldest finds associated with Aurigniacian sites in Poland lead to the conclusion that these sites may have co-occurred for some time.

Key words

Middle Palaeolithic • Early Upper Palaeolithic • optoluminescence • radiocarbon dating • Poland

Introduction

From the onset of the last glaciation up to the middle of the interpleniglacial (MIS 3, ca. 40 ka cal BP), Poland was colonised by various groups of archaic humans, including Neanderthals and multiple waves of Anatomically Modern Humans (AMH). Such a situation is implied by genetic analyses of evidence from Poland and other parts of Central Europe (Hublin et al., 2020; Picin et al., 2020; Hajdinjak et al., 2021; Mylopotamitaki et al. 2024). This period is marked by various colder and warmer sub-stages, unfavourable for the development and survival of human populations (Roebroeks et al., 2011; Maier & Zimmermann, 2017). In stylistic terms, the differentiation of material cultures seems to have intensified, particularly at times of greater dispersal of those communities (Wiśniewski, 2016; Kozłowski, 2014; Jöris et al., 2022; Picin et al., 2023). In the second half of this period, there may have been a clash between the different traditions, inspiring independently evolving trends or entering into mysterious, now obscure interactions. This differentiation was related not only to the demographic condition of the individual groups of the last Neanderthals or AMH or their cultural patterns, but also likely to be connected with the use of different environmental resources and their exploitation in various conditions (Banks et al., 2008; Gilpin et al., 2016; Timmermann et al., 2022). A deeper understanding of all these variables in the life of contemporary people requires large quantities of data, including chronological data.

In the decade under review, there was a significant inflow of numerical datings from Poland, most made with traditional methods such as Accelerator Mass Spectrometry ^{14}C dating (AMS) or optimal luminescence (OSL). Other, less common techniques, such as OSL-postIRIR or AMS with pretreatment samples of organic carbon or bone samples, were also used. The discussion about the structure of the chronological data, initiated by Dean (1978), has also become more important in recent years. It still seems crucial to separate the behavioural or cultural events whose age we as archaeologists wish to know (target events) from the events that allow us to date these and other phenomena (dated events) (Dincauze, 2000).

We believe that the growth of numerical data and a better understanding of its potential and limitations brings us closer to resolving some essential questions that have hitherto been beyond the capabilities of Palaeolithic archaeology. Indeed, there are many benefits to establishing datings independent of the archaeologists' opinions. Firstly, they are beneficial in studies on the continuity of specific patterns and analyses of particular change directions over time. Those fields are, in turn, linked with palaeodemographic issues. Secondly, independent datings are useful in geoarchaeological analyses focused on reconstructing site formation (or parts thereof). Here, datings are practical indicators of stratigraphy modifications, i.e., the state of preservation of the remains.

This paper aims to show the chronological variations of the cave and open-air sites dated to a period from the onset of the Weichselian, GI-19 – GI-23 (Greenland Interstadials, MIS 5a – MIS 5d) up to the GI-8 – GI-10 (middle part of MIS 3, in light of the new numerical datings; Fig. 1). We would like to draw attention to the implication of using a more accurate chronological assessment of the remains and some of the problems arising from attempts to average or treat en masse dates with a significant degree of discrepancy. We also point to the difficulties in associating datings made by various OSL and ^{14}C methods with cultural units traditionally defined by stylistic-technological features of lithic assemblages. One of the main inspirations behind this endeavour is that ten years have passed since the publication of one of the first Polish papers presenting a broader overview of numerical datings for this period of human settlement in Poland (Bobak et al., 2013). We examine new datings of sites typical of the Middle Palaeolithic, of industries identified with the Early Upper Palaeolithic, up to the oldest signs of the Aurignacian. Additionally, we re-examined the issue

Figure 1. Location of the Middle Palaeolithic and Early Upper Palaeolithic sites discussed in the text

of differences in dating generated by using different sample preparation methods or the inclusion of other techniques. Generally, the new dating results collected here mainly attempt to clarify the chronological position or confirm previous findings, but in some cases, the data require a complete modification of the existing system.

Methods

In our work, we relied on the datings made using thermoluminescence and AMS (Fig. 2, 3). For obvious reasons, the OSL method has played and continues to play a critical role in dating relics relating to the middle phase of MIS 3, while the radiocarbon method for younger remains (Jöris & Street, 2008). Individual sites have obtained dating by both methods.

Comprehensive luminescence studies resulted in a few dozen independent outcomes from two luminescence laboratories. The research was conducted using two distinct techniques: the standard OSL method (Murray & Wintle, 2000) employing quartz grains and a method utilising feldspar grains and the pIRIR225 protocol (Thomsen et al., 2008; Buylaert et al., 2009).

The feldspar scaling studies (4 samples) were carried out in the OSL laboratory at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, while the remaining luminescence measurements were conducted in the Gliwice Luminescence Dating Laboratory (Moska et al., 2021). Both laboratories utilised the same measurement equipment to determine key luminescent parameters, such as the annual and equivalent doses. High-resolution gamma spectrometry with an HPGe detector manufactured by Canberra was employed for dose rate determination, assessing the samples' U, Th, and K content. An a-value of 0.11±0.02 was used for feldspar measurements (Kreutzer et al., 2014), and the internal potassium content

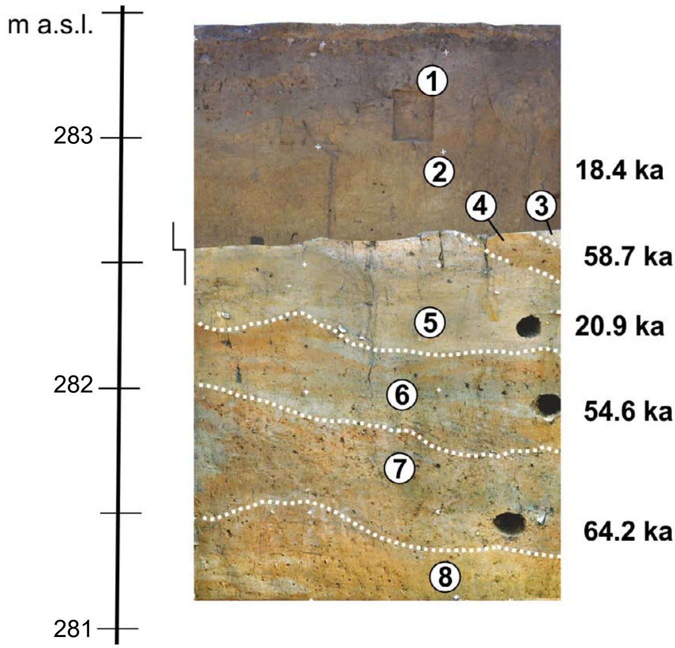


Figure 2. Dzierżysław 1. A fragment of the southern section with OSL sampling (photogrammetric model). Based on dating, layer 4 is thought to represent an older intrusion than the lower layer 5

was estimated to be 12±0.5%. Dose rate conversion factors following Guérin et al. (2011) were applied, and the cosmic dose rate was calculated based on longitude/altitude, height above sea level, and thickness of the covering sediment layer (Prescott & Hutton, 1994). For all other samples, dose rates were computed using an online dose rate calculator (Tudyka et al., 2023), which incorporates the latest conversion factors.

Risø TL/OSL DA-20 luminescence readers equipped with a 90Sr/90Y beta source were used to determine equivalent doses for the analysed study material. Standard blue stimulation diodes were employed for OSL measurements, while only IR diodes were used for the pIRIR225 protocol. The final equivalent dose (De) values for all samples were calculated using the Central or Minimum Age Model (CAM, MAM; Galbraith et al., 1999) through the R package 'Luminescence' (Kreutzer et al., 2020). The resulting age distributions are illustrated in Figure 4, showing relative probability density functions (Berger, 2010). The overdispersion parameter was calculated for all samples and was a fundamental criterion determining the suitability of a specific statistical model. It is crucial as only some samples exhibited unimodal equivalent dose distributions, allowing the use of the CAM model; therefore, only such samples can be considered to belong to well-bleached quartz (Moska et al., 2019). All necessary information about the luminescence dating is presented in Table 1.

Due to the range of this method (ca. 50 ka BP) and the availability of samples, ^{14}C dating was possible only for some of the analysed sites. These were caves Stajnia, Nietoperzowa, Koziarnia, Ciemna, and Obłazowa and an open-air site of Lubotyń, site 11. The dated samples were bones, charcoal and wood. Depending on the sample type and laboratory, different – yet published and standardised – material extraction methods for measuring isotope ^{14}C were used. In all examined cases, the presence of ^{14}C was measured with AMS (Bobak et al., 2016; Alex et al., 2017; Krajcarz

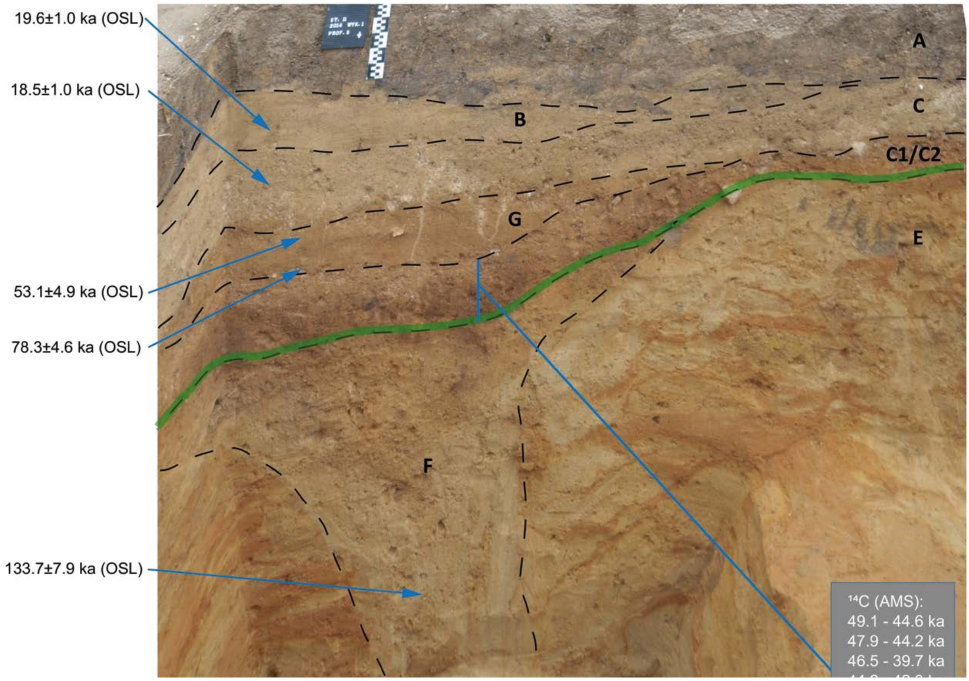


Figure 3. Lubotyń 11. A fragment of the eastern section with OSL and radiocarbon dates. Green line marks the living floor of the palaeolithic settlement

et al., 2018; Picin et al., 2020; Kot et al., 2021; Talamo et al., 2021). The samples were analysed in the laboratories in Poznań (Poz), Mannheim (MAMS), Oxford (OxA), Gliwice (GdA), and the Israeli Rehevot (RTD).

The procedure of preparing samples for dating depends on the main macromolecular component; for samples with organic carbon, the first step is the ABA (acid-base-acid) procedure, occasionally termed AAA (acid-alkali-acid), the sample bathed in a cycle of hot HCl – NaOH – HCl solutions to remove impurities. Here, we must mention the ABOx-Sc – an acid-based-oxidation-stepped combustion method invented by Bird et al. (1999) and still developed at the Oxford laboratory, which allows for a more thorough sample clean-up, which is essential for samples older than 25,000 years, where even a small proportion of younger contaminants can result in a noticeable “re-ageing” (Brock et al., 2010). Samples prepared using this procedure produce statistically older results than those prepared using the ABA method (cf. Blockley et al., 2008; Wood et al., 2012; Haesaerts et al., 2013).

For bone samples, the next stage is collagen extraction. The main challenge is obtaining a sufficiently large quantity of collagen and verifying its purity, typically by measuring parameters such as the ratio of collagen quantity to sample size, carbon and nitrogen content, and the mutual ratios of those two elements. The traditional extraction variant, described by Longin (1971), is still used, even though most laboratories have markedly improved upon it using techniques such as either HPLC (Van Klinken et al., 1994) or various variants involving ultrafiltration (Brown et al., 1988) of molecules with mass exceeding 30 kD from fractions with lower particle mass (Bronk Ramsey et al., 2004; Brock et al., 2010; Talamo & Richards, 2011). Such techniques produce larger quantities of higher-purity collagen, which is essential for samples from Pleistocene sites. Further sample preparation

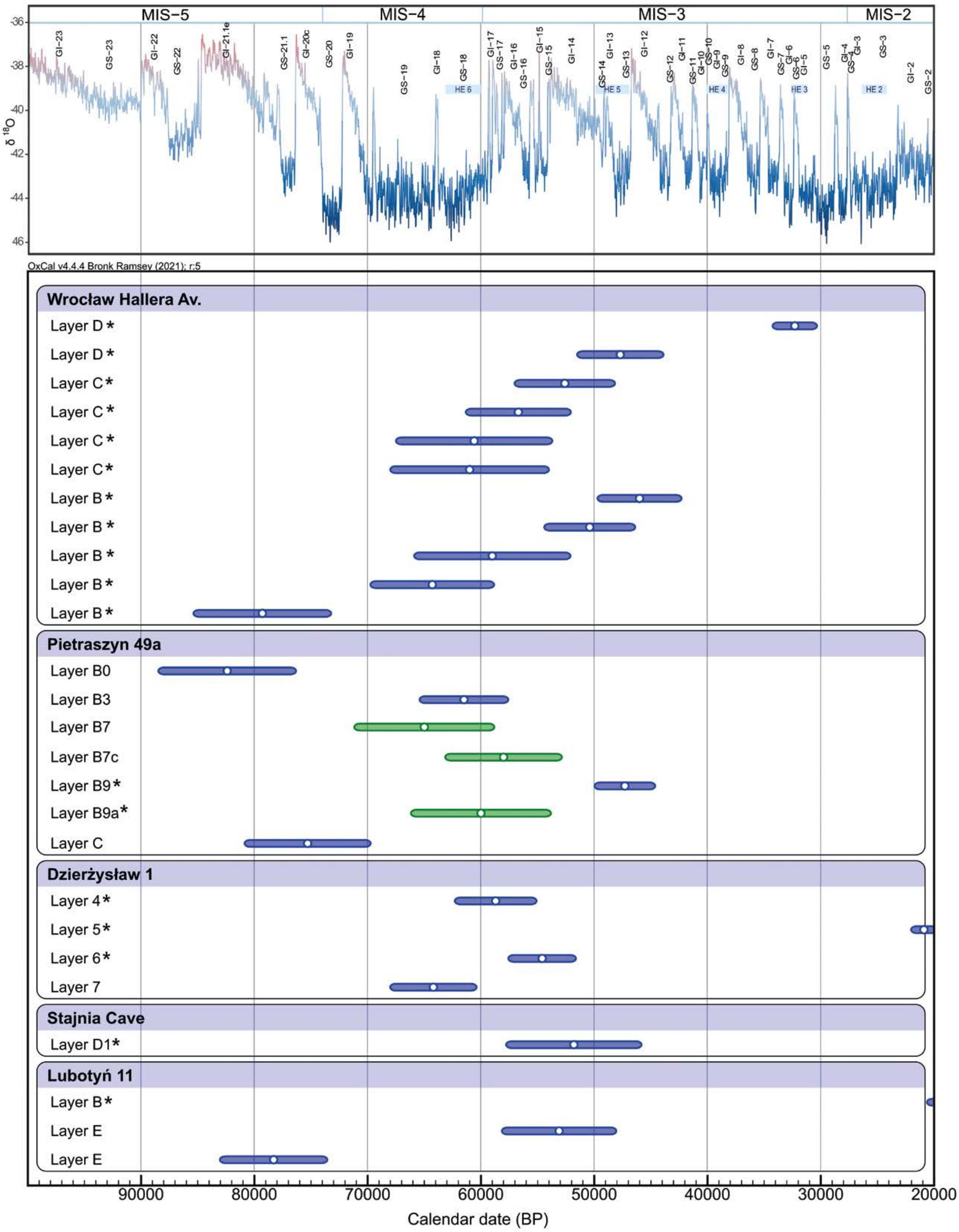


Figure 4. OSL age ranges, presented with NGRIP d18O data as a reference. Blue – OSL quartz, green – pIRIR. An asterisk indicates the place where the artefacts occurred

Table 1. OSL dates from selected sites. An asterisk in the layer column indicates the place where the artefacts occurred

Site	Lab code	Sample ID	Layer	Dose rate [Gy ka^{-1}]	Equivalent dose [Gy]	Model	OSL age [ka]	Method
Hallera AV., Wrocław	Wrocław9_2006	GdTL-860	D*	2.36±0.15	112.7±5.2	CAM	47.7±3.7	OSL quartz
	Wrocław11_2006	GdTL-861	D*	2.02±0.10	65.0±2.0	CAM	32.3±1.9	OSL quartz
	H16_4	GdTL-2650	C*	1.80±0.10	94.8±5.7	CAM	52.6±4.3	OSL quartz
	H16_2	GdTL-2648	C*	1.01±0.07	57.6±2.3	CAM	56.7±4.5	OSL quartz
	Wrocław8_2006	GdTL-859	C*	1.08±0.07	65.6±6.0	MAM	61.0±6.8	OSL quartz
	Wrocław4_2006	GdTL-855	C*	1.19±0.07	72.2±6.8	MAM	60.6±6.7	OSL quartz
	Wrocław12_2006	GdTL-862	B*	1.34±0.08	79.2±7.6	MAM	59.0±6.7	OSL quartz
	Wrocław7_2006	GdTL-858	B*	1.10±0.07	86.8±3.4	CAM	79.3±5.9	OSL quartz
	Wrocław6_2006	GdTL-857	B*	1.38±0.08	69.5±3.5	CAM	50.4±3.9	OSL quartz
	Wrocław5_2006	GdTL-856	B*	1.52±0.10	69.8±3.0	CAM	46.0±3.6	OSL quartz
	Wrocław3_2006	GdTL-854	B*	1.23±0.70	79.1±4.7	CAM	64.3±5.3	OSL quartz
	H16_3	GdTL-2649	A	0.77±0.05	193.0±21.0	MAM	250.3±31.7	OSL quartz
Pietraszyn49a		L-Eva 1535	B7	1.97±0.15	127.0±8.0	CAM	64.0±6.0	$pIRIR_{225}$
		L-Eva 1534	B7c	2.28±0.16	131.0±11.0	CAM	58.0±5.0	$pIRIR_{225}$
		L-Eva 1533	B9a*	2.44±0.16	147.0±11.0	CAM	60.0±6.0	$pIRIR_{225}$
		L-Eva 1536	D	2.04±0.15	212.0±24.0	MAM	145.0±14.0	$pIRIR_{225}$
	Pietraszyn49_1	GdTL-3183	B0	1.16±0.07	95.4±3.5	CAM	82.4±5.9	OSL quartz
	Pietraszyn49_2	GdTL-3184	B3	1.63±0.09	100.4±2.5	CAM	61.5±3.8	OSL quartz
	Pietraszyn49_3	GdTL-3185	B9*	2.27±0.11	107.2±2.5	CAM	47.3±2.6	OSL quartz
	Pietraszyn49_4	GdTL-3186	C	1.24±0.08	93.2±2.5	CAM	75.3±5.4	OSL quartz
	Pietraszyn49_5	GdTL-3187	D	0.94±0.06	174.6±13.0	MAM	186.7±18.2	OSL quartz
Dzierżysław1	Dzierżysław1	GdTL-3435	2	3.28±0.16	60.6±1.2	CAM	18.4±1.0	OSL quartz
	Dzierżysław2	GdTL-3436	4*	2.70±0.13	158.8±5.9	CAM	58.7±3.5	OSL quartz
	Dzierżysław3	GdTL-3437	5*	3.28±0.15	68.7±1.6	CAM	20.9±1.1	OSL quartz
	Dzierżysław4	GdTL-3438	6*	2.91±0.14	159.0±4.2	CAM	54.6±2.9	OSL quartz
	Dzierżysław5	GdTL-3439	7	2.56±0.12	166.3±5.4	CAM	64.2±3.7	OSL quartz
Stajnia Cave	Jask_ST_01	GdTL-1126	B*	2.39±0.10	24.2±2.0	MAM	10.1±0.9	OSL quartz
	Jask_ST_02	GdTL-1127	D1*	2.76±0.10	143.2±15.5	MAM	51.8±5.8	OSL quartz
Lubotyń 11	Lu_1 (PR-280)	GdTL-2325	B*	2.40±0.08	46.8±1.7	CAM	19.6±1.0	OSL quartz
	Lu_2 (PR-281)	GdTL-2326	C1*	2.48±0.09	45.8±1.3	CAM	18.5±1.0	OSL quartz
	Lu_3 (PR-282)	GdTL-2327	G	1.56±0.06	82.6±7.2	MAM	53.1±4.9	OSL quartz
	Lu_4 (PR-283)	GdTL-2328	G	1.42±0.05	111.9±4.6	CAM	78.3±4.6	OSL quartz
	Lu_5 (PR-284)	GdTL-2329	F	1.33±0.05	176.9±8.1	CAM	133.7±7.9	OSL quartz

steps aim to convert their carbon content into gaseous CO^2, which is then reduced to solid carbon in graphite. The material thus obtained is ready to measure its individual carbon isotope content in the accelerator.

The here analysed measurement results ("non-calibrated dates") (Tab. 2, Fig. 5) were calibrated versus the calibration curve IntCal 20 (Reimer et al., 2020) using OxCal software 4.4 (Bronk Ramsey, 2009). Unless otherwise stated, all dates in this study are calendar years before 1950, given in thousands of years (ka calBP). Calibration results are presented with a confidence of 2 sigma (95.4%).

Table 2. ^{14}C dates from selected sites. An asterisk in the layer column indicates the place where the artefacts occurred

Site	Stratigraphic position	Lab no.	^{14}C measurement	Std. dev.	Calendar age (at 95,4%)		Material	Sample treatment
					from	to		
Stajnia Cave	Level B	Poz-28891	13,500	50	16,470	16,080	Bone	no ultrafiltration
	Level C18	ETH-110248.1.1	>50,000				Bone	ultrafiltration
	Level C18	Poz-61719	20,930	140	25,680	24,910	Bone	no ultrafiltration
	Level C18	GdA-3894	21,900	90	26,370	25,930	Bone	no ultrafiltration
	Level C18	MAMS-19870	40,400	420	5600	3480	Bone	ultrafiltration
	Level C19	MAMS-19849	33,450	350	39,290	37,180	Bone	ultrafiltration
	Level C19	MAMS-19851	36,080	460	41,970	40,370	Bone	ultrafiltration
	Level C19	MAMS-19864	37,750	310	42,440	41,900	Bone	ultrafiltration
	Level D1*	ETH-99043.1.1	36,563	229	41,930	41,160	Bone (pendant)	ultrafiltration
	Level D1*	MAMS-35153	36,600	300	42,010	41,110	Bone (pendant)	ultrafiltration
	Level D1*	ETH-99042.1.1	37,903	267	42,460	42,000	Bone (awl)	ultrafiltration
	Level D1*	MAMS-35152	37,360	330	42,330	41,540	Bone (awl)	ultrafiltration
	Level D1*	MAMS-19879	44,590	690	48,470	45,630	Bone	ultrafiltration
	Level D1*	OxA-24944	44,600	2100	54,890	44,420	Bone	no ultrafiltration
	Level D1*	MAMS-19857	45,020	1380	51,960	45,020	Bone	ultrafiltration
	Level D1*	MAMS-19853	45,300	1410	52,370	45,100	Bone	ultrafiltration
	Level D1*	MAMS-19850	>49,000				Bone	ultrafiltration
	Level D1*	ETH-110246.1.1	>50,000				Bone	ultrafiltration
	Level D1*	Poz-28892	>50,000				Bone	no ultrafiltration
	Level D1*	MAMS-19852	>49,000				Bone	ultrafiltration
	Level D1*	MAMS-19863	>49,000				Bone	ultrafiltration
	Level D2*	ETH-110247.1.1	>49,000				Bone	ultrafiltration
	Level D2*	MAMS-19878	>49,000				Bone	ultrafiltration

Site	Stratigraphic position	Lab no.	^{14}C measurement	Std. dev.	Calendar age (at 95,4%)		Material	Sample treatment
					from	to		
	Level D2*	MAMS-19858	>49,000				Bone	ultrafiltration
	Level D3	MAMS-19871	>49,000				Bone	ultrafiltration
	Level D3	MAMS-19869	>49,000				Bone	ultrafiltration
	Level E*	MAMS-19856	>49,000				Bone	ultrafiltration
Ciemna Cave	Level III*	RTD-7386	55,300	5000	...	50,450	Bone	ultrafiltration
	Level III*	RTD-7494	>56,000				Bone	ultrafiltration
	Level III (sector CK)	Poz-23663	42,000	1000	46,752	43,101	Bone	no ultrafiltration
	Level IV*	RTD-7387	46,300	1400	54,830	46,060	Charcoal	no info
	Level IV*	RTD-7353	42,600	400	45,860	44,580	Bone	ultrafiltration
	Level IV*	OS-84006	38,600	290	42,751	42,251	Bone	no ultrafiltration
	Level V*	RTD-7388	>50,600				Bone	ultrafiltration
	Level V*	OS-84009	35,300	290	41,045	39,810	Bone	no ultrafiltration
	Level VIII*	RTD-7375-aA	42,633	1000	47,750	43,860	Charcoal	no info
	Layer 11 (sector CO)	Poz-25261	37,800	700	42,834	41,344	Bone	no ultrafiltration
	Layer 11 (sector CO)	Poz-27268	41,500	1000	46,126	42,870	Bone (burnt)	no ultrafiltration
Obłazowa Cave	Layer XI*	Poz-1135	36,400	700	42,280	40,260	Bone (bird)	no ultrafiltration
	Layer XV*	RTD-7396	44,700	1100	50,040	45,060	Bone	ultrafiltration
	Layer XVII*	RTD-7492	52,600	3300	...	50,130	Bone	ultrafiltration
	Layer XVII*	RTD-7400	43,900	1000	48,570	44,690	Bone	ultrafiltration
	Layer XVIIIb*	RTD-7355	39,400	300	43,140	42,490	Charcoal	no info
	Layer XVIIIb*	RTD-7397	42,600	900	47,350	43,970	Bone	ultrafiltration
	Layer XIX*	RTD-7493	47,600	1600	...	47,870	Bone	ultrafiltration

Site	Stratigraphic position	Lab no.	^{14}C measurement	Std. dev.	Calendar age (at 95,4%)		Material	Sample treatment
					from	to		
	Layer XIX*	RTD-7399	>50500				Bone (with cut-marks)	ultrafiltration
Lubotyń 11	Layer C2*	Poz-25209	44,000	3000	...	43,410	Charcoal (fire-place)	ABA
	Layer C2*	Poz-36903	43,000	1000	47,900	44,230	Charcoal (fire-place)	ABA
	Layer C2*	Poz-25208	35,100	800	41,900	38,580	Charcoal (fire-place)	ABA
	Layer C2*	Poz-36905	44,000	1100	49,070	44,600	Charcoal	ABA
	Layer C2*	Poz-36904	39,500	700	44,200	42,340	Charcoal	ABA
	Layer C2*	Poz-25207	38,100	1800	46,550	39,730	Charcoal	ABA
	Layer C2*	OxA-33315	>44,700				Charcoal	ABA
	Layer C2*	OxA-33316	>47,500				Charcoal (fire-place)	ABA
	Layer C2*	OxA-33073	>54,100				Charcoal (fire-place)	ABOX
Nietoperzowa Cave	Layer 1	Poz-56637	36,370	450	42,040	40,690	Tooth	ultrafiltration
	Layer 1	Poz-67106	42,000	1500	48,540	42,710	Tooth	ultrafiltration
	Layer 3	Poz-62582	26,800	300	31,470	30,310	Bone	no ultrafiltration
	Layer 3	Poz-56633	35,600	500	41,630	39,720	Tooth	ultrafiltration
	Layer 5*	Poz-67079	12,480	160	15,220	14,090	Tooth	ultrafiltration
	Layer 5b	Poz-63860	26,190	250	30,980	30,040	Bone	no ultrafiltration
	Layer 5*	Poz-62267	28,350	290	33,420	31,690	Tooth	ultrafiltration
	Layer 5*	Poz-56744	28,840	190	33,940	32,270	Bone	ultrafiltration
	Layer 5*	Poz-62581	29,800	300	35,030	33,660	Bone	no ultrafiltration
	Layer 5*	Poz-62270	35,400	700	41,800	39,340	Tooth	ultrafiltration

Site	Stratigraphic position	Lab no.	^{14}C measurement	Std. dev.	Calendar age (at 95,4%)		Material	Sample treatment
					from	to		
	Layer 5*	Poz-62269	37,100	900	42,770	40,550	Tooth	ultrafiltration
	Layer 5*	Poz-56634	39,400	700	44,160	42,300	Tooth	ultrafiltration
	Layer 5*	Poz-67109	40,500	1100	45,520	42,430	Tooth	ultrafiltration
	Layer 6*	Poz-56635	23,970	240	28,700	27,730	Bone	ultrafiltration
	Layer 6*	Poz-67244	24,540	190	29,190	28,320	Bone	ultrafiltration
	Layer 6*	Poz-63861	29,970	350	35,240	33,840	Bone	no ultrafiltration
	Layer 6*	Poz-62275	32,300	500	38,440	35,560	Tooth	ultrafiltration
	Layer 6*	Poz-62276	33,100	500	39,250	36,510	Tooth	ultrafiltration
	Layer 6*	Poz-56640	33,950	350	39,790	37,670	Tooth	ultrafiltration
	Layer 6*	Poz-62274	36,000	700	42,090	39,850	Tooth	ultrafiltration
	Layer 6*	Poz-67113	37,900	800	43,060	41,230	Tooth	ultrafiltration
	Layer 6*	Poz-62271	38,300	900	43,890	41,400	Tooth	ultrafiltration
	Layer 6*	Poz-67112	38,200	900	43,870	41,310	Tooth	ultrafiltration
	Layer 6*	Poz-67111	39,300	1000	44,540	42,080	Tooth	ultrafiltration
	Layer 6*	Poz-62273	40,300	1100	45,380	42,370	Tooth	ultrafiltration
	Layer 7	Poz-56631	23,900	200	28,600	27,720	Tooth	ultrafiltration
	Layer 7	Poz-67245	25,890	220	30,820	29,820	Tooth	ultrafiltration
	Layer 7	Poz-63862	31,500	500	36,940	34,790	Bone	no ultrafiltration
	Layer 7	Poz-56639	32,550	600	39,130	35,900	Bone	ultrafiltration
	Layer 7	Poz-67170	32,700	550	39,090	36,150	Tooth	ultrafiltration
	Layer 7	Poz-67107	33,650	500	39,750	37,070	Tooth	ultrafiltration
	Layer 7	Poz-67115	34,200	600	40,690	37,520	Tooth	ultrafiltration
	Layer 7	Poz-62278	37,000	800	42,570	40,650	Tooth	ultrafiltration
	Layer 7	Poz-62277	38,500	900	44,080	41,620	Tooth	ultrafiltration

Site	Stratigraphic position	Lab no.	^{14}C measurement	Std. dev.	Calendar age (at 95,4%)		Material	Sample treatment
					from	to		
	Layer 7	Poz-67110	38,500	900	44,080	41,620	Tooth	ultrafiltration
	Layer 7	Poz-62279	38,500	900	44,080	41,620	Tooth	ultrafiltration
	Layer 8	Poz-56638	39,700	700	44,290	42,410	Tooth	ultrafiltration
	Layer 8	Poz-56630	42,000	1000	46,760	43,100	Tooth	ultrafiltration
	Layer 8	Poz-67108	>45,000				Tooth	ultrafiltration
	Layer 8/9	Poz-67105	28,540	280	33,680	31,890	Tooth	ultrafiltration
	Layer 8/9	Poz-67103	30,800	500	36,190	34,380	Tooth	ultrafiltration
	Layer 8/9	Poz-56632	41,000	1000	45,710	42,700	Tooth	ultrafiltration
Koziarnia Cave	Unknown	OxA-39509	22,020	150	26,820	25,920	Bone tool	ultrafiltration
	Unknown	OxA-39539	20,870	210	25,710	24,590	Bone tool	ultrafiltration
	Unknown	Poz-82394	39,200	1100	44,720	41,920	Bone	ultrafiltration
	Layer 3-5*	Poz-119319	25,440	210	30,070	29,220	Bone	ultrafiltration
	Layer 9-11*	Poz-119320	27,340	260	31,800	31,060	Bone	ultrafiltration
	Layer 10?*	GdA-3898	32,440	240	37,370	36,240	Tooth	ultrafiltration
	Layer 12	Poz-98895	28,090	360	33,240	31,280	Charcoal	no info
	Layer 13*	Poz-98898	30,330	500	35,920	33,960	Charcoal	no info
	Layer 15	Poz-99773	37,650	900	43,120	40,930	Tooth	ultrafiltration
	Layer 15	Poz-99816	39,000	1000	44,450	41,930	Tooth	ultrafiltration
	Layer 16b*	Poz-110657	33,100	1200	40,850	35,460	Charcoal	no info
	Layer 16b*	Poz-98896	29,430	720	35,360	31,970	Charcoal	no info
	Layer 17*	Poz-98901	33,230	480	39,340	36,700	Charcoal	no info
	Layer 17*	Poz-99815	40,100	1100	45,230	42,300	Tooth	ultrafiltration
	Layer 17*	Poz-116687	40,600	1200	45,890	42,410	Tooth	ultrafiltration
	Layer 19-20*	GdA-3897	24,190	120	28,710	27,950	Bone	ultrafiltration

Results – sites and their dating

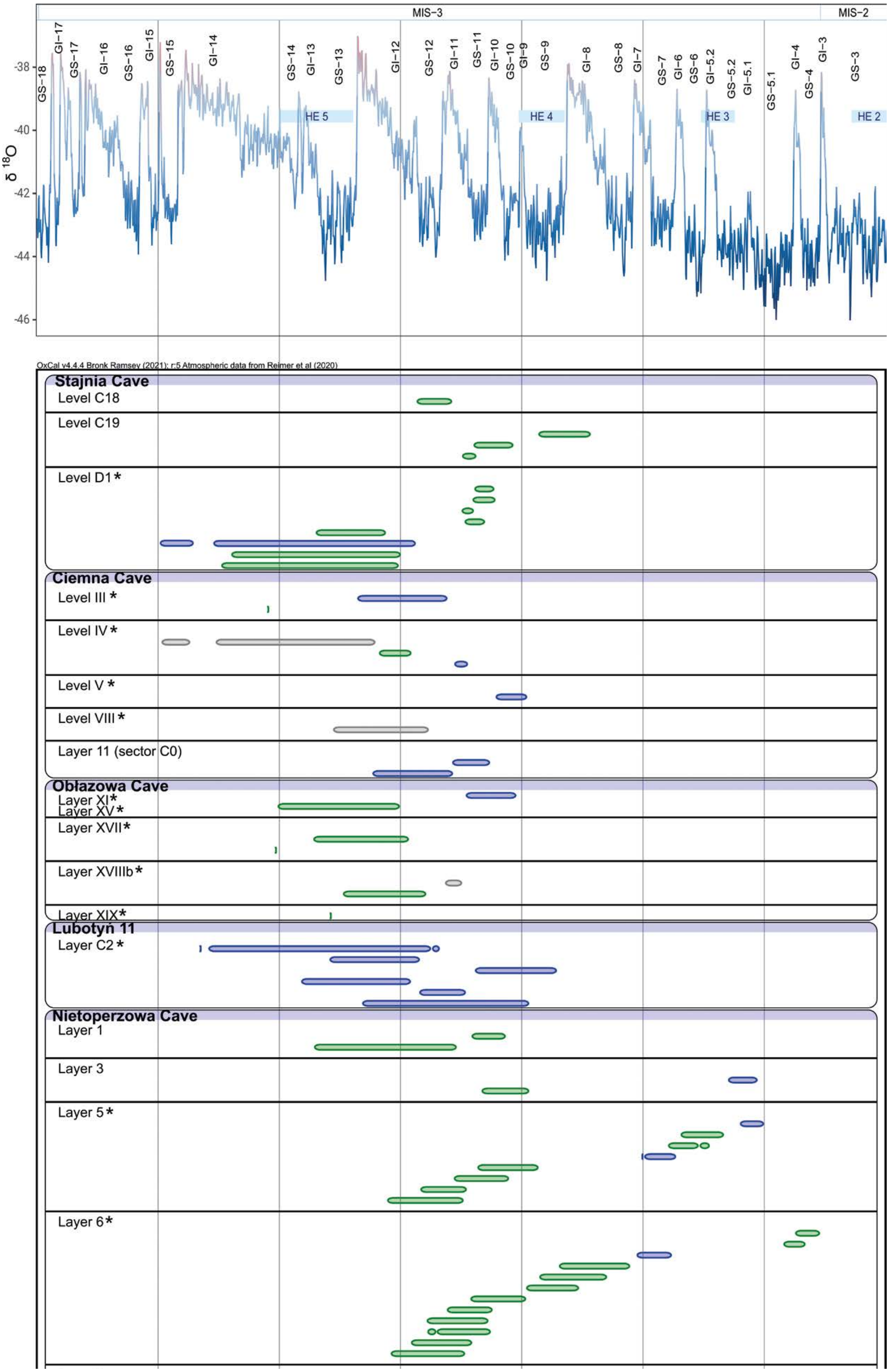
Most examined sites belong to the Middle Palaeolithic, customarily viewed as a period of Neanderthal domination (Hublin, 2009). Isolated sites represent the Szeletian or the Lincombian-Ranisian-Jerzmanowician complex (LRJ), or assemblages of the older phase of Aurignacian.

Wrocław, Hallera Av., site no. 1

The first examined site – Wrocław, Hallera Av., is located within the ice-marginal valley of the Oder River. It was intensively investigated in the 1990s and first two decades of the 21st century, revealing remains of at least two occupation levels associated with Middle Palaeolithic industries (Wiśniewski et al., 2013). Besides lithic artefacts, it yielded many animal bone remains, particularly from its lower level (layer B). The bones belonged to such fauna as the Woolly mammoth (*Mammuthus primigenius*), Woolly rhinoceros (*Coelodonta antiquitatis*) and Merck's rhinoceros (*Stephanorinus kirchbergensis*), Steppe bison (*Bison priscus*), European moose (*Alces alces*), horse (*Equus ferus*), and reindeer (*Rangifer tarandus*). Steppe bison bones prevailed in the lower level (MNI-8) (Wiśniewski et al., 2023). The lower horizon was deposited in alluvial sediments of varying fractions (B), while the upper horizon was covered by fine sandy sediments interpreted as remnant lake thermokarst depressions (C, C1, D, D1). In the lower level, clustered remains survived only in the eastern part; otherwise, they were dispersed due to fluvial processes. The upper level contained remains of production concentrations related to tool making and core reduction. The profile of the sediments, besides a series of pilot datings in 2003, was dated by OSL in 2006 and 2016 at the GADAM laboratory in Gliwice (Skrzypek et al., 2011; Wiśniewski et al., 2023). The two series show high similarity. Going by average datings, the older layer could be assigned to MIS 5a, and the younger to early MIS 3. It should be noted that the spread of datings from the lower level (w. B) is significant, covering several adjacent chronological units, specifically MIS 4 and MIS 5a – MIS 5b – MIS 5c. The oldest date was 79.3±5.9 ka (GdTL-858), while the youngest – 46.0±3.6 ka (GdTL-856). In turn, the oldest dating for the younger level (D, D1-C, C1) is 61.0±6.8 ka (GdTL-855), and the youngest is 32.3±1.9 ka (GdTL-861). Table 1 shows that at least two dates define the stratigraphically older series as overlapping with the younger series, which is caused by the unstable deposition environment subjected to periglacial processes after accumulation. These processes led to the local upward lifting of parts of the packages and mixing them with later accumulated formations. Regarding style and technology, the lower level corresponds to flake industries with bifacial technology and Levallois elements, while the upper is identified with the so-called Central European Micoquian (CEM).

Pietraszyn 49a

The recent research at the Pietraszyn 49a site in the eastern part of the Głubczyce Plateau was of invaluable significance. The site is situated on the southern slope of the Troja River valley, an Oder tributary. It was discovered by amateurs in the 1990s. At that time, the site's stratigraphic model was presented based on the trenches near the spot where the artefacts from the arable field surface were collected. Site chronology was partly based on the results of the sediments' TL dating (Foltyn et al., 2000). Between 2012 and 2022, with short breaks, the site was systematically excavated, revealing concentrations of lithic relics representing the CEM complex. During these investigations, samples for dating using two luminescence methods were taken (Wiśniewski et al., 2019). The primary method was pIRIR225, which was applied to the analysis of feldspar. The tests were complemented with traditional OSL. Four layer complexes were identified during excavations. The lowest complex contained sand-gravel layers of fluvioglacial origin (D). Higher up was sediment complex C – a conglomerate


MIS−3
MIS−2
GS−18
GI−17
GS−17
GI−16
GS−16
GI−15
GS−15
GI−14
GS−14
GI−13
GS−13
GI−12
GS−12
GI−11
GS−11
GI−10
GS−10
GI−9
GS−9
GI−8
GS−8
GI−7
GS−7
GI−6
GS−6
GI−5.2
GS−5.2
GI−5.1
GS−5.1
GI−4
GS−4
GI−3
GS−3
HE 5
HE 4
HE 3
HE 2
δ 18O
-38
-40
-42
-44
-46
OxCal v4.4.4 Bronk Ramsey (2021); r:5 Atmospheric data from Reimer et al (2020)
Stajnia Cave
Level C18
Level C19
Level D1*
Ciemna Cave
Level III *
Level IV*
Level V *
Level VIII*
Layer 11 (sector C0)
Obłazowa Cave
Layer XI*
Layer XV*
Layer XVII*
Layer XVIIIb*
Layer XIX*
Lubotyń 11
Layer C2*
Nietoperzowa Cave
Layer 1
Layer 3
Layer 5*
Layer 6*

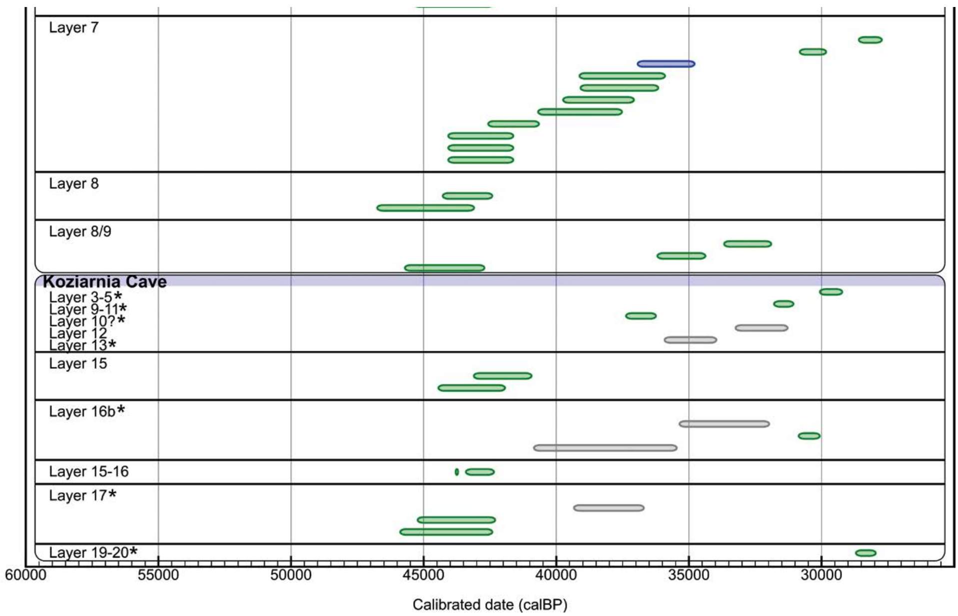


Figure 5. Radiocarbon ages, calibrated against IntCal20 curve, ranges at 2 sigma confidence, presented with NGRIP d18O data as a reference. Green: bone samples pretreated with ultrafiltration, blue: bone samples pretreated without ultrafiltration or charcoal samples pretreated with ABA protocol, grey: pretreatment method unknown. An asterisk indicates the place where the artefacts occurred

of fluvial sediments with slope processes involved. It was overlain by another complex of colluvial sediments affected by fluvial processes (B), the lowest part of which (B9) contained lithic artefacts (over 20,000) and isolated bone remains (woolly mammoth and horse). The sequence terminates in the contemporary ploughed soil (A). Based on pIRIR-225 dating, it can be concluded that the bedrock sediments (D) belong to MIS 6. A similar age was obtained using the OSL quartz method. Age determination of complex C performed with pIRIR-225 suggests its deposition during MIS 4, whereas layer B9 with artefacts was dated to the onset of MIS 3 or the second part of MIS 4 (60±6 ka). The upper layers of this complex generated similar dating results (Tab. 1). These results completely overturned the previous dating of the artefact-yielding layer at site 49a in Pietraszyn (Kozłowski, 2016). Slightly later, layer B9 in the northern profile of the site was dated to a much later period (47.3±2.6 ka) using the OSL quartz method (Tab. 1).

Dzierżysław 1

Dzierżysław, site 1, is located in the southern part of the Głubczycki Plateau. The site was uncovered on the south slope of Czarna Góra, "Schwarzer Berg" (approximately 285.3 m a.s.l.), in the southern part of the Głubczyce Plateau. The site was discovered in 1926 (Lindner, 1941). Extensive excavations were undertaken in the second half of the 20th century (1957-1959, 1962, 1989, 1992) (Kozłowski, 1964, 1965; Foltyn et al., 2000; Foltyn, 2003; Fajer et al., 2005). The works covered a strip of land located on the edge of the gravel pit and south of the gravel pit. The latter phase involved the location of a landfill in this area. The construction of two dump tanks covered the entire northern part and a large section of the southern part of the site. Excavations were undertaken before the construction of these tanks. These works produced a model of a multicultural site with three cultural horizons (older Micoquian, Bohunician, and Szeletian cultures).

Recently, an opportunity arose for a more detailed examination of the situation in site's the southern part. In 2018 and 2019, trench surveys adjoining the trenches explored in the 1990s from the south were established (Wiśniewski et al., 2022a). The lowest layer recorded in the main trench was a varied-fraction horizon of illuvial level (8; Fig. 2). The next layer (7) was formed through the degradation of the soil level during the Lower Pleniglacial of the last glacial (MIS 4). OSL dating produced a result of 64.2±3.7 ka. The higher-located cambic level (6) of brown subarctic soil, identified with interpleniglacial soil, was dated to the onset of MIS 3 (54.6±2.9 ka). Even higher was a layer of gleyed loesses (5), whose age (20.9±1.1 ka) and lithostratigraphic features correlate with loesses deposited in MIS 2. It is separated from layer 6 by over 30 ka with no sedimental record in this part of the site. The next layer (4) is the remains of a cambic origin of similar age as layer 6 (58.7±3.5 ka), hence the supposition that this is a deposit on a secondary position. Above (layers 2 and 3), we found loesses deposited at the final stages of the Upper Pleniglacial (MIS 2: 18.5±1.1 ka). Such aeolian sediments are typical of the Głubczyce Plateau (Jersak, 1991; Jary, 1996). During the last excavation season in 2019, a few isolated finds were discovered in layer 1 (contemporary ploughing horizon) at the transition zone between two layers – orange sediments (4) and gley layer (5). One artefact was recorded in layer 6. Thus, we have remains of at least two episodes, one related to groups of artefacts from layers 4 and 5, the other with layer 6. It also may be assumed that finds from layers 4 and 5 and the ones from layer 6 were redeposited by colluvial processes.

To relate these observations to previous studies, we tried to correlate the depth of the artefact deposition with sedimentary features, which were thoroughly described by the Fajer et al. (2005). The correlation between the artefacts' location and the stratigraphic model of trench I/92 and 1/2019 shows that most finds rested in the loess floor (2-3) and layers 4 and 5. The completed research allowed the construction of new chronological and taxonomic models for the southern part of Dzierżysław 1. Present results indicate the lack of sediments related to early Middle Palaeolithic (Early Micoquian) and transitional industries. Instead, we are dealing with sediments from early sub-stages of MIS 3 and from MIS 2. The analysis considering features of loess sediments showed these to be significantly transformed by periglacial processes. Remains found inside these sediments could be associated with the Micoquian culture and the Upper Palaeolithic group (Wiśniewski et al., 2022a). However, it is impossible to speak of assemblages here, as these artefact groups have probably been abandoned for a long time.

Stajnia Cave

More sites are located in the Kraków-Częstochowa Upland. One of these is the Stajnia Cave, the subject of many publications owing to the discovery of Neanderthal remains there (Urbanowski et al., 2010; Picin et al., 2020; Nowaczewska et al., 2021). The results of sediment and bone datings (including artefacts) were also widely disseminated (Żarski et al., 2017; Picin et al., 2020; Talamo et al., 2021). The cave formed during the Neogene and Pleistocene is small – 23 m × 2-4 m. The rocks of the entire massive date to the Upper Oxfordian (Żarski et al., 2017). The 2006-2010 excavations identified 15 layers of cave clay. The unique geochemical conditions preserved many organic remains, allowing for their analysis through many methods. Sediments and bone remains were dated by three methods – ^{14}C, U-Th and OSL (three samples were taken originally, and results for two were published). The ^{14}C datings are of primary importance, the first at Poznań (2 dates) and Oxford (1 date). The samples were taken from the remains of three mammals from layer D1 and show broad variation of results (Tables 3 and 4 in Żarski et al., 2017). The datings ranged from 46.4 to 14.5 ka calBP, with one date exceeding 49 ka. One OSL dating (GdTL-1127) from layer D1 may be perceived as correlated as it was 45.9 ka. Lower precision was achieved for two U-Th samples taken from mammoth teeth discovered in layer D2 (ca. 53 ka). The authors suspect layer E1 may have been deposited in the early MIS 3, yet its structural elements, i.e. rubble, were formed during the cold MIS 4 (Żarski et al., 2017). The lower deposited layers, E2, F and G, were assigned to chronological climate units of the Early Weichselian without numerical datings.

A series of ^{14}C datings made in Leipzig by the Max Planck Institute's team (Picin et al., 2020; Talamo et al., 2021) is now crucial. More AMS 20 datings of additional samples were made at the Mannheim laboratory (MAMS) (Tab. 2). Datings, supervised by S. Talamo, included bone remains from layers C18, C19, D1, D2, D3 and E1. Results from layers underlying D1, i.e., D2, D3 and E1 gave ages >49 ka or >50 ka BP, supporting previous U-Th datings (Talamo et al., 2021; Tab. 1). The dates for D1 were quite diverse, some (4 samples) generating ages of >49 ka and >50 ka, suggesting that these objects came from older layers. The further five dates from layer D1 fall into the 41.1 to 52.4 ka calBP range. Please note that the upper boundary was set by the dating of a mammoth tusk ornamented pendant (Talamo et al., 2021). Another two "young dates" in this set (between ca. 42.5 and 41.5 ka) came from a sample taken from a bone awl. The remaining dates oscillate in the range between ca. 54.8 and 45.5 ka. It demonstrates that the ornamented pendant and the awl are younger intrusions into deposits several thousand years older. Layers E, as well as D1 and D2, produced lithic artefacts whose features allow for classifying them as CEM. Additionally, layer D1 contained items representative of the Upper Palaeolithic industry. Thus, we have every reason to believe that the discussed part of the cave sediments contains both younger and older elements in the respective series. The younger layer – C19 – is dated between 42.4 and 37.2 ka. The layers following it (C18 and B) are beyond the scope of our publication.

Another aspect in the discussion about the sediment chronology in the Stajnia Cave are the biological remains of a Neanderthal human. One of the teeth discovered in layer D2 (S5000) was dated with ^{14}C to 22,480±70 due to sample contamination. A molecular analysis was therefore performed. Based on calculations, it was concluded that the mtDNA genome could be expended at approximately 116 ka according to the branch length of the mtDNA tree, but the confidence range is quite extensive (95% HPDI: 83,101-152,515 years ago). Thus, theoretically, the tooth could date back to the formation period of layer E2 (MIS 5a) or, which cannot be ruled out, to periods yet unattested by sediments or other biological remains during the Stajnia Cave investigations. Here, we consider the Eemian (MIS 5e) or late stages of the Warthe/Oder stadial (MIS 6).

Ciemna Cave

The site is located in the valley of the Prądnik River, a left-bank tributary of the Vistula. The cave is substantially elevated above the valley bottom (62 m). It is one of Poland's most sizeable cave sites with archaeological evidence, and its exploration history goes back to the second half of the mid-19th century (Krukowski, 1939; Kowalski, 1967; Valde-Nowak et al., 2014, 2016; Alex et al., 2017). It consists of several parts. The latest excavation episode started in 2007 and covered the so-called Main Chamber. During this campaign, the organic objects were dated using the radiocarbon method. Six series were distinguished in the Main Chamber. Series 1 is related to the Riss/Salian Glaciation (MIS 6), series 2 (layers 9-16) to MIS 5e – MIS 5a, layers 6-8 to MIS 4, and layers 2.3-5 to MIS 3. The artefacts from the first series (layer 17) were referred to as early Middle Palaeolithic (cultural level IX). In contrast, the second series was combined with artefacts identified with two Mousterian levels (layer 15, cultural level VIII and layer 12, cultural level VII) and the so-called Taubachian level (layer 9, cultural level VI). The next series is represented by two Micoquian layers (layer 8, cultural level V and layer 6, cultural level IV). The upper series is represented by the Micoquian (layer 2.3, cultural level III) (Valde-Nowak et al., 2014, 2016).

Numerical dating has provided exciting data for discussing the site's post-depositional changes. Radiocarbon datings form two series (Tab. 2). The first, with five samples, was analysed at the Poznań laboratory and National Ocean Sciences Accelerator Mass Spectrometry Facility, Woods Hole Oceanographic Institution, US. Samples from bones and teeth were taken from layer 11 as defined by Kowalski (1963-1968) and from layers 8, 7 and 3 in the Main Chamber excavated in 2007-2012 (Valde-Nowak et al., 2014). In four cases, these were the remains of a bear. The fifth sample was too burnt to be identifiable. Dating results ranged from 48.0 to 39.8 ka calBP. Researchers noted that datings from layers 3, 7 and 8 do not follow the stratigraphic sequence, as the date from layer 3 is older than those from the underlying layers 7 and 8. The conclusion was that only the date from layer 3 (Poz-23663: 42,000±1000) was correct and in line with parallels from layer 11 (from sector CO) explored by Kowalski. The cause of the dating inversion was explained by post-sedimentation changes or the lack of ultrafiltration.

A new series of datings began with a sample taken of charcoal from *Pinus silvestris* (RTD7375-A) from sector CK (Main Chamber) and analysing it at the DREAMS radiocarbon laboratory, Weizmann Institute – Max Planck Center for Integrative Archaeology, Israel (Valde Nowak et al., 2016). Here, the acid-base-acid (ABA) measuring procedure was used. The sample came from the middle layer with Micoquian material (layer 8). After calibration, its value was inside the upper range of the previous datings – 47.8-43.8 calBP. As this was an isolated sample, its origin and connection with human activity remain unclear. The authors correlated layer 2.3 from the Main Chamber with layer CO5 of Krukowski's trench, which had produced the largest number of relics assigned to the Micoquian. As a result, "the main Micoquian layer" was associated with the middle substage of MIS 3, suggesting that it could correspond to the GI12 warming.

The dating programme at the D-REAMS laboratory was expanded to include four bone samples – *Ursus sp.* and undetermined mammals and wood – *Betula (*Alex et al., 2017). These came from, respectively, layer 3 (2 samples), 6 (2 samples) and 8 (1 sample). The objective was to obtain datings for layers with Micoquian relics. Two bear bone samples, one from layer 6 and the other from layer 8, had dates falling outside the calibration curve (55.3±5, 46.3±1.4 ka BP). Two samples – from layers 3 and 8 (a bear and a mammal) had minimal datings of >56.0 BP and >50.6 ka BP. The wood sample turned out to be contemporary.

Summarising, the charcoal sample is younger than the series of bone datings. Unfortunately, three bone samples, as seen by Alex et al. (2017), contained slightly lower quantities of collagen. However, considering the collagen quality, %C values and the consistency of results, these samples may still be judged as reliable. Thus, all bones dated in the last series may be assumed to be >50.0 ka BP.

Obłazowa Cave

The Obłazowa Cave (site Nowa Biała 2, Nowy Targ District) is located near Nowa Biała in the Western Carpathians (Pieniny). The cave lies in the southwestern section of the limestone Obłazowa Skała hill, which, together with the Kramnica hill, constitutes the western segment of the Pieniny Spiskie Range. It was formed through the erosion of fractured limestone by the Białka River. The cavern, running along rock layers, consists of a relatively large chamber and a short entry passage. The original entrance was below the present one (Valde-Nowak et al., 2003; Valde-Nowak, 2009).

The investigations in Obłazowa began in 1985. From the very beginning, the results were so interesting that the excavations continued – with breaks – up to the second decade of the 21st century (Valde-Nowak & Nadachowski, 2014; Valde-Nowak et al., 2016), uncovering a total of 21 lithological and ten cultural layers, including one from the Upper Palaeolithic (Pavlovian – layer VIII) and Middle to Upper Transition – MUPT (Szeletian – layer XI). The remaining layers are associated with Middle Palaeolithic traditions: Mousterian (layer XIII), Charentian (layer XV), Taubachian (layer XVI, XVII, XIX and XX) and the Micoquian (layer XVIIIb) (Alex et al., 2017). The assemblages from all Middle Palaeolithic layers were almost exclusively from local radiolarite.

The first ^{14}C datings were made on samples taken in 1986-1995. These dates correspond to the Upper Palaeolithic horizon. One date corresponds to a stratum containing a Szeletian inventory. The sample was a bird bone from which a date of 36,400±700BP (Poz-1135) was obtained. Further datings were made on samples excavated in 2012-2013 from layers XV, XVII, XVIIIb and XX. Three were taken from *Pinus silvestris* charcoal (date RDT-7355, layer XVIIIb) and fragments of mammal long bones. One of the dates, from layer XIX (RDT-7399), came from a bone with cut marks (Valde-Nowak et al., 2003; Alex et al., 2017).

All dated samples came from known contexts and were collected during recent excavations. Samples underwent routine prescreening procedures at the D-REAMS laboratory (Alex et al., 2017).

One sample from layer XV falls between 50 and 45 ka BP. Two samples from layer XVII gave ages older than 44.6 ka calBP (with one open date, older than 50 ka). From layer XVIIIb, two samples were dated between 47.3 and 42.5 ka calBP. One of the lowest two samples, from layer XIX, gave an open result older than 47.9 ka BP, while the second is too an open measurement older than 50,500 radiocarbon years.

Lubotyń 11

Lubotyń 11 is located in the southern part of the Głubczyce Plateau. The site occupies the top of a hill composed of fluvioglacial sediments and was discovered in the 1930s. Excavations were carried out, with breaks, between 2006 and 2015 (Połtowicz-Bobak et al., 2013; Bobak et al., 2016). The sediment thickness is small. In the bedrock are the aforementioned fluvioglacial sediments of the Oder glaciation (layer E) and the backfill, forming a pseudomorphosis after the wedge (layer F). Above this is layer C1, composed of silty and gravelly sediments, and layer C2, composed of sandy-gravelly sediment containing a burnt material, probably residues from fuzzy fire sites. Layers C1 and C2 constitute the main deposit of archaeological material. Above the basin situated over the pseudomorphosis of the wedge, layer G was isolated, composed of sediment flowing from the neighbouring areas during the backfilling of the wedge. The site is covered by layers C (eroded loess with an admixture of sandy and gravelly material) and B (loess). Above layer B is modern humus. The redeposition of the relics (layers C1 and C2) was not significant, as indicated by the well-preserved remains of campfires. The preservation of the remains was possible because a considerable part of them were located above a pseudomorphosis left by an ice or frost wedge several metres in diameter, which formed a slight depression during the operation of the camp (Połtowicz-Bobak et al., 2013; Bobak et al., 2016).

The discovered evidence comes from an indeterminate number of episodes of the site's use by the Palaeolithic humans. A spatially indistinguishable occupation of Szeletian and Aurigniacian is evidenced at the site.

Dating by OSL was used for layers F, G, C and B. A series of ^{14}C datings (AMS) was made for charcoal from layer C2 and one of the fireplaces. All ^{14}C datings come from charcoal from layer C2 – a source of lithic artefacts – of which three: 44.0±3.0 ka (Poz-25209), 43.0±1.0 (Poz-36903), 35.10±0.8 ka (Poz-25208) come from fireplace samples, and three more from the layer itself: 44.0±1.1 ka (Poz-36905), 39.5±0.7 ka (Poz-36904), 38.1±1.8 ka (Poz-25207) (Bobak et al., 2016). A further three, as yet unpublished, dates from the C2 layer: >44.7 ka (OxA-33315) and from the focus: >47.5 ka (OxA-33316) and >54.1 ka (OxA-33073) gave an open result, defining only a terminus ante quem. The oldest of these dates was obtained from a sample prepared using the ABOX technique, and the result was clearly older than the others. After calibration, all dates fall into a wide range between >50 ka and 38.5 ka calBP.

Nietoperzowa Cave

The Nietoperzowa Cave is an example of a site where the discovered material was subject to new datings, even though the site's investigations had ended over 60 years ago. The site is located in the Częstochowa Upland, in the upper part of the Będkowska valley. Although the exploration began already in 1854, systematic studies – except for L. Kozłowski's excavations in the early 20th century – were only carried out by W. Chmielewski's team in 1956-1963. The stratigraphy was characterised by T. Madeyska-Niklewska, who identified over a dozen layers from various periods and dated them to between the end of the Middle Pleistocene and MIS 3 (Madeyska-Niklewska, 1969; Madeyska, 1982; Krajcarz & Madeyska, 2010). Artefacts representing the LRJ tradition were discovered in three layers (Chmielewski, 1961). The most substantial number was found in the lower layer (6), consisting of fine-smoothed rubble and clay with a significant admixture of charcoal. Remains of fireplaces accompanied the artefacts. Bear bones were discovered, which gave rise to the theory that the Palaeolithic group at Nietoperzowa hunted this species. A slightly lower number of finds came from layer 5a, composed of clay. This layer yielded a single fireplace. Artefacts assigned to 5a were discovered either on top of layer 6 or 1-2 cm above it. Layer 4, consisting of clay, was located on a level of mixed clay and rock rubble. It was clearly separated from layers 6 and 5a. The artefacts lay in a layer covered by the youngest loess.

The most recent dating was undertaken by the team of M. Krajcarz, who selected bear bones for the study (Krajcarz et al., 2018). Fifty-one samples were taken from the bone remains. Most of the samples underwent ultrafiltration at the Poznań Radiocarbon Laboratory. In contrast, some whose collagen was collected at the Biogeological Laboratory of Tübingen University did not undergo this procedure (Tab. 2). A few samples contained insufficient collagen or an incorrect C/N ratio result.

The datings of LRJ layers are 40.3 BP to 24.54 BP for layer 6 and from 40.5 ka BP to 26.19 ka BP for layer 5. The calibration for layer 6 produced 46.1-28.1 ka calBP (layer 6), and that for layer 5 – 46.3-29.8 ka calBP. The authors note the overlap in datings between layers 5, 6 and 7. Each of those layers was represented by two sub-groups of dates, covering periods preceding ca. 35 ka calBP and ca. 28-34 ka calBP (Krajcarz et al., 2018).

An attempt was made at Bayesian modelling. There were some problems with it, as some dates did not follow the trends, and there even was an overlap of dates from layers 5 and 6. Two models were prepared after an arbitrary decision to discard part of the datings (e.g. from layer 6). However, the result was unacceptable overall agreement indexes ($A_{overall} < 60\%$). Ultimately, it was possible to present models for the lower part, i.e. layers 6, 7, 8 and 8/9, and the upper part, i.e. layers 3, 5 and 6 (Krajcarz et al., 2018). The age of the lower boundary of layer 6, according to the first statistical model LOWER PART1, was placed in the 44.305-42.604 ka calBP range, while according to the second model LOWER PART2 – at 40.2-37.7 ka calBP. In turn, the upper boundary of layer 6, according to the model UPPER PART1, fell between 43.1 and 41.0 ka calBP, whereas according to the second model UPPER PART2 – between 38.1 and 33.9 ka calBP. The lower boundary of layer 5 is the same as the upper limit of layer 6, while the upper boundary of layer 5 would be set by the dates of layer 3 (31.3-30.5 ka calBP). According to the UPPER PART model, the boundary datings would be 31.1-30.2 ka calBP. The problem is that the older dates are older than 38 ka calBP. It should be mentioned that it is impossible to set an upper boundary using layer 4; hence, layer 3 had to be used instead.

Koziarnia Cave

Recently (2017), excavations have taken place in the Koziarnia Cave. It is located in the Ojców Plateau, in the Sąspów Valley area. The beginnings of its exploration, as that of the Nietoperzowa Cave, go back to the 2nd half of the 19th century. In 1919, S. Krukowski explored it without much success. From 1958 to 1962, it was subject to large-scale (1410 m^2) exploration by a team under W. Chmielewski. Trenches covered the main chamber and the passage. The most important finds were recorded in the central section of the passage, beginning about a dozen metres from the entrance. During these excavations, W. Chmielewski and T. Madeyska-Niklewska distinguished 21 geological and eight cultural layers with lithic artefacts and charcoal (4, 7, 10, 13, 16B, 17, 18, 20) (Chmielewski et al., 1967).

The subsequent excavations covered a small area of 2.85 m^2, some 40 m from the entrance, reaching the SE corner of Chmielewski's trench. Over a dozen layers were distinguished (A-P), and four lithostratigraphic series were defined. An attempt was made to correlate them with layer positions as described by T. Madeyska-Niklewska (Chmielewski et al., 1967). The correlation according to plate 8 and descriptions (Kot et al., 2021; 6) of the 2017 trench and trench IX/1961-62 is as follows: M – 21, H', I, H, I' and L – 17 and 19, C – 16, K' – 13, K – 14, J – 12, E – 16a, F – 16b, D – 15. W. Chmielewski distinguished the following Palaeolithic units in the individual layers: flake assemblage dated to the pre-Eemian (l. 20), Micoquian (mikocko-prądnicka) culture from early stages of Weichselian (l. 18), flake assemblage from Middle Palaeolithic (l. 17), indeterminate Middle Palaeolithic industry (layers 16b and 10), occupation visible through fireplace relics (l. 10). According to Chmielewski, the Jerzmanowician point discovered by Römer in the 19th century, had been originally deposited in layer 7 (Chmielewski et al., 1967, p. 51). At the border between trench IX and the dig into layer 7, a blade fragment was found. According to Chmielewski, these finds were associated with the Jerzmanowician, at that time known from, e.g. the Nietoperzowa Cave. Kot et al. (2021) combined these finds with layers 15-16.

Fourteen bones and nine charcoal samples were subject to ^{14}C dating (Kot et al., 2021). Earlier, W. Chmielewski did a ^{14}C dating of a bear bone, possibly from layer 7 (corresponding to layers 14-15 according to Kot et al.), and obtained a result of 39.34±0.43 ka BP. The U-series method was used on two bones. OSL method dating was also applied. Below, we only quote selected results that are pertinent to this paper.

Radiocarbon datings of the lowest layers (19-21) failed due to sample contamination. The use of OSL also produced an extremely young age. Based on the dating of the upper layers, an age older than 47 ka calBP was assumed. Layers H'/I/H/I' (equivalent to 17), H' and I, including undated layers H and I', showed ages between 47-36 ka calBP, while F (16b) appeared younger to the authors (40-35 ka calBP). Materials from layer D (15) yielded dates similar to layers 16b and 17, indicating redeposition from the lower layers. Layers K and K' (13) are dated to around 35-31 ka calBP. Some bone artefacts from the 19th-century collections were also dated and obtained ages around 26-25 ka calBP.

Finally, the evidence from layers 17 and 18 (H'/IH/I', L) was correlated to the Middle Palaeolithic, as was done by W. Chmielewski. The finds from layer 15 (D) were related to the Jerzmanovician (125 specimens). Elsewhere in this paper (Discussion), the authors also included layers 16 -E, F and G in this unit (Kot et al., 2021; 8). Overall, this evidence mainly consists of chips and flakes. Layers 13-12 (K-K') were related to the early Gravettian. Layers correlated with the Middle Palaeolithic occurrence, as well as with the period where the LRJ industry should theoretically be located and the younger level (the so-called Early Gravettian), were analysed to determine the environmental and climatic conditions in each time range. It was found that the Middle Palaeolithic fell into a more favourable period than the time of EUP development (Berto et al., 2021). Layers 17-18 were correlated with a warm oscillation corresponding to DO 12-9 based on the radiocarbon date of the *Ursus ingressus* bone. Layers 16c and 15, on the other hand, were correlated to the cooling of DO 8 and H4. Conversely, layers 31-12 were correlated with DO 7 based on a rodent and tree species analysis.

Discussion

In this section, we wish to address several issues generated by the presentation of new datings (Fig. 4-5, Tab. 1-2). In the quoted data, one may find figures leading to a radical re-examination of the accepted views on the development of the Middle Palaeolithic industries. One of these views is the theory that the Micoquian industries were deeply rooted in the past, reaching the Middle Pleistocene. This theory is partly based upon the imprecise datings from two sites: Dzierżysław 1 and Pietraszyn 49 (Foltyn & Kozłowski, 2003; Kozlowski, 2003; Kozłowski, 2016). In both cases, the artefact-yielding layers are currently dated to the last glacial (MIS 4 – MIS 3). Furthermore, in the case of Dzierżysław 1, there exist substantiated suspicions that we are looking at a palimpsest and not the remains of a single episode. The revised datings lead to a conclusion that the above mentioned evidence should not be considered when discussing the cultural taxon distinguished two decades ago. As a reminder – the authors suggested distinguishing it by a distinct name – the East Micoquian. Nevertheless, we hasten to add that we do not negate the need to distinguish Middle Pleistocene complexes with asymmetric bifacial tools, as such are known from other sites in Poland (Cyrek et al., 2014) and Eastern Europe (Stepanchuk, 2006).

The new dates resumed the discussion on the previous concepts for classifying and dating the Micoquian industries (German: Keilmessergruppe) in Central Europe (Richter, 2002; Jöris, 2006). The view initially prevailing in Poland was that the classic Micoquian assemblage from the Ciemna Cave, such as artefacts from layers 6 (Kowalski) and CO5 (Krukowski), should be dated to a period before MIS 4 (Kozłowski & Kozłowski, 1996). Using ^{14}C on samples that did not undergo pretreatment procedures in the first decades of this millennium led to the belief that these industries may have developed much longer, up to 41-47 ka calBP (Valde-Nowak et al., 2014). The later introduced sample preparation procedures revised such views, and the main Micoquian layer at the Ciemna Cave – used here as an example – must be moved again to at least >50 ka BP. These dates are roughly consistent with the upper layer from Hallera Av. in Wrocław. The youngest dates for Micoquian elements come from the Stajnia Cave (layer D1) and Obłazowa Cave (layer XVIIIb). However, based on the recently reported dating from the Stajnia Cave by Talamo et al. (2021), it might be suggested that there are much more chronologically diverse elements in the D1 layer than we had previously assumed (see comments below). Theoretically, the organic remains older than ca. 45 ka calBP in the Stajnia Cave may not directly relate to lithic artefacts. Also, the dating of a single sample from layer XVIIIb in the Obłazowa Cave, identified as Micoquian, could be relatively young – ca. 43 ka calBP. However, samples from the stratigraphically younger layer XVII indicate a much older age – ca. 53 ka, laying above the calibration curve. In conclusion, one may surmise that no reliably dated remains of Central European Micoquian younger than GI-12 exist. It should be noted that dates indicating an age younger than GI-12 have been obtained in some regions of central Europe. Such sites are represented by, e.g. Pouch, Saxony Anhalt (Weiss, 2015) and Sesselfelsgrotte, G-Komplex (Richter, 2002), Kůlna Cave, layer 7a and 6a, and Šipka Cave (Neruda & Nerudová, 2013, 2014). In the latter two cases, radiocarbon dating is strongly inconsistent with OSL dating (Nejman et al., 2011; Richter, 2002).

The appearance of newly dated sites associated with the EUP must also be mentioned. The first is the open site of Lubotyń 11. One should note that the OSL sediment datings are inconsistent with the stratigraphic sequence. A series of ^{14}C datings made for the cultural layer had a high error level. After calibration, it stretched over an enormous period of about ten thousand years. These dates seem to cover several stages of occupation by a Szeletian group or groups, and the youngest phase probably should be associated with the presence of humans using Aurignacian artefacts. The finds from those two taxonomic units are separated neither vertically nor horizontally. Additionally, the youngest date comes from the same fireplace, which produced older datings associated with the Szeletian. Thus, the existing dates do not allow for establishing the lower chronological limit for Lubotyń 11, besides suggesting that it does not extend beyond GI-10 and H4.

The next issue concerns the time frame of the LRJ complex. Here, the data from the Nietoperzowa Cave, which produced the largest collection of points, are of fundamental importance (Chmielewski, 1961; Krajcarz et al., 2018; Wiśniewski et al., 2022b). The just completed modelling shows the lower boundary for layer 6 in one of the Bayesian models to oscillate around 44 ka calBP, while the upper boundary is around 41 ka calBP. It corresponds with the GI-11 and GI-10. Using a date from layer 3 to set the upper boundary at ca. 31 ka calBP seems questionable. In our opinion, such a date is improbable. The authors of the last analysis (Krajcarz et al., 2018) also draw attention to the integrity of groups of artefacts assigned to individual layers, i.e., 6, 5 and 4. Separating artefacts between the very thin layer 6 and the overlaying layer 5 is particularly problematic. Given all the above, it would be extremely challenging to set the upper boundary using dates obtained from the Nietoperzowa Cave evidence (Kozłowski, 2017). Notably, datings have recently been published for a stylistically and technologically matching collection from Ilsenhöhle in Ranis (layers 8-9). The dates (47.5-45.8 ka calBP and 46.8-43.3 ka calBP, respectively) push the lower limit of the emergence of this industry in central Europe (Mylopotamitaki et al., 2024).

Another set of question marks is raised by the latest reflections on the LRJ chronology in the Koziarnia Cave (Kot et al., 2021). Here again, we see the inconsistency between the dates and the layer sequence, with some dates from layer 15 being older than those from the underlying layer 16b. Another question is whether layers 15 and 16b belong to the LRJ at all. One should recall that mid-20th-century scholars could not establish the origin of the Jerzmanowician point discovered in the 19th century (Chmielewski et al., 1967). Chmielewski intuitively associated the specimen with the self-distinguished layer 7. However, the team conducting the last campaign in the Koziarnia Cave assigned layers 15 and 16 to the LRJ using an inventory without diagnostic elements. Therefore, it becomes problematic to link a point discovered in the 19th century to any of the layers (15-16b).

Among the dating results introduced in the last decade is a series of records relating to sites or strata identified with the Aurignacian complex. As these have recently been discussed in detail in separate papers (Davies et al., 2015; Stefański, 2018; Talamo et al., 2021; Picin et al., 2023), we will not comment on them further. Again, we would like to point out that these valuable materials are often found in an older cultural context, as in the Stajnia Cave and Lubotyń, site 11. The newly obtained data from the Stajnia Cave demonstrate that the presence of groups with Aurignacian inventories can be dated as early as GI-10. A slightly older range is presented for layer II of the Księcia Józefa site (45-42 ka calBP) based on a wood sample (Sitlivy et al., 2009). Considering the broader geographical context, i.e. the Bukk Mountains region in northern Hungary, from which dates of Aurignacian layers older than 40,000 were obtained, it cannot be excluded that materials from the Polish site may be equally old (Davies & Hedges, 2008-2009; Chu, 2018).

The new dates have also rearranged our views on the theories concerning the formation of the individual sites. These findings support the possibility of various disturbances, which are not apparent in contexts without numerical datings. It concerns the sediment environment of caves and some open-air sites. One example may be the intrusion of objects from younger to older layers and the other way around, e.g. in the already mentioned Stajnia Cave. One may note that layer D1, associated with the most important finds at that site, such as the biological remains of Neanderthal humans in the context of Middle Palaeolithic artefacts (Picin et al., 2020), yielded objects whose dates position them as some 3-4 ka younger than the other dated remains. Objects introduced into layer D1 are correlated with the oldest stage of the Aurignacian in Poland (Talamo et al., 2021). It is possible that the mixing of the evidence to some extent also affected the lower layer, hence the presence of, e.g. a Neanderthal tooth molecularly dated to at least MIS 5a in much later sediments (D2). Dislocation, as shown by the datings presented in this paper, may have affected objects and fragments of layers possibly moved into younger or, conversely, older contexts – see the inconsistencies in the datings from Dzierżysław, site 1, or Hallera Av. in Wrocław.

For many years, we have faced discrepancies in dates obtained by different methods (Richter et al., 2009; Moska et al., 2019). However, we are increasingly dealing with discrepancies in datings obtained with various techniques within the same method. An example is the radiocarbon dating obtained from a sample prepared with the ABOX procedure from site 11 in Lubotyń. Its age, determined to be above 54.1 ka BP, is beyond the calibration curve range; however, based on an uncalibrated measurement, it can be argued that it determines an age above 50,000 calendar years BP. Such an age is difficult to interpret unequivocally. It may indicate an older phase of human occupation associated with the Middle Palaeolithic. It may also demonstrate the importance of the ABOX procedure in preparing samples close to the limit of the ^{14}C method and, therefore, perhaps the need for a new dating of this site. At present, a binding interpretation does not seem to be possible. Another example concerns OSL dating incorporating quartz and feldspar analysis. In this case, the layer (B9) containing the remains of the Micoquian clusters has been given different dates. The chronological assessment based on quartz is about 13.0 ka younger than the results of feldspar measurements. In order to resolve which method brings us closer to determining the age of the 'target event' sensu Dean (1978), a more significant number of dates by both methods would have to be obtained.

Conclusion

This paper presents a new model of the cultural unit range based on a series of sites numerically dated between MIS 5d and the middle phase of MIS 3 in the area north of the Carpathians. The current conclusions are founded on dates obtained mainly through the OSL and AMS methods. Based on the dating of the geological strata and their contents, it has been established that the critical sites for the concept of the Middle Pleistocene origin of the Micoquian complex contain much younger remains, now dated to the MIS 4 – MIS 3 period. The final chronological framework of the Middle Palaeolithic industries is unclear, but it is unlikely that they developed in Poland's present area during GI-12 – GI-10. Instead, the most reliable data indicate they occurred before the H5 cooling. The industries identified with the EUP are chronologically diverse. The Lubotyń site, with the remains of a group/groups of the Szeletian culture, can be dated over a reasonably wide time range (49-39 ka and maybe older). Consequently, it can be concluded that the chronology of the Late Middle Palaeolithic sites does not overlap with the dating of the EUP sites, or if it does, it is only in a short episode.

Regarding the LRJ, the upper limit has now been modelled at ca. 44 ka, which links this unit to GI-12 – GI-10. The upper limit is, unfortunately, difficult to establish. Data from the Nietoperzowa Cave would indicate its possible survival to the post-H4 period. Very relevant information is provided by the recent dating of Aurigniacian remains, which suggests the presence of a new cultural trend in the Vistula Valley as early as GI-10. Hopefully, new data from the Mamutowa Cave, where the excavations started a few years ago (oral inf. A. Picin), will soon fill these dating gaps of the EUP sites.

The increased number of dated samples and more accurate documentation of their positions opens a new chapter in the archaeology of the Middle Palaeolithic and EUP in Poland, directed towards a better understanding of the site formation processes. The examples cited here demonstrate that both caves and open sites were subjected to complex transformations of the stratigraphic layout and spatial position of the remains of human activities. These disturbances do not currently allow age assessment by simple date averaging or subjective selection of dates corresponding to preconceived assumptions. An entropy reduction in this respect should be brought about by integrating the chronological sampling with in-depth geological studies based, for example, on microstratigraphic analysis.

Acknowledgements

The research was financially supported by the National Science Centre, Poland (grant no. 2017/25/B/HS3/00925). We would like to express our gratitude to the anonymous peer reviewers who generously dedicated their time and expertise to review and provide constructive feedback on this research paper.

Editors' note:
Unless otherwise stated, the sources of tables and figures are the author's, on the basis of their own research.

References

Alex, B., Valde-Nowak, P., Regev, L., & Boaretto, E. (2017). Late Middle Paleolithic of Southern Poland: Radiocarbon dates from Ciemna and Obłazowa Caves. *Journal of Archaeological Science: Reports*, *11*, 370-380. https://doi.org/10.1016/j.jasrep.2016.12.012

Banks, W. E., d'Errico, F., Peterson, A. T., Kageyama, M., Sima, A., & Sánchez-Goñi, M.-F. (2008). Neanderthal Extinction by Competitive Exclusion. *PLoS ONE*, *3*(12), e3972. https://doi.org/10.1371/journal.pone.0003972

Berger, G. W. (2010). An alternate form of probability-distribution plot for D_e values. *Ancient TL*, *28*(1), 11-22.

Berto, C., Krajcarz, M. T., Moskal-del Hoyo, M., Komar, M., Sinet-Mathiot, V., Zarzecka-Szubińska, K., … & Kot, M. (2021). Environment changes during Middle to Upper Palaeolithic transition in southern Poland (Central Europe). A multiproxy approach for the MIS 3 sequence of Koziarnia Cave (Kraków-Częstochowa Upland). *Journal of Archaeological Science: Reports*, *35*, 102723. https://doi.org/10.1016/j.jasrep.2020.102723

Bird, M. I., Ayliffe, L. K., Fifield, L. K., Turney, C. S. M., Cresswell, R. G., Barrows, T. T., & David, B. (1999). Radiocarbon Dating of "Old" Charcoal Using a Wet Oxidation, Stepped-Combustion Procedure. *Radiocarbon*, *41*(2), 127-140. https://doi.org/10.1017/S0033822200019482

Blockley, S. P. E., Bronk Ramsey, C., & Higham, T. F. G. (2008). The Middle to Upper Paleolithic transition: dating, stratigraphy, and isochronous markers. *Journal of Human Evolution*, *55*(5), 764-771. https://doi.org/10.1016/j.jhevol.2008.08.009

Bobak, D., Płonka, T., Połtowicz-Bobak, M., & Wiśniewski, A. (2013). New chronological data for Weichselian sites from Poland and their implications for Palaeolithic. *Quaternary International*, *296*, 23-36. https://doi.org/10.1016/j.quaint.2012.12.001

Bobak, D., Połtowicz-Bobak, M., Jary, Z., Raczyk, J., & Moska, P. (2016). Chronologia osadnictwa szeleckiego na stanowisku Lubotyń 11, pow. głubczycki, w świetle bayesowskiego modelowania datowań. *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego*, *37*, 11-21. https://doi.org/10.15584/misroa.2016.37.1

Brock, F., Higham, T., Ditchfield, P., & Bronk Ramsey, C. (2010). Current Pretreatment Methods for AMS Radiocarbon Dating at the Oxford Radiocarbon Accelerator Unit (Orau). *Radiocarbon*, *52*(1), 103-112. https://doi.org/10.1017/S0033822200045069

Bronk Ramsey, C. (2009). Bayesian Analysis of Radiocarbon Dates. *Radiocarbon*, *51*(1), 337-360. https://doi.org/10.1017/S0033822200033865

Bronk Ramsey, C., Higham, T., Bowles, A., & Hedges, R. (2004). Improvements to the Pretreatment of Bone at Oxford. *Radiocarbon*, *46*(1), 155-163. https://doi.org/10.1017/S0033822200039473

Brown, T. A., Nelson, D. E., Vogel, J. S., & Southon, J. R. (1988). Improved Collagen Extraction by Modified Longin Method. *Radiocarbon*, *30*(2), 171-177. https://doi.org/10.1017/S0033822200044118

Buylaert, J. P., Murray, A. S., Thomsen, K. J., & Jain, M. (2009). Testing the potential of an elevated temperature IRSL signal from K-feldspar. *Radiation Measurements*, *44*(5-6), 560-565. http://dx.doi.org/10.1016/j.radmeas.2009.02.007

Chmielewski, W. (1961). *Civilisation de Jerzmanowice*. Wrocław-Warszawa-Kraków: Zakład Narodowy im. Ossolińskich.

Chmielewski, W., Kowalski, K., Madeyska-Niklewska, T., & Sych, L. (1967). Wyniki badań osadów jaskini Koziarni w Sąspowie, pow. Olkusz. *Folia Quaternaria*, *26*, 1-69.

Chu, W. (2018). The Danube Corridor Hypothesis and the Carpathian Basin: Geological, Environmental and Archaeological Approaches to Characterizing Aurignacian Dynamics. *Journal of World Prehistory*, *31*, 117-178. https://doi.org/10.1007/s10963-018-9115-1

Cyrek, K., Sudoł, M., Czyżewski, Ł., Osipowicz, G., & Grelowska, M. (2014). Middle Palaeolithic cultural levels from Middle and Late Pleistocene sediments of Biśnik Cave, Poland. *Quaternary International*, *326-327*, 20-63. https://doi.org/10.1016/j.quaint.2013.12.014

Davies, W., & Hedges, R. (2008-2009). Dating a type site: Fitting Szeleta Cave into its regional chronometric context. *Praehistoria*, *9-10*, 35-45.

Davies, W., White, D., Lewis, M., & Stringer, C. (2015). Evaluating the transitional mosaic: frameworks of change from Neanderthals to *Homo sapiens* in eastern Europe. *Quaternary Science Reviews*, *118*, 211-242. https://doi.org/10.1016/j.quascirev.2014.12.003

Dean, J. S. (1978). Independent Dating in Archaeological Analysis. In M. B. Schiffer (Ed.), *Advances in Archaeological Method and Theory*, 1 (pp. 223-255). Academic Press. https://doi.org/10.1016/B978-0-12-003101-6.50013-5

Dincauze, D. F. (2000). *Environmental archaeology. Principles and practice*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511607837

Fajer, M., Foltyn, E., Kozłowski, J. K., Pawełczyk, W., & Waga, M. J. (2005). The multilayer Palaeolithic site of Dzierżysław I (Upper Silesia, Poland) and its environmental context. *Přehled výzkumů*, *46*, 13-33.

Foltyn, E. (2003). Uwagi o osadnictwie kultur z ostrzami liściowatymi na północ od łuku Karpat. *Przegląd Archeologiczny*, *51*, 5-47.

Foltyn, E., & Kozłowski, J. K. (2003). The lower level of the site of Dzierżysław I, Opole voivodship (Silesia, Poland) and the problem of the Bohunician. *Eurasian Prehistory*, *1-2*, 79-116.

Foltyn, M. E., Foltyn, E., & Kozłowski, J. K. (2000). Première évidence de l'âge pré-éemien des industries à pièces bifaciales asymétriques en Europe centrale. In A. Ronen, & M. Weinstein-Evron (Eds.), *Toward Modern Humans. The Yabrudian and Micoquian 400–50 k-years ago* (pp. 167-172). Oxford: BAR Publishing.

Galbraith, R. F., Roberts, R. G., Laslett, G. M., Yoshida, H., Olley, J. (1999). Optical dating of single and multiple grains of quartz from Jinmium Rock Shelter, Northern Australia: Part I. Experimental design and statistical models. *Archaeometry*, *41*(2), 339-364. https://doi.org/10.1111/j.1475-4754.1999.tb00987.x

Gilpin, W., Feldman, M. W., & Aoki, K. (2016). An ecocultural model predicts Neanderthal extinction through competition with modern humans. *PNAS*, *113*(8), 2134-2139. https://doi.org/10.1073/pnas.1524861113

Guérin, G., Mercier, N., & Adamiec, G. (2011). Dose rate conversion factors: update. *Ancient TL*, *29*(1), 5-8.

Haesaerts, P., Damblon, F., Nigst, P., & Hublin, J.-J. (2013). ABA and ABOx radiocarbon cross-dating on charcoal from Middle Pleniglacial loess deposits in Austria, Moravia, and Western Ukraine. *Radiocarbon*, *55*(2), 641-647. https://doi.org/10.1017/S0033822200057799

Hajdinjak, M., Mafessoni, F., Skov, L., Vernot, B., Hübner, A., Fu, Q., ... & Pääbo, S. (2021). Initial Upper Palaeolithic humans in Europe had recent Neanderthal ancestry. *Nature*, *592*, 253-257. https://doi.org/10.1038/s41586-021-03335-3

Hublin, J.-J. (2009). The origin of Neandertals. *PNAS*, *106*(38), 16022-16027. https://doi.org/10.1073/pnas.0904119106

Hublin, J.-J., Sirakov, N., Aldeias, V., Bailey, S., Bard, E., Delvigne, V., ... & Tsanova, T. (2020). Initial Upper Palaeolithic *Homo sapiens* from Bacho Kiro Cave, Bulgaria. *Nature*, *581*, 299-302. https://doi.org/10.1038/s41586-020-2259-z

Jary, Z. (1996). *Chronostratygrafia oraz warunki sedymentacji lessów południowo-zachodniej Polski na przykładzie Płaskowyżu Głubczyckiego i Wzgórz Trzebnickich*. Studia Geograficzne, 63. Wrocław: Wydawnictwo Uniwersytetu Wrocławskiego.

Jersak, J. (1991). Lessy formacji umiarkowanie wilgotnej na Płaskowyżu Głubczyckim. In J. Jersak (Ed.), *Less i osady dolinne* (pp. 10-49). Prace Naukowe Uniwersytetu Śląskiego w Katowicach, 1107.

Jöris, O. (2006). Bifacially backed knives (Keilmesser) in the Central European Middle Palaeolithic. In N. Goren-Inbar, & G. Sharon (Eds.), *Axe age. Acheulian tool-making from quarry to discard* (pp. 287-310). London: Equinox Publishing.

Jöris, O., Neruda, P., Wiśniewski, A., & Weiss, M. (2022). The Late and Final Middle Palaeolithic of Central Europe and Its Contributions to the Formation of the Regional Upper Palaeolithic: a Review and a Synthesis. *Journal of Paleolithic Archaeology*, *5*, 17. https://doi.org/10.1007/s41982-022-00126-8

Jöris, O., & Street, M. (2008). At the end of the ^{14}C time scale—the Middle to Upper Paleolithic record of western Eurasia. *Journal of Human Evolution*, *55*(5), 782-802. https://doi.org/10.1016/j.jhevol.2008.04.002

Kot, M., Krajcarz, M. T., Moskal-del Hoyo, M., Gryczewska, N., Wojenka, M., Pyżewicz, K., ... & Mackiewicz, P. (2021). Chronostratigraphy of Jerzmanowician. New data from Koziarnia Cave, Poland. *Journal of Archaeological Science: Reports*, *38*, 103014. https://doi.org/10.1016/j.jasrep.2021.103014

Kowalski, S. (1967). Ciekawsze zabytki paleolityczne z najnowszych badań archeologicznych (1963-1965) w jaskini Ciemnej w Ojcowie, pow. Olkusz. *Materiały Archeologiczne*, *8*, 39-46.

Kozlowski, J. K. (2003). From bifaces to leaf points. In M. Soressi, & H. L. Dibble (Eds.), *Multiple approaches to the study of bifacial technologies* (pp. 149-163). Philadelphia: University of Pennsylvania, Museum of Archaeology and Anthropology.

Kozłowski, J. K. (1964). *Paleolit na Górnym Śląsku*. Wrocław-Warszawa-Kraków: Zakład Narodowy im. Ossolińskich.

Kozłowski, J. K. (1965). Stanowisko górnopaleolityczne Dzierżysław I, pow. Głubczyce na Górnym Śląsku w świetle badań przeprowadzonych w 1962 roku. *Wiadomości Archeologiczne*, *30*(3-4), 461-477.

Kozłowski, J. K. (2014). Middle Palaeolithic variability in Central Europe: Mousterian vs Micoquian. *Quaternary International*, *326-327*, 344-363. https://doi.org/10.1016/j.quaint.2013.08.020

Kozłowski, J. K. (2016). Taxonomy of the Early Middle Palaeolithic in Central Europe. *Litikum*, *4*, 19-27. https://doi.org/10.23898/litikuma0016

Kozłowski, J. K. (2017). Transcarpathian cultural connections and raw material circulation in the Middle/Upper Palaeolithic transition. *Anthropologie*, *55*(1-2), 27-41.

Kozłowski, J. K., & Kozłowski, S. K. (1996). *Le Paléolithique en Pologne*. Grenoble: Editions Jérôme Millon.

Krajcarz, M. T., & Madeyska, T. (2010). Application of the weathering parameters of bones to stratigraphical interpretation of the sediments from two caves (Deszczowa Cave and Nietoperzowa Cave, Kraków-Częstochowa Upland, Poland). *Studia Quaternaria*, *27*, 43-54.

Krajcarz, M. T., Krajcarz, M., Ginter, B., Goslar, T., & Wojtal, P. (2018). Towards a Chronology of the Jerzmanowician – a New Series of Radiocarbon Dates from Nietoperzowa Cave (Poland). *Archaeometry*, *60*(2), 383-401. https://doi.org/10.1111/arcm.12311

Kreutzer, S., Burow, C., Dietze, M., Fuchs., M., Schmidt, C., Fischer, M., ... & Mittelstrass, D. (2020). *Luminescence: Comprehensive Luminescence Dating Data Analysis. R package version 0.9.10*. https://CRAN.R-project.org/package=Luminescence. Accessed 2021 July 28.

Kreutzer, S., Schmidt, C., DeWitt, R., & Fuchs, M. (2014). The *a*-value of polymineral fine grain samples measured with the post-IR IRSL protocol. *Radiation Measurements*, *69*, 18-29. http://dx.doi.org/10.1016/j.radmeas.2014.04.027

Krukowski, S. (1939). Paleolit. In S. Krukowski, J. Kostrzewski, R. Jakimowicz (Eds.), *Prehistoria ziem polskich. Encyklopedia Polska* (pp. 1-117). Warszawa-Kraków: PAU.

Lindner, H. (1941). Neue Ergebnisse der Altsteinzeitforschung im südlichen Oberschlesien. *Nachrichtenblatt für deutsche Vorzeit*, *17*, 29-36.

Longin, R. (1971). New method of collagen extraction for radiocarbon dating. *Nature*, *230*(5291), 241-242. https://doi.org/10.1038/230241a0

Madeyska, T. (1982). The stratigraphy of Palaeolithic sites of the Cracow Upland. *Acta Geologica Polonica*, *32*(3-4), 227-242.

Madeyska-Niklewska, T. (1969). Górnoplejstoceńskie osady jaskiń Wyżyny Krakowskiej. *Acta Geologica Polonica*, *19*(2), 341-392.

Maier, A., & Zimmermann, A. (2017). Populations headed south? The Gravettian from a palaeodemographic point of view. *Antiquity*, *91*(357), 573-588. https://doi.org/10.15184/aqy.2017.37

Moska, P., Bluszcz, A., Poręba, G., Tudyka, K., Adamiec, G., Szymak, A., & Przybyła, A. (2021). Luminescence dating procedures at Gliwice Luminescence Dating Laboratory. *Geochronometria*, *48*(1), 1-15. https://doi.org/10.2478/geochr-2021-0001

Moska, P., Jary, Z., Adamiec, G., & Bluszcz, A. (2019). Chronostratigraphy of a loess-palaeosol sequence in Biały Kościół, Poland using OSL and radiocarbon dating. *Quaternary International*, *502*(Part A), 4-17. https://doi.org/10.1016/j.quaint.2018.05.024

Murray, A. S., & Wintle, A. G. (2000). Luminescence dating of quartz using an improved single-aliquot regenerative-dose protocol. *Radiation Measurements*, *32*(1), 57-73. http://dx.doi.org/10.1016/S1350-4487(99)00253-X

Mylopotamitaki, D., Weiss, M., Fewlass, H., Zavala, E. I., Rougier, H., Sümer, A. P., ... & Hublin, J.-J. (2024). *Homo sapiens* reached the higher latitudes of Europe by 45,000 years ago. *Nature*, *626*, 341-346. https://doi.org/10.1038/s41586-023-06923-7

Nejman, L., Rhodes, E., Škrdla, P., Tostevin, G., Neruda, P., Nerudová, Z., ... & Grün, R. (2011). New chronological evidence for the Middle to Upper Palaeolithic transition in the Czech Republic and Slovakia: New optically stimulated luminescence dating results. *Archaeometry*, *53*(5), 1044-1066. https://doi.org/10.1111/j.1475-4754.2011.00586.x

Neruda, P., & Nerudová, Z. (2013). The Middle-Upper Palaeolithic transition in Moravia in the context of the Middle Danube region. *Quaternary International*, *294*, 3-19. https://doi.org/10.1016/j.quaint.2011.08.035

Neruda, P., & Nerudová, Z. (2014). New radiocarbon data from Micoquian layers of the Kůlna Cave (Czech Republic). *Quaternary International*, *326-327*, 157-167. https://doi.org/10.1016/j.quaint.2013.10.015

Nowaczewska, W., Binkowski, M., Benazzi, S., Vazzana, A., Nadachowski, A., Stefaniak, K., ... & Hublin, J.-J. (2021). New hominin teeth from Stajnia Cave, Poland. *Journal of Human Evolution*, *151*, 102929. https://doi.org/10.1016/j.jhevol.2020.102929

Picin, A., Hajdinjak, M., Nowaczewska, W., Benazzi, S., Urbanowski, M., Marciszak, A., ... & Talamo, S. (2020). New perspectives on Neanderthal dispersal and turnover from Stajnia Cave (Poland). *Scientific Reports*, *10*, 14778. https://doi.org/10.1038/s41598-020-71504-x

Picin, A., Stefański, D., Cieśla, M., & Valde-Nowak, P. (2023). The Beginning of the Early Upper Paleolithic in Poland. *Journal of Paleolithic Archaeology*, *6*, 12. https://doi.org/10.1007/s41982-023-00140-4

Połtowicz-Bobak, M., Bobak, D., Badura, J., Wacnik, A., & Cywa, K. (2013). Nouvelles données sur le Szélétien en Pologne. In P. Bodu, L. Chehmana, L. Klaric, L. Mevel, S. Soriano, N. Teyssandier (Eds.), *Le Paléolithique supérieur ancien de l'Europe du Nord-Ouest* (pp. 485-496). Société Préhistorique Française.

Prescott, J. R., & Hutton, J. T. (1994). Cosmic ray contributions to dose rates for luminescence and ESR dating: Large depths and long-term time variations. *Radiation Measurements*, *23*(2-3), 497-500. http://dx.doi.org/10.1016/1350-4487(94)90086-8

Reimer, P. J., Austin, W. E. N., Bard, E., Bayliss, A., Blackwell, P. G., Bronk Ramsey, C., ... & Talamo, S. (2020). The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0-55 cal kBP). *Radiocarbon*, *62*(4), 725-757. https://doi.org/10.1017/RDC.2020.41

Richter, D., Tostevin, G., Škrdla, P., & Davies, W. (2009). New radiometric ages for the Early Upper Palaeolithic type locality of Brno-Bohunice (Czech Republic): comparison of OSL, IRSL, TL and ^{14}C dating results. *Journal of Archaeological Science*, *36*(3), 708-720. https://doi.org/10.1016/j.jas.2008.10.017

Richter, J. (2002). Die ^{14}C-Daten aus der Sesselfelsgrotte und die Zeitstellung des Micoquien/M.M.O. *Germania*, *80*, 1-22.

Roebroeks, W., Hublin, J.-J., & MacDonald, K. (2011). Continuities and Discontinuities in Neandertal Presence: A Closer Look at Northwestern Europe. In N. Ashton, S. G. Lewis, & C. Stringer (Eds.), *The ancient human occupation of Britain* (pp. 113-123). Developments in Quaternary Sciences, 14. Amsterdam: Elsevier.

Sitlivy, V., Zięba, A., & Sobczyk, K. (2009). *Middle and Early Upper Palaeolithic of Krakow region. Księcia Józefa*. Monographie de Préhistoire Générale, 7. Bruxelles: Musées royaux d'Art et d'Histoire.

Skrzypek, G., Wiśniewski, A., & Grierson, P. F. (2011). How cold was it for Neanderthals moving to Central Europe during warm phases of the last glaciation? *Quaternary Science Reviews*, *30*(5-6), 481-487. https://doi.org/10.1016/j.quascirev.2010.12.018

Stefański, D. (2018). The Early Upper Palaeolithic assemblage of arch-backed points from Kraków-Zwierzyniec site 1. In P. Valde-Nowak, K. Sobczyk, M. Nowak, & J. Źrałka (Eds.), *Multas per gentes et multa per saecula* (pp. 63-70). Kraków: Jagiellonian University.

Stepanchuk, V. (2006). *Niznyi i srednyi paleolit Ukrainy*. Cernovcy: Zelena Bukovina.

Talamo, S., Nowaczewska, W., Picin, A., Vazzana, A., Binkowski, M., Bosch, M. D., ... & Hublin, J.-J. (2021). A 41,500 year-old decorated ivory pendant from Stajnia Cave (Poland). *Scientific Reports*, *11*, 22078. https://doi.org/10.1038/s41598-021-01221-6

Talamo, S., & Richards, M. (2011). A Comparison of Bone Pretreatment Methods for AMS Dating of Samples >30,000 BP. *Radiocarbon*, *53*(3), 443-449. https://doi.org/10.1017/S0033822200034573

Timmermann, A., Yun, K.-S., Raia, P., Ruan, J., Mondanaro, A., Zeller, E., ... & Ganopolski, A. (2022). Climate effects on archaic human habitats and species successions. *Nature*, *604*, 495-501. https://doi.org/10.1038/s41586-022-04600-9

Thomsen, K. J., Murray, A. S., Jain, M., & Bøtter-Jensen, L. (2008). Laboratory fading rates of various luminescence signals from feldspar-rich sediment extracts. *Radiation Measurements*, *43*(9-10), 1474-1486. http://dx.doi.org/10.1016/j.radmeas.2008.06.002

Tudyka, K., Koruszowic, M., Osadnik, R., Adamiec, G., Moska, P., Szymak, A., … & Poręba, G. (2023). μRate: An online dose rate calculator for trapped charge dating. *Archaeometry*, *65*(2), 423-443. https://doi.org/10.1111/arcm.12828

Urbanowski, M., Socha, P., Dąbrowski, P., Nowaczewska, W., Sadakierska-Chudy, A., Dobosz, T., … & Nadachowski, A. (2010). The first Neanderthal tooth found North of the Carpathian Mountains. *Naturwissenschaften*, *97*, 411-415. https://doi.org/10.1007/s00114-010-0646-2

Valde-Nowak, P. (2009). Obłazowa and Hłomcza: Two Paleolithic sites in the North Carpathians province of Southern Poland. In B. Adams, & B. S. Blades (Eds.), *Lithic materials and Paleolithic societies* (pp. 196-207). Oxford: Willey-Blackwell Publishing. https://doi.org/10.1002/9781444311976.ch14

Valde-Nowak, P., Alex, B., Ginter, B., Krajcarz, M. T., Madeyska, T., Miękina, B., … & Zarzecka-Szubińska, K. (2014). Middle Paleolithic sequences of the Ciemna Cave (Prądnik valley, Poland): The problem of synchronisation. *Quaternary International*, *326-327*, 125-145. https://doi.org/10.1016/j.quaint.2014.01.002

Valde-Nowak, P., Alex, B., Ginter, B., Krajcarz, M. T., Madeyska, T., Miękina, B., … & Zarzecka-Szubińska, K. (2016). Late Middle Palaeolithic occupations in Ciemna Cave, southern Poland. *Journal of Field Archaeology*, *41*(2), 193-210.

Valde-Nowak, P., & Nadachowski, A. (2014). Micoquian assemblage and environmental conditions for the Neanderthals in Obłazowa Cave, Western Carpathians, Poland. *Quaternary International*, *326-327*, 146-156. https://doi.org/10.1016/j.quaint.2013.08.057

Valde-Nowak, P., Nadachowski, A., & Madeyska, T. (Eds.) (2003). *Obłazowa Cave. Human activity, stratigraphy and palaeoenvironment*. Kraków: Institute of Archaeology and Ethnology Polish Academy of Sciences.

Van Klinken, G. J., Bowles, A. D., & Hedges, R. E. M. (1994). Radiocarbon dating of peptides isolated from contaminated fossil bone collagen by collagenase digestion and reversed-phase chromatography. *Geochimica et Cosmochimica Acta*, *58*(11), 2543-2551. https://doi.org/10.1016/0016-7037(94)90030-2

Weiss, M. (2015). Stone tool analysis and context of a new late Middle Paleolithic site in western central Europe – Pouch-Terrassenpfeiler, Ldkr. Anhalt-Bitterfeld, Germany. *Quartär*, *62*, 23-62. https://doi.org/10.7485/QU62_2

Wiśniewski, A. (2016). The First humans. Societies of the Lower and Middle Palaeolithic. In J. Kabaciński (Ed.), *The Past Societies 1. 500,000 – 5,500 BC* (pp. 45-96). Warszawa: Instytut Archeologii i Etnologii PAN.

Wiśniewski, A., Adamiec, G., Badura, J., Bluszcz, A., Kowalska, A., Kufel-Diakowska, B., … & Zych, J. (2013). Occupation dynamics north of the Carpathians and Sudetes during the Weichselian (MIS5d-3): The Lower Silesia (SW Poland) case study. *Quaternary International*, *294*, 20-40. https://doi.org/10.1016/j.quaint.2011.09.016

Wiśniewski, A., Jary, Z., Moska, P., Pyżewicz, K., Ciombor, M., Krawczyk, M., & Kasprzak, M. (2022a). Middle Palaeolithic, Transitional or Upper Palaeolithic: Geoarchaeological revision of the southern part of the loess site Dzierżysław 1, SW Poland. *Quaternary International*, *632*, 94-111. https://doi.org/10.1016/j.quaint.2021.10.015

Wiśniewski, A., Lauer, T., Chłoń, M., Pyżewicz, K., Weiss, M., Badura, J., … & Zarzecka-Szubińska, K. (2019). Looking for provisioning places of shaped tools of the late Neanderthals: A study of a Micoquian open-air site, Pietraszyn 49a (southwestern Poland). *Comptes Rendus Palevol*, *18*(3), 367-389. https://doi.org/10.1016/j.crpv.2019.01.003

Wiśniewski, A., Pyżewicz, K., Serwatka, K., Kot, M., Kerneder-Gubała, K., & Gruždź, W. (2022b). Lincombian-Ranisian-Jerzmanowician points were used primarily as hunting weapons: morphological and functional analysis of points from Nietoperzowa Cave, southern Poland. *Archaeological and Anthropological Sciences*, *14*, 90. https://doi.org/10.1007/s12520-022-01552-z

Wiśniewski, A., Wilczyński, J., Przybylski, B., Ciombor, M., & Stefaniak, K. (2023). Bovid Bone Accumulation in Late Middle Palaeolithic Poland. *Journal of Field Archaeology*, *48*(3), 180-197. https://doi.org/10.1080/00934690.2022.2142384

Wood, R. E., Douka, K., Boscato, P., Haesaerts, P., Sinitsyn, A., & Higham, T. F. G. (2012). Testing the ABOx-SC method: Dating known-age charcoals associated with the Campanian Ignimbrite. *Quaternary Geochronology*, *9*, 16-26. https://doi.org/10.1016/j.quageo.2012.02.003

Żarski, M., Winter, H., Nadachowski, A., Urbanowski, M., Socha, P., Kenig, K., … & Marciszak, A. (2017). Stratigraphy and palaeoenvironment of Stajnia Cave (southern Poland) with regard to habitation of the site by Neanderthals. *Geological Quarterly*, *61*(2), 350-369. https://doi.org/10.7306/gq.1355

Article first received • 14 February 2024
Article accepted • 6 May 2024