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Nucléus mésolithique de Glanów. Collection de Musée archéologique de Cracovie (grâce a l'aimable autorisation de Mirosław Zając; photo par Agnieszka Susuł)

ADRESSE DE LA RÉDACTION
Instytut Archeologii Uniwersytetu Jagiellońskiego, ul. Gołębia 11, PL 31-007 Kraków
mniauj@interia.pl; mszprzybyla@gmail.com

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Professor BOLESŁAW GINTER

THIS VOLUME OF *RECHERCHES ARCHÉOLOGIQUES, NOUVELLE SERIE*
IS DEDICATED
TO PROFESSOR BOLESŁAW GINTER
ON HIS 75TH BIRTHDAY

In 2013 Professor Bolesław Ginter turned seventy five, therefore his students, colleagues and friends, together with editorial board of *Recherches Archaéologiques NS*, decided to dedicate to him the 5th and 6th volumes combined.

Professor is one of the most eminent and respected European authorities in the field of Paleolithic and Mesolithic issues. In 1961 he graduated from the Faculty of Philosophy and History at the Jagiellonian University, reaching his master's degree in archaeology. In 1966 he acquired his PhD and in 1973 he became Assistant Professor. In 1985 he received the title of Associate Professor and he obtained the full professorship in 1994. He is an educator and researcher, appreciated in many different centers. He has been conducting lectures at the University of Rzeszów since several years and in 2011 he was granted the *honoris causa* doctorate of the University of Wrocław. During his academic career he held scientific internships and invited lectures in the Czech Republic, Slovakia, Ukraine, Germany, Denmark, Switzerland and Italy. In the years 1984–1987 Professor Bolesław Ginter was Vice Dean of the Faculty of History and Philosophy at the Jagiellonian University and in the years 1990–1993 the Vice Rector. From 1985 to 2008 he was head of the Department of Stone Age Archaeology at the Jagiellonian University. Professor was a member of the Central Council of Science and Higher Education, and from January 3'rd 2003, he served as Vice Chairman of the eighth cadency. Professor Bolesław Ginter conducted excavations at many sites. As particularly important we should mention the Balkan works, which embraced, e.g. Middle- and Upper Paleolithic sequences in Bacho Kiro and Temnata Caves. Last but not least were the works in Egypt, which initially had been performed in cooperation with the Centre of Mediterranean Archaeology of the University of Warsaw and subsequently were run by share of the *Deutsches Archäologisches Institut* and encompassed predynastic positions of El-Tarif and Armant (west and south of Luxor) and also Qasr el-Sagha (north of the Fayum Oasis). In the years 1994–2005 Professor co-led the excavations in the Peloponnese, in the cave no. 1, in the Klissoura Gorge in Argolid. They led to the documentation of the first comprehensive sequence of the Neanderthal stratum in this part of Meditteranean Europe. From among Polish positions we should distinguish co-direction of a long-term, so far lasting project of the research of the main chamber of the Ciemna Cave in Ojców. He also directed an investigative project of the Committee for Scientific Research: "The site of the Magdalenian culture in Dzierżysław in Upper Silesia".

Professor's studies enriched the Paleolithic flint workshops systematics by contents of fundamental significance. It can be best proven by the brilliant habillitation thesis titled *Wydobywanie, przetwórstwo i dystrybucja surowców i wyrobów krzemiennych w schyłkowym paleolicie północnej części Europy* środkowej from 1974 and the monograph from the same year *Spätpaläolithikum in Oberschlesien und im Oberen Warta Flussgebiet*. Among other monographs, it would be hard not to mention about such important, co-edited

items like *Excavation in the Bacho Kiro Cave (Bulgaria)*, *Predynastic Settlement near Armant*, *Temnata Cave. Excavation in Karlukovo Karst Area, Bulgaria* (1992, 1994, 2000), and also co-authorship of an eminent and repeatedly resumed academic textbook *Technika obróbki i typologia wyrobów kamiennych paleolitu i mezolitu* (1975).

Professor Bolesław Ginter has published a total of 170 scientific items. He is the author, co-author or co-editor of 14 books. He supervised 19 masters and 5 doctors. He has participated in the sessions of numerous scientific bodies on the electoral basis. Professor is a deputy president of the Comittee of Prae- and Protohistoric Sciences Polish Academy of Sciences, a member of the boeard of Archaeological Commission of the Kraków Branch of Polish Academy of Sciences, and member of following Commisions of the Polish Academy of Art and Sciences: Paleogeography of Quaternary, European Affairs, Praehistory of Polish Carpathians. He is deputy chairman of the XXXII Commission of *Union Internationale des Sciences Préhistoriques et Protohistoriques*, member correspondent of *Deutsches Archäologisches Institut,* member of International Association of Egyptologists and American Academy in Rome.

In recognition of his services, Professor Bolesław Ginter was six times individually awarded and twice as a team by the Minister of Education. Eight times he received the Award of the rector of the Jagiellonian University. He was honored by the Knight's Cross and Officer's Cross of the Order of Polonia Restituta and the Medal of the National Education Commission.

Paweł Valde-Nowak

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Dariusz Bobak[1], Marta Połtowicz-Bobak[2]

Bayesian age modelling of the Magdalenian settlement in the territory of present-day Poland

Abstract: The paper addresses the problem of the use of Bayesian methods for modelling age of the Magdalenian settlement on the territory of contemporary Poland. Basing on 14C datings of 10 sites we present the chronological frames of settlement on particular sites and we model occupation dynamic of Polish territory. Bayesian methods made it possible to clarify and in some cases to significantly narrow time frames of Magdalenian settlement on the research area.

Keywords: Bayesian methods, chronology, age modelling, Magdalenian, Poland

1. Introduction

The chronology of the discussed phenomena belongs to the most important problems of the studies on the earliest history of mankind. It includes the dating of individual sites as well as the determination of chronological frames for entire taxonomic units.

Undoubtedly, a turning point in the studies on chronology of prehistoric sites was the popularization of dating with the use of the ^{14}C method, especially the AMS technique, allowing for the dating of the tiniest organic remains. Its application is especially important in the studies on the Old Stone Age. Pieces of charcoal or bones found frequently at Palaeolithic sites are often too small to be dated with the use of the standard method.

In recent years, the increase of the number of datings related to Palaeolithic sites from the territory of Poland has been noted. It refers to the number of sites for which ^{14}C datings were obtained as well as to the number of dates coming from individual sites.

Such a situation can be observed also in the case of Magdalenian sites. From among almost 40 assemblages belonging to this taxonomic unit, ten (Fig. 1) provided ^{14}C dates obtained from bones (5 sites) or wood charcoal (4 sites). In one case the dates were obtained from bones and from charcoal (Wilczyce). From one site (Hłomcza) only TL dates come. Only two sites (the cave in Zalas,

[1] Foundation of the Rzeszów Archaeological Centre & Institute of Archaeology, Rzeszów University; Moniuszki St. 10, 35-015 Rzeszów, Poland; dbobak@lithics.eu
[2] Institute of Archaeology, Rzeszów University; Rzeszów, Poland.

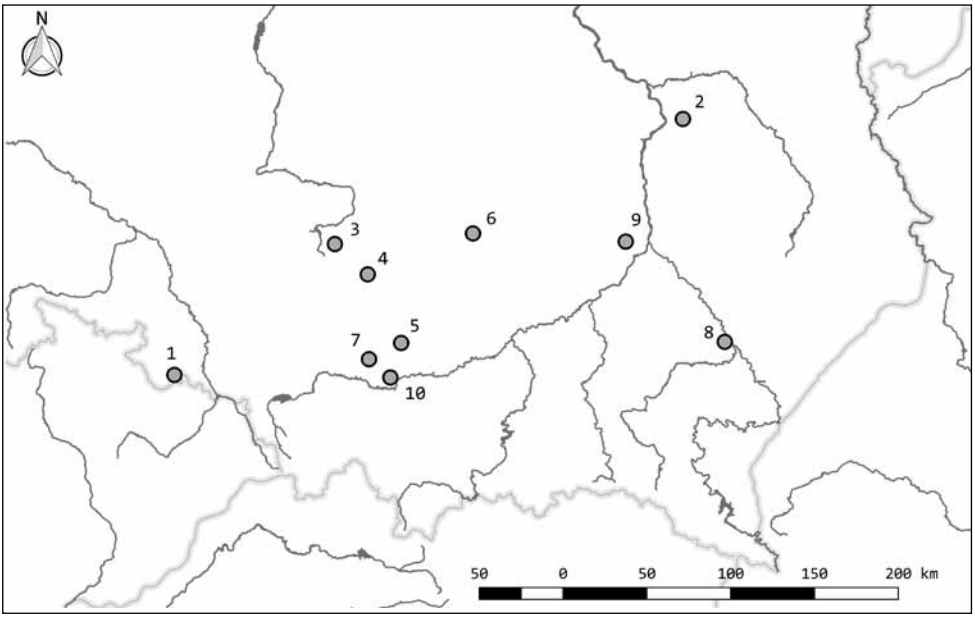

Fig. 1. Location of the sites being subject of the analysis: 1 – Dzierżysław; 2 – Klementowice; 3 – Komarowa Cave; 4 – Krucza Skała Cave; 5 – Maszycka Cave; 6 – Mosty; 7 – W Zalasie Cave; 8 – Wierzawice; 9 – Wilczyce, 10 – Wołowice

the Krucza Skała cave) provided the dates coming from more than one layer (Bocheński *et al*. 1985; Nadachowski *et al*. 2009). From four sites more than two dates were obtained, from three – two dates, including TL dates from one site, and from four – one date per each site (Table 1).

The analysis of the chronology of the Magdalenian settlement in Poland and other areas is presented in another paper (Połtowicz-Bobak 2013). The oldest dates come from the site in the Maszycka cave marking the earliest horizon of the Magdalenian settlement in the territory of present-day Poland (Kozłowski *et al*. 2012), preceding the next, main phase of the settlement by approximately 1,000 years. The main stage of settlement linked with the late Magdalenian began in the cold period GS-2a[1] corresponding roughly to Dryas I and continued until the beginning of the warming correlated with the Allerød interstadial. At a few sites (Dzierżysław, Wilczyce) ^{14}C dates may suggest that these sites were resettled many times for a long period; however, the interpretation of Dzierżysław dates is disputable (see Połtowicz-Bobak 2013, discussion p. 123). Recently published dates from Wilczyce (Schild 2014) seem to confirm that hypothesis. Regardless of all limitations resulting mainly from a relatively small number of sites dated with the use of the ^{14}C method, the analysis of the obtained dates allows us to draw some general conclusions regarding the Magdalenian settlement in the eastern part of Central Europe, including Poland (Połtowicz-Bobak 2013, 128–129).

[1] The chronological division and the reconstruction of palaeoclimatic events of the Late Glacial is based on the Greenland Ice Core Chronology 2005 (GICC05) timescale, which correlates annually counted layers from high resolution ice-cores (Andersen *et al.* 2006, Rasmussen *et al.* 2006, Svensson *et al.* 2008, Rasmussen *et al.* 2008, Svensson *et al.* 2008).

First of all, it seems that the expansion of the Magdalenian population to the east took place very quickly. The eastern boundaries of the Magdalenian range were reached almost at the same time in which other areas of Central Europe were occupied, that is during GS-2a. It also seems to be certain that the Magdalenian settlement in the territory of present-day Poland had been taking place continuously since the cold stage of GS-2a. It is impossible to distinguish two separate episodes – the older, less intense settlement during the cold phase (GS-2a) and the more intense in the warm phase (GI-1e). Therefore, it should be assumed that the climatic and environmental changes that took place at the turn of GS-2a and GI-1e have no significant impact on the expansion of the Magdalenian settlement to the east and north (Połtowicz-Bobak 2013, 128–129).

The above data constitute the basis for further discussions and studies aimed at finding more details and their verification. Some dates are also uncertain, including the series of dates from some sites. The very young "Allerød" dating of the Magdalenian, evidenced by the ^{14}C dates from a few sites, mainly from the very well preserved site in Wierzawice in south-eastern Poland (Bobak *et al.* 2010) and the youngest dates from Wilczyce (Schild 2014) is also disputable.

The basic problems connected with the chronology may be divided into two main groups. The first is the question regarding the chronology of the settlement at specific sites, how long they were occupied, whether and how many different phases may be distinguished and what the chronologic relation between them is. It mainly concerns big sites without stratigraphic data, but also those on which more than one layer containing Magdalenian materials was found.

The second, but no less important question is the establishment of the chronological frames of the settlement in a given territory, in this case in present-day Poland area as well as the directions and the rate of its spreading within the described area.

The attempt to resolve these problems is made in the present paper.

2. Research method

The theoretical grounds of the Bayesian approach to the interpretation of data are included in Bayes theorem (Bayes 1763, Fig. 1). In short, it consists in the analysis of new data related to the analysed problem ("the standardized likelihood") in the context of previous knowledge regarding that problem ("prior likelihood"). The theoretical grounds and practical application of this type of attitude was extensively described in the research literature on the subject (Litton, Buck 1995; Bronk Ramsey 1995; 1998; Buck, Sahu 2000; Bayliss *et al*. 2007; Blaauw *et al*. 2007; Bronk Ramsey 2009a; Parnell *et al*. 2011). It should be emphasised that this kind of modelling allows the drawing of conclusions that are more statistically reliable and to create a more realistic evaluation of the chronology of archaeological events.

The main assumption of this paper was the creation of the model that would allow us to determine the chronological frames of the settlement at the Magdalenian sites within the territory of Poland in a more reliable way than a simple collection of the ranges of individual datings. The model was made in the Chronological Query Language 2 (CQL2) and processed by the software OxCal 4.2, web interface build 86 (Bronk Ramsey 2009a) run on a private server. The results were calculated in two ranges of probability: 1 and 2 sigma (that is at 68.2% and 95.4% significance levels). In the analysis, the results at 1σ significance level were taken into account, which enabled to achieve more precise conclusions at the expense of lower confidence of the obtained

Table 1. Results of the modelling of the radiocarbon dates from the Magdalenian sites in Poland

Stanowisko	Unmodelled (BP)					Modelled (BP)				
	68,2		95,4			68,2		95,4		
	from	to	from	to	median	from	to	from	to	median
Boundary Maszycka-start						**18558**	**18255**	**18943**	**18159**	**18432**
R_Date Maszycka Cave (KIA-39228)	18513	18337	18603	18238	18423	18440	18245	18532	18151	18343
R_Date Maszycka Cave (KIA-39226)	18353	18168	18430	18057	18257	18334	18179	18403	18085	18255
R_Date Maszycka Cave (KIA-39227)	18342	18158	18416	18045	18245	18326	18174	18394	18077	18248
R_Date Maszycka Cave (KIA-39225)	18155	17960	18264	17882	18062	18266	18061	18320	17950	18152
R_Date Maszycka Cave (Ly-2453)	17982	17392	18289	17063	17679	18329	18029	18432	17705	18170
R_Date Maszycka Cave (Ly-2454)	19115	18391	19527	18053	18767	18432	18144	18726	17992	18297
Boundary Maszycka-end						**18251**	**17908**	**18316**	**17497**	**18044**
Boundary Dzierżysław-start						**16395**	**16014**	**16943**	**15901**	**16247**
R_Date Dzierżysław 35 (Poz-10136)	17354	17099	17476	16988	17226	17354	17099	17476	16988	17226
R_Date Dzierżysław 35 (GdA-69)	16375	16114	16543	16000	16255	16253	15998	16395	15895	16132
R_Date Dzierżysław 35 (GdA-193)	16216	15967	16320	15820	16086	16155	15942	16265	15841	16050
R_Date Dzierżysław 35 (GdA-70)	16009	15775	16125	15660	15891	16050	15849	16127	15731	15945
R_Date Dzierżysław 35 (Poz-10135)	15950	15732	16061	15629	15839	16023	15820	16092	15708	15915
R_Date Dzierżysław 35 (Poz-7318)	14140	13925	14206	13783	14023	14141	13925	14206	13783	14023
Boundary Dzierżysław-end						**15991**	**15653**	**16088**	**15136**	**15785**
Boundary Wilczyce-start						**16053**	**15800**	**16303**	**15716**	**15945**
R_Date Wilczyce 10 (OxA-16728)	15950	15732	16061	15629	15839	15891	15702	16004	15597	15795
R_Date Wilczyce 10 (OxA-26545)	15926	15690	16052	15561	15804	15876	15668	15996	15534	15769
R_Date Wilczyce 10 (OxA-26546)	15886	15637	16015	15475	15758	15851	15629	15963	15459	15735
R_Date Wilczyce 10 (Poz-14891)	15725	15451	15812	15316	15586	15721	15455	15800	15319	15583
R_Date Wilczyce 10 (Poz-19048)	15725	15355	15911	15217	15553	15718	15363	15866	15224	15545
R_Date Wilczyce 10 (Poz-3914)	15613	15350	15735	15266	15492	15611	15350	15733	15267	15492
R_Date Wilczyce 10 (OxA-16729)	15474	15229	15611	15155	15359	15475	15230	15610	15155	15359
R_Date Wilczyce 10 (Poz-3927)	15431	15178	15600	15110	15316	15431	15179	15599	15110	15316
R_Date Wilczyce 10 (Poz-14892)	15446	15026	15667	14748	15219	15447	15028	15664	14750	15219
R_Date Wilczyce 10 (Poz-3926)	15140	14866	15223	14694	14991	15140	14865	15222	14694	14991
R_Date Wilczyce 10 (Poz-14463)	15091	14671	15155	14327	14831	15091	14672	15154	14327	14831
R_Date Wilczyce 10 (Poz-14384)	14916	14436	15058	14252	14664	14917	14436	15057	14252	14664
R_Date Wilczyce 10 (Poz-14385)	14697	14202	14986	14098	14489	14696	14202	14986	14097	14489
R_Date Wilczyce 10 (Ua-20413)	14521	14097	14811	14004	14336	14517	14097	14811	14003	14337
R_Date Wilczyce 10 (Ua-20412)	14079	13829	14200	13750	13968	14079	13829	14200	13750	13968
R_Date Wilczyce 10 (Poz-19046)	13985	13612	14134	13480	13816	13985	13612	14133	13480	13816
R_Date Wilczyce 10 (Ua-15723)	13815	13565	13992	13479	13712	13816	13565	13992	13479	13712
R_Date Wilczyce 10 (Poz-19049)	13824	13547	14005	13459	13695	13823	13547	14005	13458	13696
R_Date Wilczyce 10 (Ua-15722)	13696	13332	13771	13237	13500	13694	13333	13770	13247	13501
R_Date Wilczyce 10 (Poz-19047)	13252	13126	13295	13079	13187	13276	13156	13315	13090	13214
R_Date Wilczyce 10 (Ua-15720)	13369	13116	13538	13017	13249	13395	13170	13490	13071	13281

Boundary Wilczyce – end						**13233**	**13011**	**13296**	**12760**	**13103**
Boundary Krucza Skała – start						**16427**	**15415**	**18042**	**15271**	**16021**
Boundary Krucza Skała I – start						***15796***	***15331***	***16450***	***15210***	***15610***
R_Date Krucza Skała l. 1 (Poz-1138)	15041	14590	15109	14311	14772	15111	14858	15190	14663	14970
R_Date Krucza Skała l. 2/4 (Poz-27245)	15630	15365	15745	15275	15506	15535	15290	15690	15220	15422
Boundary Krucza Skała I – end						***15015***	***14656***	***15115***	***14435***	***14815***
Boundary Krucza Skała II – start						***14753***	***14364***	***14943***	***14243***	***14574***
R_Date Krucza Skała l. 3/4 (Poz-27261)	14904	14450	15041	14269	14668	14545	14238	14749	14158	14406
R_Date Krucza Skała l. 3 (Poz-1139)	13943	13746	14045	13608	13837	13975	13772	14095	13709	13886
Boundary Krucza Skała II – end						***13910***	***13517***	***14005***	***13251***	***13689***
Boundary Krucza Skała III – start						***13422***	***13090***	***13713***	***13035***	***13283***
R_Date Krucza Skała l. 4 (Lod-407)	13464	13100	13735	12914	13299	13278	13054	13470	12933	13165
R_Date Krucza Skała l. 6 (Poz-1141)	13145	13011	13241	12890	13078	13161	13032	13269	12971	13099
Boundary Krucza Skała III – end						***13156***	***12877***	***13260***	***12425***	***13003***
Boundary Krucza Skała – end						**13096**	**12262**	**13203**	**10781**	**12606**
Boundary W Zalasie-start						**18386**	**15109**	**18393**	**15080**	**15751**
R_Date W Zalasie Cave l. 11 (OxA-6625)	15410	15145	15613	15063	15290	15370	15127	15585	15040	15261
R_Date W Zalasie Cave l. 7 (OxA-6591)	15078	14526	15170	14230	14759	15147	14692	15225	14313	14883
Boundary W Zalasie – end						**15166**	**11419**	**15212**	**11413**	**14324**
Boundary Wierzawice – start						**14976**	**13328**	**14983**	**13315**	**13709**
R_Date Wierzawice 31 (Poz-36901)	13446	13351	13471	13300	13395	13439	13338	13467	13295	13388
R_Date Wierzawice 31 (Poz-41200)	13060	12815	13160	12714	12938	13095	12830	13259	12731	12985
Boundary Wierzawice – end						**13151**	**10872**	**13240**	**10868**	**12616**
R_Date Klementowice 20 (Poz-54822)	15310	15021	15485	14764	15160	15310	15020	15485	14765	15160
R_Date Komarowa Cave (Poz-6621)	14271	14057	14532	13980	14178	14271	14057	14531	13980	14178
R_Date Mosty (Lod-107)	13411	12876	13717	12702	13158	13410	12839	13716	12702	13158
R_Date Wołowice (Gd-4654)	13030	12692	13223	12425	12839	13029	12690	13220	12425	12840

results. The calibration of ^{14}C dates was carried out on the base of IntCal13 curve (Reimer 2013).

The basic commands used in the model are as follows:

- *Sequence* – putting the series of events in a chronological order;
- *Phase* – treating a series of dates as corresponding to the same event without determining a chronological sequence between them;
- *Boundary* – in this model, the query calculating the start and end date for a given group of dates (*phase*), that is determination of the probable extent of the beginning and the end of the settlement at the site.

While creating the model for this paper, the sites were divided into three categories:

1. The sites with one absolute date. The dates from these sites were not included in the model as elements of a phase or sequence, and therefore – their start and end boundaries were not modelled; they were only presented on the graph (Fig. 2) as the calibrated radiocarbon dates.
2. The sites with more than one date for which the relation with one settlement phase was created. These dates were grouped with the command *Phase* and

Fig. 2. Bayesian model of the chronology of the Magdalenian sites in Poland

their start and end boundaries were calculated.

3. The sites with a few absolute dates accompanied with additional (mostly stratigraphic) information regarding their relative chronology. In the case of these sites, the series of dates coming from one stratigraphic unit were grouped with the command *Phase,* and the individual stratigraphic units were arranged into sequences (with *Sequence* command).

For each such group, the start and end dates were calculated. In the case of the sites belonging to group 3, the boundaries for individual phases (layers) were also calculated.

The created model consists of two basic types of multi-phase models: sequential and overlapping (Bronk Ramsey 2009a, 349).

The ^{14}C dates from ten sites and TL dates from one site were analysed. During the preliminary selection, the most uncertain dates were rejected. The ^{14}C dates from Dzierżysław obtained in the laboratory in Kiev were omitted. It was caused by the fact that the laboratory used a method other than the method applied to most cases which consisted in the dating of big bone samples, often burnt. The dated material was a total mass of bones, not only the collagen extracted from these bones. The use of such samples brought results which were inconsistent with the other results obtained from typical and small, but generally pure, samples. The doubts regarding the accuracy of these dates are additionally more justified by the framework of standard errors (approx. 300–450 years) and also by the fact that these dates are significantly – even by a thousand years – older than other AMS dates (except for one) coming from that site.

The youngest date from the cave in Zalas coming from the hearth charcoal discovered in the layer above the Magdalenian layer was also omitted (Bocheński *et al*. 1985; Kozłowski, Pettitt 2001). The said layer provided very few artefacts and it cannot be stated undoubtedly that they are actually the traces of the presence of the Magdalenian people.

No reliable model of the chronology of the settlement of Hłomcza site can be proposed due to the character of the dates, in particular due to huge standard errors of TL dating, thus the dates from the site were rejected.

The remaining dates were included in the analysed model.

The model was processed twice. In the first run, all dates were taken into account, in the second run – some dates were marked as outliers and were not included during the calculation process (and marked with question mark on the Fig. 2). These are the dates for which an internal agreement index calculated during the first run was less than 60% (Bronk Ramsey 2009b) or the dates for which ^{14}C datings are reasonably questionable regarding the link of the dated material with the analysed settlement layer.

3. Duration and phases of occupation of Magdalenian sites

The most data relating to the period of settlement may be obtained from the sites from which a series of dates come. So far, there are four such sites: the Maszycka cave (Kozłowski *et al*. 2012), Dzierżysław (Ginter *et al*. 2005; Połtowicz-Bobak 2013), Wilczyce (Fiedorczuk 2006; Irish *et al*. 2008, Schild 2014) and the Krucza Skała cave. In the last one, three additional layers were distinguished (Cyrek 1994; 1999; Nadachowski *et al*. 2009).

The oldest dates come from the Maszycka cave. In total, six dates were obtained from this site – two with the use of the conventional method (Ly-2453 and Ly-2454), and four – the AMS technique (KIA-39228, KIA-39226, KIA-39227, KIA-39225). All the values are similar although it can be

observed that the dates obtained with the use of the conventional method are a big older and a bit younger than the AMS dates, accordingly. The values of the AMS dates are comparable. The conventional dates also have a bigger standard error. The range of ^{14}C dates covers a quite long period of time equalling more than 1000 years. The age modelling allowed these time limits to be significantly restricted. Based on the modelling it can be stated that the Magdalenian settlement episode in the Maszycka cave probably happened between 18558 and 17908 cal. BP. Thus, the possible duration of the penetration of the group of hunters into Little Poland may be limited to the period of around 650 years. It is also worth paying attention to a distinct shift – "verification" of the conventional dates what were adjusted, as the result of modelling, to the other dates that indicate the more probable time of settlement. The considerable compactness of the modelled period of time indicating actually the single settlement episode at that site and the pureness of dated samples as well as their connection and contemporaneity with the settlement can be noted.

The series of six dates also comes from the Dzierżysław 35 site. All dates were obtained from animal bones, mainly mammoth, one – (Poz-7318) – from burnt bones. After modelling, four of them (GdA-69, GdA-193, GdA-70, Poz-10135) spans around the period of time between 16395 and 15653 cal. BP. There are no distinct intervals within these periods that could be interpreted as separate phases of settlement.

Two dates: one much older (Poz-10136) and one much younger (Poz-7318) differ significantly from the coherent picture presented above. The oldest date – 14150±70 uncal. BP (Poz-10136) comes from the bone (tooth) of the mammoth found in the pit directly linked with a residential place (Ginter *et al*. 2002). However, this tooth might have belonged to an animal that died a long time before and got to the site due to the collecting of bones in the vicinity. This hypothesis is supported by the fact that from the mammoth bones unearthed at the site a series of dates close to 40000 uncal. BP years were obtained (unpublished reports from the laboratories in Gliwice and Kiev). The youngest date (12150±70 uncal. BP, Poz-7318) comes from the burnt bones dated in the laboratory in Poznań. It is similar to one of the younger dates obtained in the Kiev laboratory. Such an age, much younger than determined on the basis of most of the samples, may be the consequence of the contamination of samples and, as a result, a false shifting of the date to a younger period. It is possible due to the type of dated material, that is burnt bones.

Therefore, it seems that both the dates that are significantly different from the modelled period of time of the probable inhabitation of the site may be incorrect and, as such, they should be accepted with considerable caution. In light of the above presented remarks, these dates should be treated as outliers. Thus, it can be assumed that the settlement in Dzierżysław consisted of one phase that corresponds to the phase within the period from 16395 to 15653 cal. BP. Of course, it does not mean that the site was set up during one stay of the group of hunters. Undoubtedly, it was revisited many times, but it seems that it happened within some continuous periods of time, in one- or a few-year cycles. Also the fact that the materials belong to one, very characteristic facies of the Magdalenian with triangles supports the assumption that this is a one-phase site. It is hard to imagine that this site was visited for more than 700 years by the population belonging only to one facies whose technology, the selection of raw materials and composition of tools did not change during the entire period. Therefore, it can be concluded that the probable time limits of the

settlement of the camp may be considerably narrowed, and located somewhere in the period between modelled dates.

Different situation is observed in Wilczyce 21 pleistocene dates come from that site, some of them obtained from charcoal, and some – from bones. These dates creates a chain encompassing all the late Magdalenian settlement period – from GS-2a up to GI-1b. As well oldest as youngest dates were obtained from charcoal (sometimes small samples) and bones. There is no visible interval in the distributions of dates which may suggest a settlement hiatus. On the contrary, modelled dates show clearly that the camp was systematically settled by Magdalenian groups during about 2500 years. Thereby this is the only open site in Poland on which we can successfully show multiple settlement phases. It is worth mentioning that the observation is only possible thanks to series of ^{14}C datings. It should be remembered that the materials in Wilczyce did not lie on the primary deposit but in the ice wedge filling. In fact, all the finds were found in the secondary deposit without the possibility to distinguish a vertical or horizontal stratigraphy. Similarly to Dzierżysław, it is not possible to separate the artefacts from the material having features that allow us to divide it into few phases.

As a result of bayesian modelling very long period of settlement, lasting between 16053 and 12760 cal BP without possibility of specifying particular phases, is visible.

The third site that provided a series of dates is the Krucza Skała cave. It is also the only site with three known phases of settlement found in a stratigraphic position (Cyrek 1999; 2010). The traces of settlement are interpreted as the remains of short-term hunting camps probably inhabited once. All dates come from bones. From the oldest layer two dates were obtained (12970±60 (Poz-27245) and 12520±70 (Poz-1138) uncal. BP). One of them is well fitted into the cold period GS-2a, the second – (Poz-1138) is located at the turn of two periods: GS-2a and GI-1e. The Bayesian modelling allowed to widen significantly and also move back the probable age placing the date at the upper limit of the cold stage GS-2a. Based on the above it can be assumed that the oldest settlement phase in the Krucza Skała cave should be rather linked to the period preceding the warmer interval GI-1e connected with the interstadial Bølling according to the Polish understanding of this term. Thus, it is older than it has been assumed until now (see Nadachowski *et al*. 2009; Połtowicz-Bobak 2013). The settlement episode took place between 15796 cal. BP and 14656 cal. BP.

The younger, middle settlement phase of the cave is dated with the use of two dates: (12480±60 (Poz-27261), 11980±70 (Poz-1139) uncal. BP). The older corresponds to GI-1e, a warmer period, and the younger – the cold GI-1d corresponding to Dryas II. As the result of modelling, the date Poz-2726 was "made younger", which allowed us to slightly approximate both dates. Nevertheless, the significant difference between them is still clearly visible; these dates do not overlap within the probability limits. Thus, the question should be posed: are the settlement traces in layer 4 the evidence of a single stay of the hunting group and the differences between the dates are the consequence of contamination, or are we dealing here with two different settlement episodes? The former possibility is supported by the fact that from the same level, the date 2240±35 uncal. BP was obtained from the bones (Nadachowski *et al*. 2009). According to the model, the settlement of the middle phase of the cave in Krucza Skała inhabitation should be placed between 14753 cal. BP and 13517 cal. BP.

The youngest dates (11450±200 uncal. BP (Lod-407), 11210±80 uncal. BP (Poz-1141)) suggest that the settlement took place in the

last warm period of the Late Pleistocene and, more precisely, in the cold interval within that period (GI-1b). The date modelling allows to approximate the values of both dates. Consequently, it can be assumed that the youngest settlement episode happened between 13422 cal. BP and 12877 cal. BP.

Therefore, the settlement in the cave in Krucza Skała includes three episodes that took place in a few periods divided by long intervals and in changing ecological conditions. First of all, the modelling allowed us to move the oldest settlement phase back in time and to conclude that it probably happened a bit earlier, possibly before the beginning of the warming identified with the interstadial Bølling. The inconsistency between the dates from the middle layer is also obvious and supports the thesis about the contamination of the samples. Thus, it is hard to establish undoubtedly whether the settlement took place in a warmer or colder climatic episode, and the interpretation of dates should be carried out cautiously.

Both the beginning and, in particular, the end of the period of settlement in the cave were placed in a very long time interval that results from the discrepancies between specific dates. It is a consequence of the small number of dates corresponding to each settlement phase. As it was mentioned above, the model used here is the most efficient for three or more dates that may be considered to be contemporary, and in the event of Krucza Skała each phase is marked by two dates. Although this limitation is balanced by the existing stratigraphic sequence, that is the information regarding the relative age of each sample, huge discrepancies in dating of the samples coming from the same layer (and consequently considered to be contemporary) contributed to obtaining the long time periods corresponding to each of the phases.

The interpretation of the dates from Wierzawice poses similar difficulties. So far, two dates coming from that site have been obtained: 11560±40 (Poz-36901) and 11 080±130 (Poz-41200) uncal. BP). Both are placed within the limits of interstadial Allerød; the older refers to the older warm phase, and the younger – rather to the colder interval, GI-1b. The latter date is encumbered with a strikingly large standard error. This site is a classic example of a short-term hunting camp settled only once (Bobak *et al*. 2010). Both dates were obtained from the samples of hearth charcoal undoubtedly connected with settlement and the use of fire at that time. Thus, if there is such a big difference between them (after calibration the range of dates does not cover even at 68.2% significance level) and even after the age modelling the values of both samples do not cover, it can suggest the possible contamination of the samples connected, among others, with their shallow location. As the result of modelling, the probable age of the settlement at the site is now located within very wide time limits including the period from GS-2a till GS-1, whereas the probability of a very early or very late chronology is, according to the modelled schedule, pretty low. The much more interesting fact is that according to the model, although the probability that the site was inhabited after GI-1e is the highest, the earlier presence of the hunter group cannot be completely excluded. It is even more interesting that such a chronology would be more consistent with the character of the chipped artefacts. In order to explain the question of dating the site in Wierzawice, new ^{14}C dates need to be obtained.

From the site in the cave in Zalas two dates were obtained (Bocheński *et al*. 1985; Kozłowski, Pettitt 2001), but each of these dates relates to a different layer. After modelling, the older date from layer 11 (12820±80 (OxA-6625) uncal. BP) shows the ranges between 15370 and 15127 cal. BP, which allows to locate the settlement in

the colder phase GS-2a, but the younger date (12530±110 (OxA-6591) uncal. BP), after modelling, has very wide ranges including the period from GS-2a till GI-1c (with 95.4% probability). The small number of dates makes the obtaining of the sufficiently reliable result of the modelling of the time relating to this site settlement impossible.

Due to the same reason, the modelling of the age of the settlement of the sites from which single dates come from is impossible. In their case, the model just carried out the calibration of radiocarbon markings and they only indicate the possible time limits of the settlement of a given site. It is worth to pay attention to the date from Klementowice-Kolonia (12730±70 uncal. BP (Poz-54822) uncal. BP) (Wiśniewski 2013) that is within the GS-2a period. The dating of the Komarowa cave locates this site within GI-1e that confirms the current assumptions (Nadachowski *et al*. 2009). The very wide ranges of probability of the time of the settling the sites in Mosty (Cyrek 1986) and Wołowice (Sobczyk 1993) do not provide the ground for any more precise conclusions and they are only the representation of the fact of possessing the single dates for these sites and the very wide limits of the errors of standard ^{14}C dates.

4. Conclusions

The date modelling enables to determine the probability of the settlement of individual sites within a specific period of time together with the correction of the ranges of given datings. It also facilitates a separation of doubtful datings although their inclusion or exclusion from the dating series corresponding to a given site is a matter of interpretation taking into account other data relating to its stratigraphic position or the features of archaeological materials. But it is subject to having a series of a few dates at one's disposal. One or two dates constitute insufficient source material to draw reliable conclusions based on them. Nevertheless, in the event of two dates it is possible to determine the relation between them, and this in turn may show e.g. the inconsistency of dates, such as in the case of Wierzawice.

Except for chronological observations within given sites, Bayesian age modelling also enables the examination of the possible dynamics of the Magdalenian settlement within the Polish territory. Of course, the oldest episode is the middle-Magdalenian episode from the Maszycka cave, well recognized and described in the research literature (Kozłowski *et al*. 1995). The modelling of dates shows a very clearly marked episode with well-defined limits of the possible settlement. Its older age and differences in comparison to other sites are also clearly visible. The remaining sites line up into one sequence from GS-2a till GI-1b. No substantial hiatuses that could suggest the existence of a few separate waves of expansion of the Magdalenian settlement to the east are noted. The big number of sites inhabited in the period preceding GI-1e is striking. It is also significant that such sites are located in the eastern and western parts of Poland. The oldest dates, also after rejecting the disputable date from the mammoth bone come from Dzierżysław, and a bit younger – from Wilczyce. The beginning of the settlement in Wilczyce roughly corresponds to the end of the settlement in Dzierżysław. A bit younger than the oldest phase in Wilczyce is Klementowice-Kolonia campsite. The older phase of the settlement of the cave in Zalas may be contemporaneous to it. Such a distribution of datings constitutes an argument for the thesis that the Magdalenian settlement spread to the Polish territories from Moravia and confirms the thesis previously posed on the base of the analysis of Central European dates (Połtowicz-Bobak 2013), and then it spread very quickly to the east

reaching its eastern range already before GI-1e. The date from Klementowice is very important since it confirms the said thesis, undoubtedly indicating that already in the cold period Magdalenian hunters penetrated relatively far to the north, to the borders of the highlands and the Plain. It is consistent with the hypothesis presented above. The modelled data from the Kraków-Częstochowa Upland indicate that the cave areas were penetrated at the same time. Since the cave in Zalas is interpreted as a small workshop directly linked with the large workshops in Brzoskwinia, it may be assumed that the latter were also exploited during GS-2a.

The younger settlement is not so well documented. However, it is hard to say whether it is the consequence of the less intense settlement of the territory of present-day Poland, or whether it results from a small number of dated sites. The datings of the youngest sites seem to confirm their late chronology, although the already signalised problem with the discrepancy of the dates from Wierzawice and the very wide range of the dates from Mosty and Wołowice is striking. The dating of the site in Wołowice is justifiably controversial (Połtowicz-Bobak 2013, also further reading). In the light of the applied method, the most concise dating of the settlement traces dated to the youngest warm phase of the Late Pleistocene (Allerød) comes from the youngest layer from the Krucza Skała cave and from Wilczyce.

The age modelling allowed us to specify more precisely and verify the data being in our possession due to the increase of the number of ^{14}C dates and the development of the studies on a calibration curve. The model presented herein shows the picture of a fast process of settlement of the present-day Polish territory by the Magdalenian people and a stable settlement process that took place during the entire period of the late Magdalenian. The thesis of the direction of the spread of the complex within Polish areas is also confirmed. However, the consistent differentiation of more than one settlement layer at the open sites was not possible.

At the same time, the need to obtain a larger series of dates from individual sites seems to be obvious. In fact, only a series of dates allows us to reliably model the chronological ranges of the settlement of the sites and, consequently, also in the micro- and macro-regional scale. Bayesian age modelling is a method allowing the integration of various chronological data (dating with the use of physical methods; stratigraphic information) and the creation of a statistically reliable model based on these data, much more reliable than only a simple summary of the ranges of individual dates.

Chronologia osadnictwa kultury magdaleńskiej na terytorium dzisiejszej Polski w świetle modelowania bayesowskiego

Zagadnienie chronologii obserwowanych zjawisk należy do najważniejszych zagadnień w badaniach nad dziejami człowieka. Dotyczy to zarówno określenia wieku poszczególnych stanowisk jak też ram chronologicznych całych jednostek taksonomicznych.

Ostatnie lata przyniosły wzrost liczby datowań stanowisk magdaleńskich z terenów ziem polskich. Dotyczy to zarówno liczby stanowisk, dla których pozyskano datowania ^{14}C jak i liczby dat pochodzących z poszczególnych miejsc.

Analizę chronologii osadnictwa magdaleńskiego, m. in. w Polsce przedstawiono w innej pracy (Połtowicz-Bobak 2013). Najstarsze daty pochodzą z jaskini Maszyckiej, wyznaczając jednocześnie najwcześniejszy horyzont osadniczy magdalenienu na terenach ziem polskich (Kozłowski *et al*. 2012), wyprzedzający o około 1000 lat następną, główną fazę, która rozpoczyna się w zimnym okresie GS-2a odpowiadającym mniej więcej Dryasowi I i trwa nieprzerwanie aż po początki ocieplenia korelowanego z interstadiałem Allerød. Na kilku stanowiskach daty ^{14}C mogą sugerować, że stanowiska te były zasiedlane wielokrotnie przez bardzo długi czas, aczkolwiek interpretacja ta może być dyskusyjna.

Analiza dat pozwoliła na wysunięcie kilku ogólnych wniosków. Przede wszystkim wydaje się, że ekspansja ludności magdaleńskiej na wschód następowała bardzo szybko, a osadnictwo magdaleńskie na terenach ziem polskich trwało nieprzerwanie od zimnego stadium GS-2a. Nie da się wydzielić dwóch oddzielnych epizodów – starszego, mniej intensywnego osadnictwa w fazie zimnej (GS-2a) oraz bardziej intensywnego w fazie ciepłej (GI-1e) (Połtowicz-Bobak 2013).

Podstawowe problemy związane z chronologią można podzielić na dwie najważniejsze grupy. Pierwsza to pytanie, jak wygląda czas osadnictwa na poszczególnych stanowiskach; jak długo były one zasiedlane, czy – i jak wiele różnoczasowych faz można na nich wyróżnić i jaka jest chronologiczna relacja pomiędzy nimi. Dotyczy to przede wszystkim stanowisk dużych, pozbawionych danych stratygraficznych ale także tych, na których zaobserwowano więcej niż jedną warstwę zawierającą materiały magdaleńskie.

Drugim – nie mniej ważnym problemem jest ustalenie ram chronologicznych osadnictwa na danym terytorium, w tym przypadku na terenach ziem polskich, oraz kierunków i tempa rozprzestrzeniania się go na badanym obszarze. Odpowiedź na te pytania jest celem analizy przy zastosowaniu metody Bayesa.

Analizie poddano daty ^{14}C z 10 stanowisk. Podczas wstępnej selekcji odrzucono te, które budziły największe wątpliwości.

Najstarsze daty pochodzą z Jaskini Maszyckiej. Ze stanowiska tego uzyskano ich w sumie 6, z czego dwie – metodą konwencjonalną, cztery zaś – techniką AMS. Wszystkie wartości są zbliżone. Rozpiętość dat ^{14}C obejmuje dość szeroki przedział czasu obejmujący niemal 1000 lat. Modelowanie wieku pozwoliło na znaczne zawężenie tych granic. Na jego podstawie można stwierdzić, że magdaleński epizod osadniczy w Jaskini Maszyckiej miał miejsce pomiędzy 18574 i 17987 cal. BP, a więc ramy czasowe możliwej okupacji Maszyckiej zostały zawężone do około 600 lat. Daty konwencjonalne zostały wyraźnie przesunięte i dopasowane do pozostałych.

Modelowanie dat z Dzierżysławia pozwoliło na ustalenie, że najprawdopodobniej jest to stanowisko jednofazowe, choć oczywiście kilkakrotnie zasiedlane przez grupy łowców. Z kolei bogate stanowisko w Wilczycach jest stanowiskiem wielofazowym, zasiedlanym w przez cały czas trwania osadnictwa późnomagdaleńskiego na ziemiach polskich: od GS-2a aż po GI-1c. Wniosek ten można wysnuć wyłącznie na podstawie analizy serii dat, gdyż materiały znajdują się na złożu wtórnym.

Modelowanie wieku dla wielowarstwowego stanowiska w Kruczej Skale pozwoliło na sprecyzowanie wieku poszczególnych faz. Pozwoliło przede wszystkim na cofnięcie najstarszej fazy osadniczej i uznanie, że prawdopodobnie miała ona miejsce nieco wcześniej, przed rozpoczęciem ocieplenia identyfikowanego z interstadiałem Bølling. Widać też wyraźnie niezgodność pomiędzy datami z poziomu środkowego co wzmacnia tezę o możliwym zanieczyszczeniu próbek. W efekcie więc trudno jest jednoznacznie ustalić czy osadnictwo miało miejsce w cieplejszym czy chłodniejszym epizodzie klimatycznym, zaś w interpretacji dat powinno się zachować ostrożność. Zarówno początek jak i, zwłaszcza, koniec osadnictwa w jaskini jest oznaczony w bardzo szerokim przedziale czasu co wynika z rozbieżności pomiędzy poszczególnymi datami.

Na trudności natrafiamy przy interpretacji dat z Wierzawic. Pozyskano stamtąd jak dotąd dwie daty mieszczące się w granicach interstadiału Allerød przy czym starsza odnosi się do starszej fazy ciepłej GI-c1, młodsza zaś raczej do chłodniejszego epizodu GI-1b. W przypadku tej drugiej daty uderzający jest także bardzo duży błąd standardowy. Obydwie daty uzyskano z prób węgli drzewnych pochodzących z ogniska, a więc z pewnością związanych z osadnictwem i paleniem ognia w tym samym czasie. Jeśli więc pomiędzy nimi istnieje tak duża różnica i nawet po modelowaniu wieku wartości obydwu nie pokrywają się ze sobą, to może to wskazywać na możliwość zanieczyszczenia próbek. Wg modelu jednak nadal największe jest prawdopodobieństwo, że stanowisko zasiedlano po GI-1e.

Nie da się natomiast wymodelować czasu zasiedlenia stanowisk, z których pochodzą pojedyncze daty.

Modelowanie dat pozwala nakreślić prawdopodobieństwo zasiedlania poszczególnych stanowisk w określonym przedziale czasu, przy jednoczesnym skorygowaniu zasięgu poszczególnych datowań. Ułatwia też wydzielenie datowań wątpliwych.

Oprócz obserwacji chronologicznych w obrębie poszczególnych stanowisk bayesowskie modelowanie wieku pozwala też na prześledzenie prawdopodobnej dynamiki osadnictwa magdaleńskiego na terenach ziem polskich. Oczywiście, najstarszy jest ślad pobytu grupy magdaleńskiej z Jaskini Maszyckiej. Widać tu wyraźnie zaznaczony epizod o dobrze uchwyconych granicach możliwego osadnictwa oraz jego znacznie starszy wiek. Datowania pozostałych stanowisk układają się zasadniczo w jeden ciąg, począwszy od GS-2a aż po GI-1b. Nie notuje się wyraźniejszych hiatusów, które mogłyby sugerować istnienie kilku odrębnych fal ekspansji osadnictwa magdaleńskiego na wschód. Uderza duża liczba stanowisk, które zasiedlane były w okresie poprzedzającym GI-1e. Stanowiska te występują tak w Polsce zachodniej jak i wschodniej.

Modelowanie wieku pozwoliło na uściślenie a miejscami weryfikację danych posiadanych przez nas dzięki przyrostowi dat ^{14}C i rozwojowi badań nad krzywą kalibracyjną. Z przedstawionego modelu wyłania się obraz szybkiego zasiedlenia terenów ziem polskich przez ludność magdaleńską oraz stabilnego osadnictwa przez cały okres późnego magdalenienu. Potwierdza się też teza o kierunku rozprzestrzenienia kompleksu na terenach ziem polskich. Na stanowiskach otwartych nie dało się natomiast wydzielić w sposób niebudzący wątpliwości więcej niż jednej fazy osadniczej ; wyjątkiem jest obozowisko w Wilczycach. W jego przypadku wielofazowość można było wykazać dzięki analizie dużej serii dat. Wyraźnie widać konieczność pozyskiwania większych serii dat z poszczególnych stanowisk. Tylko bowiem serie pozwalają na wiarygodne modelowanie zasięgów chronologicznych osadnictwa na stanowiskach a w efekcie też w skali mikro- czy makroregionalnej. Bayesowskie modelowanie wieku jest metodą pozwalającą na integrację różnorodnych danych chronologicznych (datowania metodami fizycznymi, informacje stratygraficzne) i stworzenie na ich podstawie statystycznie wiarygodnego modelu, o wiele wiarygodniejszego niż tylko proste sumowanie zakresów poszczególnych dat.

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