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THE EPIGRAVETTIAN AND THE MAGDALENIAN IN POLAND: NEW CHRONOLOGICAL DATA AND AN OLD PROBLEM

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Abstract: The aim of the paper is to present a new chronological model of recolonisation of the area located north of the Sudetes and the Carpathians after Late Glacial Maximum (LGM). Until recently, it was believed that reoccupation of these areas occurred only due to the Magdalenian people. New chronometric data (radiocarbon and optoluminescence ones) coming from the Magdalenian and Epigravettian sites together with the application of Bayesian modelling of new records allowed us to present another model. In the light of the new research, it seems that the groups classified as the Epigravettian and Magdalenian could have coexisted at the same time in the same areas. The new model states that it is possible to assume coexistence of these groups during the period of 2300 years between 16500 and 14200 years BP.

Keywords: chronological records, Bayesian method, recolonization, Epigravettian, Magdalenian, Poland.

1. INTRODUCTION

One of the most intriguing issues concerning the prehistory of the late Pleistocene is the period between 20000 and 15000 cal BP, when a harsh climate, natural and demographic changes occurred in Central Europe. It is believed that at that time the dynamics of occupation and cultural landscape also changed (Terberger and Street, 2002; Svoboda and Novák, 2004). Until recently, it was maintained that the reoccupation of part of this area, which is located north of the Carpathians and the Sudetes took place only due to the Magdalenian people (see remarks Street *et al.*, 2009). Limited data allowed only to suggest that the Epigravettian groups could have appeared incidentally in these areas, exploiting these territories in non-systematic manner (e.g. Kozłowski, 1992, 2007). The Epigravettian settlement refuges were situated in the south, *i.e.* in Slovakia (Kaminská, 2014) and Czech Republic (Nerudová and Neruda, 2015).

In recent years, considering Polish territories, thanks to new research projects as well as rescue excavations, the amount of new chronometric data concerning both the Epigravettian and the Magdalenian have increased (e.g. Wilczyński, 2009; Połtowicz-Bobak, 2012).

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These two cultural units are different mainly with regard to the methods of lithic production. Even though the blanks production in both cases was directed towards getting blades, due to different methods of core treatment, clear differences are noticeable. They can be observed, for instance, in the case of the Epigravettian where the blades with flat butts predominated, while as for the Magdalenian blades with *en éperon butts* were present. Moreover, the differences can be seen in the treatment of certain tools, such as backed blades. In our opinion, the people of these two discussed units also implemented the slightly different mobility strategies, and in some cases they managed stone raw materials in different ways (see further comments: Wilczyński, 2009; Wiśniewski *et al.*, 2012a, where further literature, Połtowicz-Bobak, 2013).

Therefore, these data lead us to ask new questions regarding the course of recolonization of the area situated from the north of the Carpathians and the Sudetes during the period from 19000 to 15000 cal BP. The first question explores the issue whether it is possible to talk about the recolonization inspired solely by the groups of the Magdalenian culture, or we are dealing with a more complex picture of penetration into the Subcarpathian territories? If so, the next question is if the chronological records allow us to assume the possibility of coexistence of populations 'producing' the Epigravettian and the Magdalenian assemblages at the same time?

Considering the outlined issue, we would like to present the results of the analysis of a series of absolute dates obtained by means of the radiocarbon AMS method, as well as the conventional one, and the OSL method for the samples coming from the sites located in Silesia and Lesser Poland (**Fig. 1**). We focus on the largest assemblages from Polish territory, in case of which there are no taxonomic doubts and those which recently obtained a reliable chronological interpretation.

The analysis of absolute dating was performed by constructing a series of Bayesian models by means of the OxCal 4.2 software (Bronk Ramsey, 2009a), using the calibration curve IntCal13 (Reimer *et al.*, 2013). Chronological ranges of various phases modelled in this way have presented a higher level of reliability than those designated by a simple choice of extreme dates as indicators of the beginning and the end of given settlement episode (see Wood, 2015).

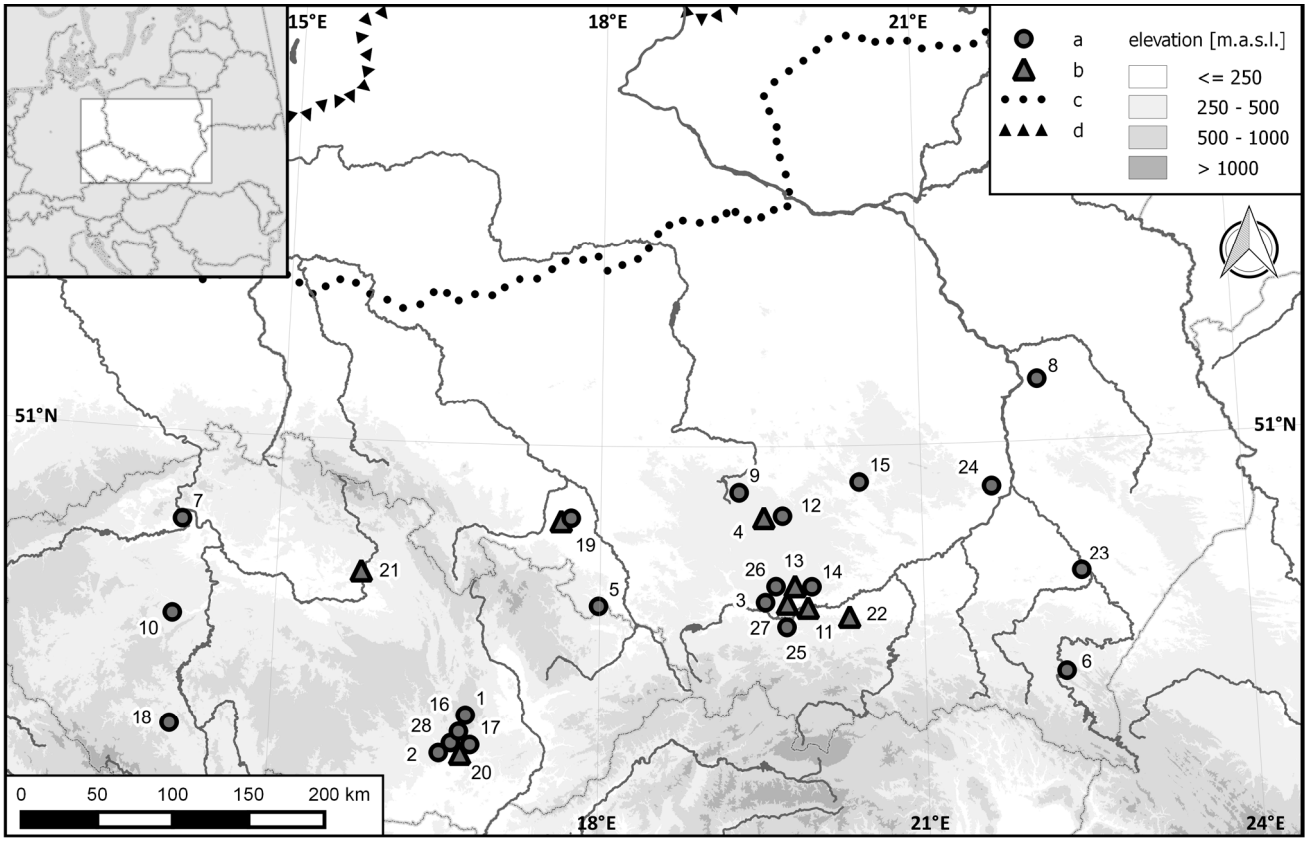

Fig. 1. *Location of sites mentioned in the text. 1: Balcarova skála, 2: Brno Štýřice III (formerly known as Brno, Videňska st. 3), 3: Brzoskwinia, 4: Deszczowa Cave, 5: Dzierżysław 35, 6: Hłomcza, 7: Keblice, 8: Klementowice-Kolonia 20, 9: Komarowa Cave, 10: Koněpruská Cave, 11: Kraków, Spadzista St. C2, 12: Krucza Skała Cave, 13: Mamutowa Cave, 14: Maszycka Cave, 15: Mosty 13, 16: Nová Drátenická, 17: Pekárna Cave, 18: Putim, 19: Sowin 7, 20: Stránská skála IV, 21: Svobodné Dvory, 22: Targowisko 10, 23: Wierzawice 31, 24: Wilczyce 10, 25: Wołowice, 26: Zalas Cave, 27: Zawalona Cave, 28: Žitného Cave. Legend items: a: Magdalenian sites, b: Epigravettian sites, c: LGM range, d: Pommeranian phase range.*

The results show that the existing model of recolonization of Polish territory is not as clear as it seemed. The most important result of the analysis is the determination of coexistence of the Magdalenian and the Epigravettian assemblages in the same areas and at the same time. It seems, however, that the coexistence of the Epigravettian and the Magdalenian is currently better confirmed for the older period of the Magdalenian, represented by the assemblage from Maszycka Cave. The results allow us to consider the possibility of overlapping the Epigravettian and late Magdalenian settlement in later period (16500–15000 cal BP).

This paper deals with assemblages commonly identified with the so-called Epigravettian and the Magdalenian cultures. Like many other archaeologists, we believe that the two taxonomic units are the expression of different traditions, which of course is not synonymous with the assumption that both groups represent different populations in genetic terms.

2. MATERIAL AND METHODS

In our paper, we have considered mainly 6 sites which provided 56 radiocarbon dates and 4 OSL dates, placing the remains in the GS-2 and GI-1. The aforementioned sites are worth noting because of more numerous and more representative inventories in typo-technological terms, and therefore an assessment of their taxonomic affiliation does not raise any doubt. The data come from the sites that were excavated in a systematic way, often for many seasons. Apart from the basic group of sites, the sites (in the number of 8) with a small number of artefacts have been included in our considerations, as well as the ones with ambiguous dating, even though sometimes they provided relatively rich inventories (**Fig. 1**). We have not included the assemblages in the analysis which did not receive absolute dating records.

In total, (after the rejection of a part of dates) 53 ^{14}C dates and 4 OSL dates were used in the research (**Table 1**). Most of the radiocarbon dates were obtained using the AMS method.

Speaking of the sites, they are located in southern Poland. Most of them are open sites, situated in the upland areas. A small amount of artefacts is represented by the remains coming from caves or rock shelters.

Below we have presented the data concerning the Epigravettian and the Magdalenian sites, emphasizing the issue of dating. As already pointed out, we would like to focus on the sites with a representative number of artefacts, which recently have received a series of numerical dates. We have discussed separately the sites which do not meet these criteria, even though they are included in the Epigravettian or the Magdalenian.

The Epigravettian

Sowin 7

The site Sowin 7 is located in south-west Poland, within the Niemodlin Wall, bordered by the valleys of the Nysa Kłodzka River and the Ścinawa Niemodlińska River (approximately 200 m above sea level). The site is situated from 25 m to nearly 40 m above the bottom of the surrounding valleys. The site was excavated on the surface exceeding 70 m^2. Initially, about 400 artefacts were obtained from the area of 40 m^2 (Furmanek *et al.*, 2001, see remarks Wiśniewski *et al.*, 2012a). The excavations were carried out from 2012 to 2015 providing more than 2000 artefacts localized 3D (the study on the inventory is in progress). The Epigravettian materials were in fine sands, located on sand and gravel sediments of glacial origins. The artefacts were covered with a layer of sands of aeolian origins. These sands contained traces of periglacial processes. The sediments were covered by modern arable topsoil. At the top of aeolian sands and in the topsoil the Magdalenian materials were recorded.

The Epigravettian artefacts formed two clusters. The distribution of artefacts and their state of preservation did not indicate post-depositional processes influencing the site's formation. The Epigravettian products were mostly made of local erratic flint. Single artefacts represented imported raw materials (radiolarite, Jurassic flint?).

In order to establish dating records of the Epigravettian artefacts, the OSL method was used, due to the fact that no 'reliable' organic samples were obtained. Two samples from sediments were collected there, where the Epigravettian artefacts were found, as well as two samples from the top layer of aeolian sands delivered the study material. Dates of sediments in which the Epigravettian assemblage was located fell respectively into 15470 ± 860 and 16200 ± 920 years ago (OSL). As we can see, the difference is approximately 700 years, therefore, the lower limit of the 'older' sample dates back to 17100 years. In both cases, the date of the sediment belongs to the GS-2.1a, which is correlated with the oldest Dryas (see for example Rasmussen *et al.*, 2014).

The samples from the top layer of aeolian sands are OSL dated as follows: 13830 ± 860 and 14710 ± 900 years. The difference between the dating of the samples is approximately 900 years. The lower limit reaches 15600 years overlapping the results of dating of sediments located below. The established records of the aeolian sands should be treated as minimal, *i.e.* terminus post quem. In other words, the Magdalenian artefacts cannot be older than the established date. The difference in dating of the Epigravettian layer reaches from 800 to 2400 years. The results situate the top layer of aeolian sediments in the GI-1.

Table 1. *List of analysed Epigravettian, middle and late Magdalenian dates from the territory of Poland. The last column indicates if the date was considered as outlier and rejected from the further analysis.*

Site	Method	Lab code	Measured age (BP)	Is outlier?
		Epigravettian		
Deszczowa Cave	^{14}C	Gd-10212	17480 ± 310	no
Deszczowa Cave	^{14}C	GdA-964	16150 ± 280	no
Kraków - Spadzista C2	^{14}C	Ly-2541	17400 ± 310	no
Targowisko	^{14}C	Poz-14691	14820 ± 70	no
Targowisko	^{14}C	Poz-14692	14790 ± 80	no
Targowisko	^{14}C	Poz-14695	14720 ± 70	no
Targowisko	^{14}C	Poz-14694	14520 ± 70	no
Targowisko	^{14}C	Poz-14693	13720 ± 70	yes
Zawalona Cave	^{14}C	n.a.	15380 ± 340	no
Zawalona Cave	^{14}C	n.a.	14060 ± 340	no
Sowin 7	OSL	GdTL-2497	16204 ± 916	no
Sowin 7	OSL	GdTL-2496	15474 ± 857	no
		Maszycka Cave (Middle Magdalenian)		
Maszycka Cave	^{14}C	Ly-2454	15490 ± 319	no
Maszycka Cave	^{14}C	KIA-39228	15115 ± 60	no
Maszycka Cave	^{14}C	KIA-39226	15025 ± 50	no
Maszycka Cave	^{14}C	KIA-39227	15015 ± 50	no
Maszycka Cave	^{14}C	KIA-39225	14855 ± 60	no
Maszycka Cave	^{14}C	Ly-2453	14520 ± 240	no
		Late Magdalenian		
Krucza Skała Cave	^{14}C	Poz-27245	12970 ± 60	no
Krucza Skała Cave	^{14}C	Poz-1138	12520 ± 70	no
Krucza Skała Cave	^{14}C	Poz-27261	12480 ± 60	no
Krucza Skała Cave	^{14}C	Poz-1139	11980 ± 70	no
Krucza Skała Cave	^{14}C	Lod-407	11450 ± 200	no
Krucza Skała Cave	^{14}C	Poz-1141	11210 ± 80	no
W Zalasie Cave	^{14}C	OxA-6625	12820 ± 80	no
W Zalasie Cave	^{14}C	OxA-6591	12530 ± 110	no
Klementowice 20	^{14}C	Poz-54822	12730 ± 90	no
Wilczyce 10	^{14}C	OxA-16728	13180 ± 60	no
Wilczyce 10	^{14}C	OxA-26545	13155 ± 65	no
Wilczyce 10	^{14}C	OxA-26546	13125 ± 65	no
Wilczyce 10	^{14}C	Poz-14891	13020 ± 60	no
Wilczyce 10	^{14}C	Poz-19048	13000 ± 110	no
Wilczyce 10	^{14}C	Poz-3914	12960 ± 60	no
Wilczyce 10	^{14}C	OxA-16729	12870 ± 60	no
Wilczyce 10	^{14}C	Poz-3927	12840 ± 70	no
Wilczyce 10	^{14}C	Poz-14892	12770 ± 120	no
Wilczyce 10	^{14}C	Poz-3926	12620 ± 60	no
Wilczyce 10	^{14}C	Poz-14463	12550 ± 80	no
Wilczyce 10	^{14}C	Poz-14384	12480 ± 70	no
Wilczyce 10	^{14}C	Poz-14385	12390 ± 100	no
Wilczyce 10	^{14}C	Ua-20413	12315 ± 90	no
Wilczyce 10	^{14}C	Ua-20412	12110 ± 90	no
Wilczyce 10	^{14}C	Poz-19046	11960 ± 140	no
Wilczyce 10	^{14}C	Ua-15723	11890 ± 105	no
Wilczyce 10	^{14}C	Poz-19049	11870 ± 120	no
Wilczyce 10	^{14}C	Ua-15722	11665 ± 135	no
Wilczyce 10	^{14}C	Ua-15720	11400 ± 135	no
Wilczyce 10	^{14}C	Poz-19047	11340 ± 60	no
Dzierżysław 35	^{14}C	Poz-10136	14150 ± 70	yes
Dzierżysław 35	^{14}C	GdA-69	13500 ± 80	no
Dzierżysław 35	^{14}C	GdA-193	13370 ± 80	no
Dzierżysław 35	^{14}C	GdA-70	13220 ± 70	no
Dzierżysław 35	^{14}C	Poz-10135	13180 ± 60	no
Dzierżysław 35	^{14}C	Poz-7318	12150 ± 70	yes
Sowin 7	OSL	GdTL-2494	14711 ± 856	no
Sowin 7	OSL	GdTL-2495	13830 ± 895	no
Komarowa Cave	^{14}C	Poz-6621	12260 ± 60	no
Mosty	^{14}C	Lod-107	11290 ± 280	no
Wierzawice	^{14}C	Poz-36901	11560 ± 40	no
Wierzawice	^{14}C	Poz-41200	11080 ± 130	no

Technological, typological and functional analysis of the Epigravettian artefacts indicates the presence of traces of differentiated activities, which involved not only repair and preparation of a tool kit, but also processing organic materials (in the light of use-wear study, personal communication, B. Kufel-Diakowska).

Targowisko 10

The site Targowisko 10 is located in Lesser Poland on the border of the Subcarpathia and the Sandomierska Basin. It is situated in the valley of the Raba River, which is a tributary of the Vistula River (Wilczyński, 2009). Its location is approximately 10 m above the present valley bottom of the river (203 m above sea level). The Epigravettian materials were deposited within a layer of slope loess with inclusions of sandy laminas below 1.3 m from the current ground level. Above it, two successive layers of slope loess were distinguished, covered with contemporary soil. Works on the site were associated with a wider project of archaeological rescue excavations. Thanks to this research, the excavations covered a large area. It was found out that the Palaeolithic material was distributed in the area of about 400 m^2, and southern part of the site was not excavated because it was beyond the area of development. The excavations provided 4708 finds, mainly made of flint and single bone artefacts (*Equus Sp.* and *Rangifer tarandus*). Raw materials in the form of obsidian and Mikuszowice chert link the inventory with southern zone. Furthermore, the most important discoveries made there were the remains of five hearths. It is worth mentioning that some of uncovered artefacts were associated with these hearths.

The chronology of human stay is determined by the AMS radiocarbon dating of charcoal. Individual samples from each hearths were analysed. The species of wood, from which samples were taken, was not determined. Apart from one sample dated to 13720 ± 70 BP (Poz-14693), the results show very little dispersion. The youngest date of this series is 14520 ± 70 BP (Poz-14694), while the oldest 14820 ± 70 BP (Poz-14695; see notes of Wilczyński, 2009). After dates calibration, except the rejuvenated sample from the hearth No. II, the chronology can be placed on the GS-2.1b and GS-2.1a borderline.

The relations of refittings between the hearths (I-IV), as well as the location of hearths in a distance from each other, may indicate that they were formed rather during one or several stays in one season. Microscopic analyses of the surface of the stone artefacts indicate significant dynamics associated with production and replacement of tools, as well as their use at the site (Kufel-Diakowska, 2014).

Other finds

With reference to the Epigravettian assemblages, and sometimes the Epigravettian or the Magdalenian ones, it is possible to include some poor collections, such as e.g. the collection from Zawalona Cave in Mników (Kraków Upland). The researchers found a poor inventory of flint products in layer E at this site composed of loess and loessy debris. Established dates were based on bones dating falling into GS-2: 15380 ± 340 BP, 14060 ± 340 BP (Alexandrowicz *et al.*, 1992). As for the Epigravettian culture, a relatively large collection of artefacts from layer 2 in Mamutowa Cave in Wierzchowie was uncovered. Unfortunately, for this layer two radiocarbon dates were obtained, which were extremely divergent: 20260 ± 250 BP (Gd-10021) and 11650 ± 200 BP (Gd-10024) (Kozłowski and Kozłowski, 1996), and therefore they were not included in this study. What is more, a poor collection from layer VIIIa from Deszczowa Cave is also included (Cyrek, 1999; Cyrek *et al.*, 2000).

The Magdalenian

Maszycka Cave

Maszycka Cave is located about 20 km north of Kraków, in the valley of the Prądnik River, approximately 65 m above its present floor. This is a small cave with a broad entrance facing S/SW. In front of the cave there is a terrace, which during its occupation was about 8 m long. The settlement included the main chamber at the entrance, the terrace in front of the cave, and a small chamber at the back of the cave (Kozłowski *et al.*, 1995). The site was discovered in 1883. In the same year G. Ossowski conducted excavations, which covered virtually the entire interior of the cave. Horizontal distribution of artefacts was not recorded. The exact vertical arrangement of artefacts was not recorded either. We know that the materials originate mainly from the layer of loess. Next excavations were carried out on the terrace by S. K. Kozłowski in 1962–1966. In their course, less numerous products were acquired. The inventory included 292 flint artefacts in total, mostly made of local Jurassic flint, as well as 98 bone products, including *navettes* and one pendant (Kozłowski *et al.*, 2012). The site provided human bones. It was interpreted as a campsite inhabited at the turn of autumn and winter (Kozłowski *et al.*, 1995). What is more, imports of stone raw materials (approximately 5% of the entire inventory) indicate the connection of the complex both with the areas situated to the west of the site (erratic flint, Plattensilex from the Altmühl River valley, striped flint from south-eastern Germany?), as well as to the east of it, *i.e.* the areas associated with the classic range of the Epigravettian assemblages (Dniester and Volyn flint). In addition, as for the southern direction, *i.e.* from the Pieniny Mountains, radiolarites were transported, while from the areas to the north of the site – chocolate flint (Kozłowski *et al.*, 1995). The chronology of the assemblage from Maszycka Cave was determined based on a series of ^{14}C dates obtained from bone tools, animal bones and human bones (Kozłowski *et al.*, 2012). The dates were obtained by the conventional method (2)

and the AMS (4). The results revolve around 15000 years BP. Therefore, it is the oldest Magdalenian site in Central Europe. Its chronology precedes by nearly 1000 years further signs of occupation of this area by the Magdalenian groups (Bobak and Połtowicz-Bobak, 2014).

Dzierżysław 35

The site Dzierżysław 35 is located in the Głubczyce Plateau, in the valley of the small Morawka River. The hills surrounding the site reach the altitude about 50–60 m above the valley floor. Archaeological materials were at the top layer of yellowish brown clay mixed with redeposited loess. They were covered by bog type sediments (Ginter *et al.*, 2007). The remains of the campsite/campsites covered a surface of about 400 m^2. The site provided about 45000 flint artefacts, mainly made of erratic flint, as well as single products of radiolarite of southern origins and quartzites from the Sudetes. There was also a series of products made of hematite, e.g. ornaments and vessels made of geodes. Traces of a shelter-like feature and remains of hearths were discovered. The structure of assemblages and spatial arrangement of artefacts, which is characterized by the presence of numerous clusters, indicate that they are the remains of several stays of human groups (Ginter *et al.*, 2002, 2005; Ginter and Połtowicz, 2004).

The site has a series of radiocarbon dates obtained from animal bones including a mammoth and an indeterminate species. In the analysis only dates obtained by the AMS method were used (6) (Połtowicz-Bobak, 2012). They oscillate around 12100–14100 years BP.

Wilczyce 10

The site Wilczyce 10 is located in Lesser Poland, within the Sandomierska Upland, in the valley of the Opatówka River, on top of a hill, 40 meters above the valley floor. There were two levels of younger upper loess from the beginning of the LGM recorded at the site, with two cryogenic horizons with pseudomorphs after ice wedges. Archaeological artefacts were deposited in the fill of the pseudomorph from the upper horizon. The site provided nearly 55000 flint artefacts made of several kinds of flint, primarily the chocolate and Turon flint (Królik, 2014). The flint products were accompanied by bone tools of various types and female figurines made both of antler and flint (Fiedorczuk *et al.*, 2007) as well as remains of a child furnished with a necklace of arctic fox teeth (Irish *et al.*, 2008; Sulgostowska, 2014) and numerous animal remains, part of which bore traces of human activities (Lasota-Moskalewska, 2014). The nature of finds allows us to interpret the site as a trace of multiple stays. It is believed that the hunting campsite was inhabited in winter and early spring (Krajcarz and Krajcarz, 2014). The determination of site's chronology is based on a large series of AMS dates (established from animal bones) which are within the range from 11340 ± 60 BP to 13180 ± 60 BP (Schild, 2014, Fig. 4.16). In the analysis, some dates were rejected whose values differed from the time considered the period of Magdalenian settlement.

Klementowice-Kolonia site 20

Another Magdalenian site, which was widely studied, is the campsite in Klementowice-Kolonia. It is located in the western part of the Nałęczowski Plateau in eastern Poland in the valley of the Kurówka River, on a short and gentle slope of a small loess elevation, approximately 8 m above the valley floor (Wiśniewski *et al.*, 2012b; Wiśniewski, 2012). The site is located in the loess area, where the Vistulian loess is deposited on the older Warta sediments of this type.

The excavations covered more than 300 m^2. Artefacts formed two clusters differing, amongst others, in terms of raw material composition and typological structure. Only a portion of materials from one of clusters remained *in situ*, in the illuvial level of soil horizon. In total, more than 11000 flint artefacts were acquired. Noteworthy is a big series of piercers. Speaking of tools production, several types of raw materials were used, mainly local erratic flint as well as Świeciechów flint, and to a lesser extent, other rock types. Lithic artefacts are accompanied by stone plates and pebbles. Also a small number of bones with traces of cutting were found. The analysis of the palaeozoological material indicates the possibility of hunters' stay at the end of summer or in early autumn. The place was used several times (Wiśniewski, 2012; Wiśniewski *et al.*, 2012b). In order to date the site, only one ^{14}C date was obtained from charcoal, which falls into one of the episodes in the GS-2.1a (Wiśniewski, 2015).

Other Magdalenian sites

Apart from aforementioned classical sites from Poland, there are also known inventories which are not clear in terms of chronology and taxonomic affiliation. With regard to them, it is necessary to include inventories from several layers of different chronology from Krucza Skała Cave (Cyrek, 1994; Nadachowski *et al.*, 2009). The oldest date from layer 2/4 (12970 ± 60 BP Poz-27245) indicates the presence of the Magdalenian group in the period GS-2.1a, while the youngest one comes from the end of the Magdalenian settlement in Poland (11450 ± 200 BP Lod-407, 11210 ± 80 Poz-1141) (ibid.).

The period preceding warming GI-1e indicates also the date from the older layer (layer 11) from Zalas Cave (12820 ± 80 BP OxA-6625). The finds uncovered there are interpreted as the remains of a small workshop, associated with a large complex in Brzoskwinia (Kozłowski and Pettit, 2001; Bocheński *et al.*, 1985). The younger date, obtained from the located above charcoal layer (12530 ± 110 BP OxA-6591), corresponds already to the period GI-1e.

Chronology of the other Polish sites is either undetermined or younger than the GS-2. Considering such sites, we may include the Magdalenian level of site Sowin 7. The OSL dates obtained for it, as it was mentioned above, determine only the maximum age of aeolian sediments deposition. The situation is similar in the case of site Hłomcza, where the chronology was determined by TL (Łanczont *et al.*, 2002). What is more, the sites with absolute dating younger than GS-2 are the following: Komarowa Cave, Mosty and Wierzawice. One of the ^{14}C dates from Wołowice is too young and does not apply to the Magdalenian assemblage, as it is believed (Połtowicz-Bobak, 2013, where further references).

Methods

In order to determine the occupational time limits of studied cultural complexes, the Bayesian analysis of available absolute dates (^{14}C and OSL) was used. The main advantage of this approach is, first of all, that it provides measurable reliability coefficients (Bronk Ramsey, 2009a) of the results and enables the researchers to receive greater statistical inference (Bronk Ramsey, 1995, 1998). It allows us to create a more realistic chronological framework for the analysed phenomena, and sometimes it is possible to obtain more precise dating of these phenomena (see Higham, 2011; Higham *et al.*, 2012; Riede and Edinborough, 2012; Wicks *et al.*, 2014). Analyses were carried out using the OxCal software version 4.2 (Bronk Ramsey, 2009a), and radiocarbon dates were calibrated according to the IntCal13-Northern Hemisphere curve for terrestrial samples (Reimer *et al.*, 2013).

The first stage was the outlier analysis. It was carried out separately for each of sites for which three or more dates were obtained and which are most likely the remains of a single stay of the human group. Its aim was to nominate dates, which for various reasons did not 'fit' the other dates of the given site, which may be the result of sample contamination or lack of links of dated material with archaeological context (see Scott, 2011). The analysis was based on the workflow proposed by Bronk Ramsey (2009b) and available in OxCal. It was assumed that the dates should be rejected if the posterior probability of being outliers exceeds 0.5. Therefore, two dates from site Dzierżysław 35 were eliminated in this way (Poz-10136 and Poz-7318) and one from Targowisko 10 (Poz-14693) (**Table 1**).

After eliminating outliers, the other dates were used to construct a Bayesian model, reflecting chronological and genetic relationships between studied cultural complexes.

As mentioned in the section 2 – The Epigravettian, three of the Epigravettian dates have uncertain relationship with the settlement. They are the radiocarbon dates from Zawalona Cave (15380 ± 340 BP and 14060 ± 340 BP, no lab codes) and two OSL dates from Sowin 7 (GdTL-2497, GdTL-2496). We decided to create two concurrent models, of which the first one consults the dates (Model 1) and the second does not (Model 2). The models were built on the following assumptions:

1) each of the analysed settlement episodes is independent, not related genetically (in the analysed area) to others,
2) there is a possibility of temporal overlapping of individual events.

Individual dates were grouped in *Sequences* and *Phases*, while the chronological range for each of analysed cultural complexes were determined by query *Boundary* (Bronk Ramsey, 2009a). Moreover, the duration of each settlement episode was also calculated (by a *Span* command), as well as the duration of the following periods: the intervals between the middle and late Magdalenian settlement, the period of overlapping Epigravettian and Magdalenian settlements or the hiatus between them (query *Difference*).

For the entire model and for individually modelled date ranges, individual and overall agreement indices were calculated, as well as the convergence integral (C). These parameters are diagnostic indicators which inform if the analysed set of dates has provided statistically significant distribution of probability. In order to estimate the probability of possible relationships between the end of the Epigravettian and the beginning of the late Magdalenian settlement, query *Order* was used. Its result was then visualised (**Fig. 3**) by the prob.phases.relat.r R script (Alberti, 2016).

3. RESULTS

Table 2 shows the results of modelling for the confidence level of 68.2% and 95.4%, but further reasoning was based on the data obtained for 2 sigma, *i.e.* with the probability of 95.4% (**Fig. 2**). Although the results of the modelling were generated with an accuracy of one year, they are rounded up to 10 in the **Table 1** and as for the subsequent analysis the dates and time intervals are given in full hundreds of years.

The first step in the model evaluation is the analysis of the agreement indices. For these indices, the values above 60% are assumed acceptable (Bronk Ramsey, 1995, 2009a). The entire model presents both high agreement index (A_{model}), as well as the overall agreement index ($A_{overall}$). Also, the results of individual agreement index (A) and convergence integral (C) for individual dates usually reach values close to 100%, although there are the exceptions *i.e.* two dates from Maszycka Cave (Ly-2453 and Ly-2454), for which A fell below 60%. However, the researchers decided not to remove these dates from the model, because the results of outlier analysis for this site did not indicate clearly the need for their rejection. It should be also taken into account that, as it was pointed out by Bronk Ramsey (2009b) '1 in 20 samples are likely to fall below this level and such rejection should also be based on other criteria'. In the case of Maszycka Cave such a criterion can be both the time when the dates were

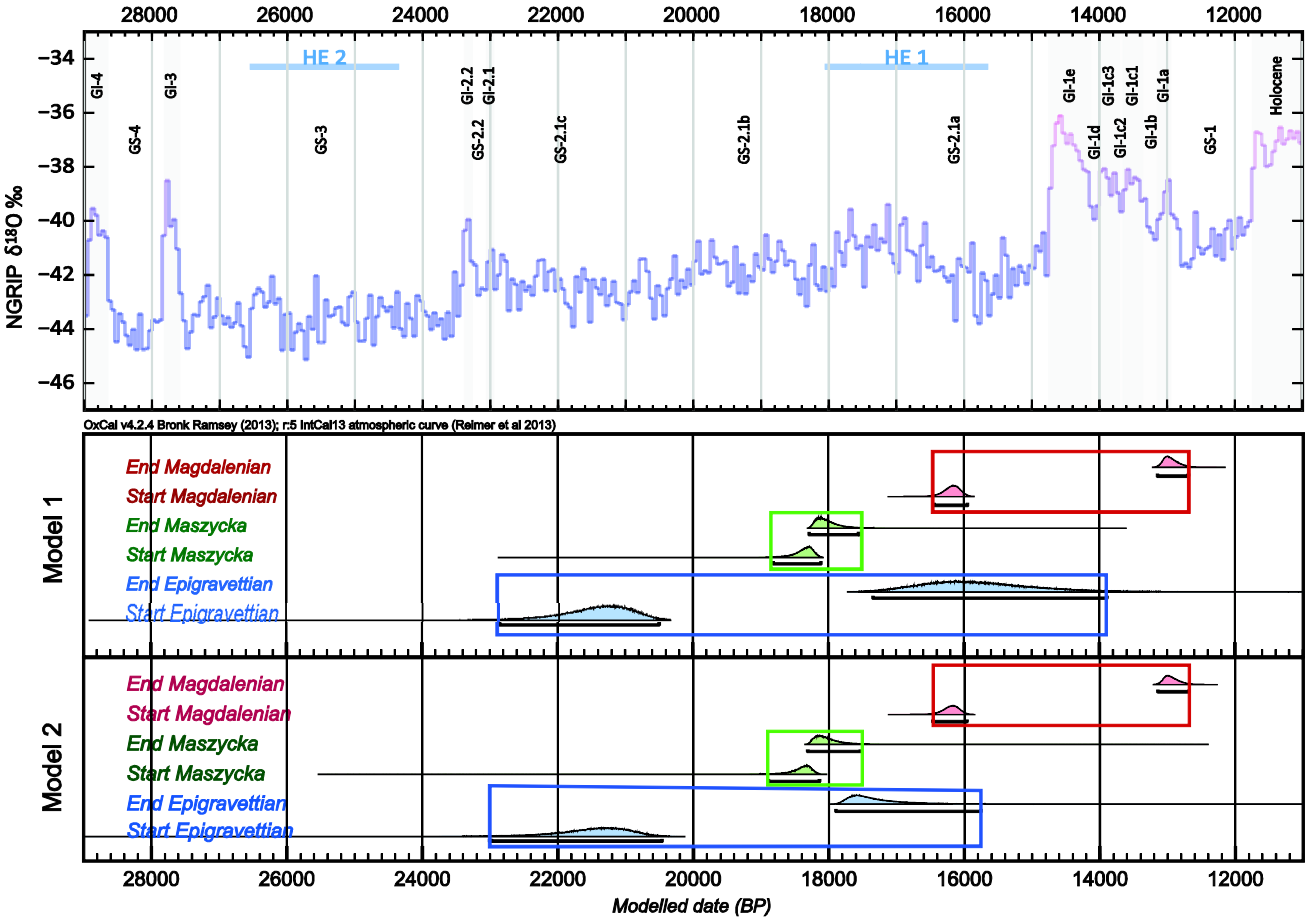

Fig. 2. *Bayesian models of the chronology of Epigravettian and Magdalenian on the background of palaeoclimatic event record of NGRIP oxygen isotope curve (GICC05modelext timescale, by Rasmussen et al., 2014). Probability distributions for dates and modelled events shown with 95,4% confidence level.*

established (the 'older' dates are clearly different from the younger dates), as well as the dating method (conventional and AMS ones). Finally, considering primarily a slight deviation from the 60% threshold, it was decided to leave these dates in the model. In summary, the obtained values of diagnostic parameters allow us to assume that in the light of the analysed data the model has been constructed properly, it is internally consistent and, thus, does not provide a formal basis for the rejection of its results.

As mentioned above, the models were constructed with the assumption of overlapping phases. Three settlement phases were separated: the Epigravettian, the middle Magdalenian (represented only by Maszycka Cave) and the younger Magdalenian one. The following data were obtained:

- dates of the beginning (*Boundary start*) and the end(*Boundary end*) of each of the analysed settlement episodes,
- information regarding the duration of individual episodes (*Span*),

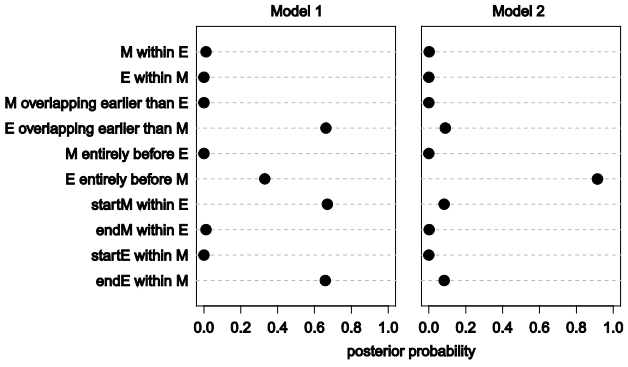

Fig. 3. *Two models of probabilities of possible chronological relationships between Epigravettian and late Magdalenian, based on the results of the OxCal Order query (Bronk Ramsey, 2009a), generated by prob.phases.relat.r script (Alberti, 2016). E — Epigravettian, M — late Magdalenian, startE — start of Epigravettian, startM — start of late Magdalenian, endE, — end of Epigravettian, endM — end of late Magdalenian.*

Table 2. *Results of Bayesian age modelling of two discussed models of Epigravettian and Magdalenian settlement chronology. A_{model}: model agreement index, $A_{overall}$: overall agreement index, %: probability distribution range, C: convergence integral.*

Model	Name	Modelled (BP)						
		from	to	%	from	to	%	C
Model 1 (A_{model}=80.0, $A_{overall}$=75.7)	Phase							
	Sequence							
	Boundary Start Epigravettian	21940	20820	68.2	22950	20460	95.4	95.6
	Phase Epigravettian							
	Boundary End Epigravettian	16810	15130	68.2	17370	13890	95.4	96.8
	Span Epigravettian	4400	6660	68.2	3670	8260	95.4	97.0
	Sequence							
	Boundary Start Maszycka	18500	18220	68.2	18850	18130	95.4	98.2
	Phase Maszycka							
	Boundary End Maszycka	18260	17950	68.2	18320	17560	95.4	97.9
	Span Maszycka	0	480	68.2	0	1180	95.4	97.5
	Sequence							
	Boundary Start Magdalenian	16300	16060	68.2	16470	15960	95.4	99.7
	Phase Magdalenian							
	Boundary End Magdalenian	13080	12860	68.2	13150	12680	95.4	99.6
	Span Magdalenian	3050	3410	68.2	2920	3640	95.4	99.7
	Order							
	=End Magdalenian	13080	12860	68.2	13150	12680	95.4	99.6
	=Start Magdalenian	16300	16060	68.2	16470	15960	95.4	99.7
	=End Maszycka	18260	17950	68.2	18320	17560	95.4	97.9
	=Start Maszycka	18500	18220	68.2	18850	18130	95.4	98.2
	=End Epigravettian	16810	15130	68.2	17370	13890	95.4	96.8
	=Start Epigravettian	21940	20820	68.2	22950	20460	95.4	95.6
	Difference End Epigravettian – Start Magdalenian	–620	1060	68.2	–1200	2320	95.4	97.5
Model 2 (A_{model}=82.4, $A_{overall}$=78.9)	Phase							
	Sequence							
	Boundary Start Epigravettian	22020	20840	68.1	23410	20480	95.4	96.4
	Phase Epigravettian							
	Boundary End Epigravettian	17800	17030	68.2	17910	15680	95.4	99.1
	Span Epigravettian	3310	4990	68.2	2840	7060	95.4	98.6
	Sequence							
	Boundary Start Maszycka	18500	18220	68.2	18850	18130	95.4	96.0
	Phase Maszycka							
	Boundary End Maszycka	18270	17950	68.2	18320	17550	95.4	96.4
	Span Maszycka	0	470	68.2	0	1170	95.4	96.6
	Sequence							
	Boundary Start Magdalenian	16300	16060	68.2	16470	15960	95.4	99.8
	Phase Magdalenian							
	Boundary End Magdalenian	13080	12860	68.2	13150	12690	95.4	98.7
	Span Magdalenian	3050	3410	68.2	2920	3640	95.4	99.7
	Order							
	=End Magdalenian	13080	12860	68.2	13150	12690	95.4	98.7
	=Start Magdalenian	16300	16060	68.2	16470	15960	95.4	99.8
	=End Maszycka	18270	17950	68.2	18320	17550	95.4	96.4
	=Start Maszycka	18500	18220	68.2	18850	18130	95.4	96.0
	=End Epigravettian	17800	17030	68.2	17910	15680	95.4	99.1
	=Start Epigravettian	22020	20840	68.1	23410	20480	95.4	96.4
	Difference End Epigravettian – Start Magdalenian	–1670	–780	68.2	–1810	580	95.4	98.9

- information regarding the duration of an interval between episodes or the period of overlapping individual episodes (*Difference*),
- information of relative order of events (*Order*).

Both models gave similar results. The only difference is the modelled end of the Epigravettian settlement on the analysed area.

According to the Model 1, the beginning of the Epigravettian settlement in Poland can be dated to the period between 23000 and 20500 cal BP, while the end fell into the period between 17400 and 13900 cal BP. The duration of the Epigravettian settlement ranges from 3700 to 8300 years. Such a significant margin of error is caused mainly by large margins of error for dates from chronologically 'outermost' sites: Deszczowa Cave and Krakow-Spadzista, determining the beginning of the settlement, as well as Sowin 7 and Zawalona Cave, being chronologically the youngest Epigravettian sites. In Model 2, where some of the questionable dates were not taken into consideration, the range changes significantly. The phase starts, as in Model 1, between 23000 and 20500 cal BP, but its end falls in the years between 17900 and 15700 cal BP with span of 2800–7100 years.

In the case of Maszycka Cave, a short duration of the settlement episode (see Kozłowski *et al.*, 1995, 2012) is well confirmed by the modelled dates. The beginning of this episode can be placed between 18900 and 18100 cal BP, while its end — between 18300 and 17500 cal BP, and the duration from 0 to 1200 years. It should be emphasized that this period probably should be narrowed down significantly. After the rejection of older dates (in terms of the time when the analysis was conducted), *i.e.* Ly-2453 and Ly-2454, the period would be significantly reduced.

The last, the youngest of the analysed settlement episodes (the late Magdalenian one) started between 16500 and 16000 cal BP, and it ended in the period between 13100 and 12700 cal BP, and its modelled duration amounted between 2900 and 3600 years.

Query *Difference* allowed us to calculate the hiatus duration or the period of overlapping not completely simultaneous events, *i.e.* the period between the Epigravettian and the late Magdalenian settlement as well as the period between the late Magdalenian settlement and the episode from Maszycka Cave. In both of the models, the Maszycka settlement episode falls completely into chronological range of the Epigravettian settlement. The chronological gap between the middle and late Magdalenian lasted from 1300 to 2200 years.

In the case of the late Magdalenian and the Epigravettian settlement, the situation is more complex. According to Model 1, it is possible that the two episodes overlapped (in the period of up to 2300 years), or there was a gap between them lasting up to 1200 years. The probability matrix of possible relations of the phases, generated by *Order* query and visualised by a prob.phases.relat.r script (**Fig. 3**) show that the possibility of overlapping is 0.66 and the probability of the gap between them equals 0.34. Model 2 gives us a completely different result of these relations: there is only a slight (0.09) possibility of overlapping these two phases and the settlement hiatus between them is much more probable (0.91).

4. DISCUSSION

The data presented above allow us to discuss some important issues. The first of them concerns an attempt to determine the authors of Central European recolonization immediately after the end of the LGM. In the case of areas situated west from the Elbe River, it is assumed, of course, that the recolonization took place thanks to the Magdalenian culture including its ancestors. The model (today criticized) of pioneering and residential phases was accepted previously (Housley *et al.*, 1997 vs. Blockley *et al.*, 2000). Until recently, the same model was regarded for the area located between the Odra River and the Bug River (e.g. Kozłowski, 1964, 1985, 1987; Kozłowski and Kozłowski, 1977; Połtowicz-Bobak, 2013 and others). In this paper, we propose a different model, which assumes that the process of recolonization was of complex nature in terms of cultural diversity. This is indicated by the remains of two groupings, *i.e.* the Magdalenian culture and the Epigravettian culture dated to the same period. This period is obviously quite significant because it could range up to 2300 years. Both groupings exploited the same biomes: steppe and steppe-tundra. Malacological data and study on rodents from Zawalona Cave revealed the presence of species typical of a cold and temperate climate (Alexandrowicz *et al.*, 1992). It is very likely that in the area of Poland both groups exploited similar fauna. The data from the site Targowisko (Wilczyński, 2009) and Maszycka Cave (Kozłowski *et al.*, 1995) indicate the presence of a reindeer and a horse. The same taxa occurred in layer E of Zawalona Cave (Alexandrowicz *et al.*, 1992). What is more, the fact that remains of both groupings contain the evidence of penetration of the same geographical regions draws our attention. This is indicated by the lithic raw materials imported from the Carpathians region (see Kaminská 2001; Přichystal, 2009). They are, amongst others, radiolarites and obsidian recorded in the Epigravettian assemblages from Sowin and Targowisko (Wilczyński, 2009) and radiolarites in the inventory from Dzierżysław (Połtowicz-Bobak, 2012) and Wilczyce (Królik, 2014).

The second question concerns the determination of chronological framework of the Magdalenian and the Epigravettian coexistence. Based on the model 1 presented in this paper, the period of possible 'coexistence' could range between 18500 and 13900 years ago. The younger border of this range is defined by the Magdalenian sites Dzierżysław 35 and Wilczyce as well as the supplementary data from Zalas Cave, and the data from the Epigravettian site Sowin 7. The dates for the inventory from Zawalona Cave are similar, but due to the small number it cannot be relied upon. Dating of the Epigravettian assemblage from Sowin 7 also is not certain because it refers to the chronology of the mineral deposit, which contains artefacts. It seems that this assemblage may be a bit older. Taking this into account, the younger boundary of overlapping the Magdalenian and the

Epigravettian remains at the moment should be treated with caution (model 2). The older border of overlapping the Magdalenian and the Epigravettian assemblages is determined by the remains of the middle phase of the Magdalenian culture from Maszycka Cave and the Epigravettian assemblage from Targowisko. It should be emphasized that both assemblages obtained a relatively large number of homogeneous dates. This makes the lower range more certain than the upper limit. Chronological *overlapping* between the two entities, whose representatives used almost the same regional sources, provokes us into asking questions about their relationship. Taking into account the previous discussions and results presented in this paper, one can consider the legitimacy of three models.

In the first model, it is suggested that the Epigravettian acted as a substrate for the Magdalenian expanding from a Central European centre located in the Carpathian zone (Maier, 2015). Therefore, the Epigravettian assemblages from Poland in this sense are the traces of the Magdalenian centre progenitors. In our opinion, this model is currently difficult to accept. Its biggest weakness lies in the fact that, in the light of current data, overlapping dating of Epigravettian and Magdalenian assemblages is visible. The assemblages from Targowisko and possibly from Sowin 7 seem to be younger or simultaneous with some Magdalenian assemblages, such as Maszycka Cave or Dzierżysław 35. Another weakness of this model lies in the lack of evidence of the presence regarding several Magdalenian centres. On the contrary, in older and middle phases stylistic connections between western and eastern area are visible (see e.g. Kozłowski *et al.*, 1995; Ginter *et al.*, 2005). This model contradicts also the results of technological analyses of Epigravettian and Magdalenian assemblages, showing large differences in production of basic blanks, *i.e.* blades and the lack of technological continuum (seee.g. Pyżewicz *et al.*, 2014; Wilczyński, 2009; Wiśniewski *et al.*, 2012a). It should be also noted that population of both groupings probably occupied the territories north of the Carpathians and the Sudetes in a slightly different way. The Epigravettian remains evidence high mobility. The available data suggest the use of the residential system (see further Wiśniewski *et al.*, 2012a). Whereas, in the case of the Magdalenian, it is possible to notice an increased diversity of Magdalenian assemblages during the time, in terms of size and structure (Połtowicz-Bobak, 2013). Therefore, the assemblages recoding the traces of a short stay can be identified, and it cannot be ruled out, that they can be limited to a narrow range of tasks associated with obtaining raw materials or food supply (e.g. Sowin 7, upper level, Hłomcza). What is more, the remains of camps used repeatedly (Dzierżysław 35, Klementowice, Wilczyce) may be noticed. It can be assumed that the colonization in the area situated to the north of the Carpathians between the Odra River and the Bug River basins might have had a logistical character in the middle phase of the Magdalenian culture.

Another model, that can be tentatively called the model of 'displacement or replacement' of the Epigravettian population by more numerous, coming from the west Magdalenian groups, indicates a possibility of adopting Magdalenian innovations by local Epigravettian groups (see Wilczyński, 2009). Its probability is strengthened by the fact of a relatively long period of possible interactions, which lasted (according to the dates) approximately more than 2000 years. Its weakness, like the previous model, is the lack of evidence of adoption of even some elements by any of the communities. While not dismissing the model No. 2, in our opinion, a more likely scenario is the 'model of independent coexistence' of representatives of the Epigravettian and the Magdalenian group-s. This period roughly coincides with the early and middle phase of development of the Magdalenian culture in Central Europe. Basic facts indicating such a scenario are primarily the ones shown above, that is overlapping absolute dating, and the absence of evidence of interactions between individual groups which might have resulted for example in technological or typological borrowings. At the same time, it seems that one should not exclude the possibility of contacts between the two communities as evidenced by the imports of stone raw materials found at Magdalenian sites from the areas already beyond the reach of the Magdalenians and within the range of the Epigravettian groups. These imports are known also from older and younger sites, corresponding to the later phase of the Magdalenian settlement (e.g. Volhynia flint from Maszycka Cave and Wierzawice, Slovak limnoquartzite from the site Łąka). The possibility of contact is also indicated by the fact of occupation of the same geographical and ecological zone as well as the necessity of exploitation of the same raw material sources.

Considering the possibility of overlapping of both groupings traces in some areas, it is necessary to mention the anthropological findings. Based on them, it can be stated that the exploration of territory inhabited by another group is possible. However, the existence of social or economic relations between newcomers and local hunters needs to take place. It should be noted that the territories do not have clearly defined boundaries, and besides, they can change over time, even during a year (Kelly, 2013). R. Kelly points out (2013) that we should not be involved in the studies of territoriality in the modern meaning, but we should aim to evaluate the manner and range of access to various areas and sources located there. Low density of settlement and scattered sources in upland areas between 18th and 15th millennium BP could have resulted in the lack of their permanent protection due to negative advantage rate resulting from such actions (according to Economic Defensibility Model, Dyson-Hudson and Smith, 1978). This, in turn, might have facilitated access to sources to 'external' groups.

A similar 'chronological and taxonomic' situation is observed in areas of the Czech Republic, while there are perceptible differences between Moravia and Bohemia. Speaking of these areas, there are several sites, both Epigravettian and Magdalenian, which provided radiocarbon dates. The Epigravettian sites prove the episodic presence of the population of this taxonomic unit in the areas of both Bohemia and Moravia, first in the 19th and 18th millennium BP (Stránská skála IV, Svobodné Dvory) (Verpoorte and Šída, 2009; Šída *et al.*, 2006), and then in the 15th millennium BP. The latter mentioned period determines the sites Brno Štýřice III (Nerudová *et al.*, 2012, Nerudová and Neruda, 2015) and Velké Pavlovice (14460 ± 230 BP GRN-16139, Valoch, 2010), *i.e.* the most important for our consideration Moravian Epigravettian sites. These two sites define well the end of the Epigravettian settlement.

The oldest Magdalenian sites come from caves Balcarova skála (13930 ± 100 BPGRN-28448; Valoch and Neruda, 2005) and Nová Drátenická (the oldest date 13870 ± 140 BP OxA-1953; Svoboda *et al.*, 1995). Regarding the second case, the site dating is so problematic that the cited date is one of three; two other dates were much younger which made the site chronology uncertain. Slightly younger are the traces of settlement from a number of sites dated to GS-2.1a (Pekárna Cave, Žitného Cave, Moravia), KoněpruskCave (Bohemia), open sites Putim and Keblice (Bohemia) (Połtowicz-Bobak *et al.*, 2014, there further references). It is worth noting that there was a clearer, lasting for about five thousand year hiatus between the Epigravettian and the Magdalenian settlement in Bohemia, while in Moravia the situation is similar to that observed in Poland. The dates modelling indicates that the youngest Epigravettian and the oldest Magdalenian dates may overlap. Inference regarding dating of the Moravian sites is burdened, however, with much greater degree of uncertainty due to the fact that these sites usually have one date or a few but very strongly divergent, therefore, it makes the interpretation difficult.

5. CONCLUSION

The presented study focusing on the analysis of dating of the Epigravettian and Magdalenian assemblages led us to several conclusions. Firstly, the research indicates that the Epigravettian and the Magdalenian could have existed in Central Europe, probably with many gaps, simultaneously for about 4500 years. Unfortunately, it is currently impossible to specify the framework dates, but it seems that it happened between 18500 and 13900 years BP, while the older part of this period belongs to the middle phase of the Magdalenian represented by the Maszycka Cave episode. Possible coexistence of the Epigravettian and late Magdalenian groups can be placed between 16500 and 13900 years BP, regarding the aforementioned reservations. Secondly, these groups probably used the same sources, e.g. rock raw materials in Polish territories, exploiting the same areas of similar or even identical climate and natural conditions. Taking into account the wider chronological perspective, namely the period from 20000 to 13000 years, it seems that the Epigravettian culture, probably represented by various groups, about 15000 years ago disappeared from the area located west from the Bug River, while the dominant grouping became the population representing the Magdalenian patterns. Nevertheless, the interaction between the Epigravettian and Magdalenian groups has still remained an unsolved issue. However, we do not eliminate the possibility of contacts. If they had taken place, they did not leave traces in the material culture of the Epigravettian or Magdalenian sites.

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