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^{14}C-BASED ABSOLUTE CHRONOLOGY OF THE MALICE CULTURE REASSESSED

ABSTRACT

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This article addresses the absolute chronology of the Malice culture. It presents a Bayesian modelling based on an elementary assessment of accuracy and precision of all the relevant ^{14}C age measurements. Thanks to the preliminary qualitative evaluation, the newly built models are of higher statistical agreement than previous ones. Based on the refined models, the Early stylistic phase (Ia) of the Malice culture can be dated to around 4770-4600, the Classic one (Ib) – 4630-4440, Post-Classic one (Ic) – 4460-4390, and the Late one (II) – 4390-4290/4250 BCE. Accordingly, subphase Ia can be synchronised with: phase Polgár-Csőszhalom II, phase Lengyel I and the subphase Stichbandkeramik IVa; subphase Ib with: phases Polgár-Csőszhalom III and Proto-Tiszapolgár, the Santovka phase of the Lengyel culture as well as *Stichbandkeramik* IVb; Ic subphase with: the Classical phase-Tiszapolgár culture and the Lengyel II phase; phase II with: the late Tiszapolgár/earliest Bodrogkeresztúr culture and the Lengyel III phase.

Keywords: Lesser Poland, Upper Silesia, Western Volhynia, Malice culture, radiocarbon chronology, Bayesian inference

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INTRODUCTION

The progress in the research on the radiocarbon-based absolute chronology of the Malice culture has already been summarised twice since 2022 (see Zastawny 2022; Kadrow 2023). It might therefore be thought that chronometric studies have just gained such a momentum that approaching the problem for the third time in such a short period may not be justified.

Given the intensity of archaeological research conducted nowadays and the widespread use of ^{14}C dating over the past few decades, it is not surprising that the lists of radiocarbon age measurements published in the cited articles very quickly became outdated. Even the research conducted at the time those studies were written provided new ^{14}C dates. The newly performed ones include ^{14}C age determinations produced for two Malice culture burials discovered at site Kraków-Nowa Huta-Zesławice 88 and a few more graves unearthed at site Smroków 4. The resulting dates and the specification of dated organic remains, along with the key parameters characterising them, have already been published (Piotrowska *et al.* in press). Hence, only some of the archaeological contexts of the samples will be described in more detail here, namely the ones that are certainly worth disseminating. Radiocarbon dating of the contexts in question is certainly revealing. However, does a handful of additional data, even if quite important, justify writing yet another article on this topic?

The way these few additional ^{14}C age measurements will be presented below may rightly recall the old-fashioned formula of the article written by Jan Bakker and co-authors (1969), the publication of which 55 years ago created the ground for the research on the radiocarbon chronology of the Younger Stone Age in the Vistula and Oder basins. If such dates had appeared shortly after, they could have perhaps been considered groundbreaking. Also, every such data point would have certainly enriched significantly every following study and date list appearing over the next three decades, when the production of radiocarbon age determinations remained quite limited (*cf.,* Kurzątkowska 1985; Breunig 1987; Jankowska 1990; Forenbacher 1993; Czebreszuk and Szmyt 2001). Presently though, addressing a separate paper to a few additional ^{14}C dates may seem a somewhat obsolete idea. An increase in the number of radiocarbon age determinations performed by some laboratories is measured in tens, if not hundreds of thousands per decade. In order to keep them under any control, not only increasingly larger databases (see for example, Hinz *et al.* 2012; Barta *et al.* 2013; Capuzzo *et al.* 2014; Manning *et al.* 2016; Martínez-Grau *et al.* 2021; Vondrovský *et al.* 2023), but also dedicated data lakes or even data warehouses are being created all over Europe (see for example, Bronk Ramsey *et al.* 2019; Bird *et al.* 2022; Roe and Hinz 2022). Also, lists of newly obtained ^{14}C dates are published as compactly as possible (see for example, Chmielewski *et al.* 2021; Pospieszny and Nowaczyk 2022). So, are there any sound reasons for approaching again the ^{14}C -based absolute chronology of the Malice Culture?

In any case, the value of the pool of relevant results of ^{14}C age measurements cannot be measured solely by their number but also by their accuracy and precision. Regardless of the current perception of the work completed by Bakker and co-authors, one should bear in mind that they were already applying rudimentary quality criteria for assessing the precision and accuracy of their dates (Bakker *et al.* 1969, 5). Since then, the general 'chronometric awareness' has been constantly growing, and today it would not even be possible to do justice to and cite all the studies dealing with the reliability of radiocarbon dating of various archaeological finds. Let us just point out that also in the course of the studies directly addressing the ^{14}C -based chronology of the Neolithic and Eneolithic in the Odra and Vistula basins, considerable efforts have been made to sort this issue out either *ad hoc* (see for example Nowak 2017, supplementary material) or in a systemic way (*cf.*, Czebreszuk and Szmyt 2000, 69-70; Chmielewski 2020a, 55-69). And yet, the studies referred to at the beginning of this paper completely ignore the qualitative factor and equalise the reliability of all the statistically analysed ^{14}C dates.

In order to demonstrate and correct chronological miscalculations resulting from the chronological modelling carried out on the basis of overly simplified assumptions, we decided to perform the Bayesian statistical analyses anew, this time though preceding them with an elementary assessment of the accuracy and precision of all the radiocarbon age measurements constituting the output set. The architecture of the eventual sequential models included additional prior arguments resulting from the qualitative specification. All the discrepant results were critically analysed with a particular emphasis put on the effect of quantity and quality of the ^{14}C dates used for the modelling on the differences.

MATERIAL AND METHODS

Initially, the data pool consisted of 55 radiocarbon age measurements related to 42 contexts associated with the Malice culture in the vast area covering western Volhynia, Lesser Poland and Upper Silesia. The results of all the measurements, along with the specification of dated organic material samples and their archaeological contexts, are listed alphabetically in Table 1.

Except for the hitherto unpublished human burials from Kraków-Nowa Huta-Zesławice and Smroków, the description of all the archaeological contexts, for which the analysed radiocarbon ages were measured, is rather succinct; it has been limited to names of archaeological sites, numbers of features and their functional attribution. However, every record contains references to works providing a more comprehensive information on the given find and its wider context.

Each ^{14}C-dated and diagnostic archaeological assemblage of the Malice culture was assigned to its development phase in accordance with the widely accepted phasing, which originally was presented by Anna Dzieduszycka-Machnikowa (Dzieduszycka-Machnikowa

Table 1. List of radiocarbon ages that are connected with the Malice culture. A detailed explanation of the system of archaeological phasing of the Malice culture and the system of assessment of the accuracy and precision of the measurements is provided in the text

No.	Site	Feature no.	Type of feature	Phase	Material dated	Laboratory no.	Radiocarbon age (BP)	Date quality	References
1	Aleksandrowice 2 (AKD2)	376	settlement pit	Ia	charcoal (Quercus sp.; fragment of a twig)	Poz-121003	5890 ±35	Ba2	Micyk *et al.* 2020; Zastawny 2022; Kadrow 2023
2	Iwanowice Włościańskie (Góra Klin) 1 (IWW1)	8	settlement pit	Ia[1]	charcoal (undet.)	GrN-5977	5855 ±40	Bc2	Dzieduszycka-Machnikowa, Lech 1976; Breunig 1987
3	Kichary Nowe (Pole Bolenia) 2 (KNW2)	72	settlement pit	Ia	charcoal (undet.)	Gd-6967	5730 ±130	Bc4	Kowalewska-Marszałek 2004; Kaczanowska, Kozłowski 2006
4	Kraków-Nowa Huta-Zesławice 88 (NHZ88)	B820	human burial	Ib	human bone (♀, 25-30 yrs; left rib)	GdA-7310	5640 ±30	Aa2	Piotrowska *et al.*, in press; unpublished burial (Fig. 2)
5	Kraków-Nowa Huta-Zesławice 88 (NHZ88)	C150	human burial	Ib	human bone (♀, 20-25 yrs; left rib)	GdA-7312	5690 ±30	Aa2	Piotrowska *et al.*, in press; unpublished burial (Fig. 3)
6	Kraków-Nowa Huta-Zesławice 88 (NHZ88)	Y421	human burial	Ic	human bone (♀, 20-30 yrs; long bone)	GdA-7428	5545 ±40	Aa2	Piotrowska *et al.*, in press; unpublished burial (Fig. 5)
7	Kraków-Olszanica 2 (KRO2)	20	settlement pit	Ia	charcoal (Quercus sp.)	Poz-77984	5830 ±40	Ac2[2]	Zastawny 2022; Kadrow 2023
8	Kraków-Witkowice II (KRW2)	7	settlement pit	x[3]	animal bone (Bos sp.)	Poz-43316	5525 ±35	Da2[4]	Zastawny 2015; Zastawny 2022; Kadrow 2023
9	Las Stocki 7 (LST7)	57	settlement pit	x	charcoal (undet.)	Gd-4164	5400 ±140	Dc4	Zakościelna 1996; Kadrow, Zakościelna 2000; Chmielewski 2008; Włodarczak 2017; Zastawny 20232; Kadrow 2023
10	Las Stocki 7 (LST7)	57	settlement pit	x	charcoal (undet.)	Gd-2715	5400 ±80	Dc3	Zakościelna 1996; Kadrow, Zakościelna 2000; Chmielewski 2008; Włodarczak 2017; Zastawny 2022; Kadrow 2023

11	Las Stocki 7 (LST7)	28	settlement pit	x	charcoal (undet.)	Gd-1724	5350 ±60	Dc3	Pazdur *et al.* 1994; Kadrow 1996; Zakościelna 1996; Kadrow, Zakościelna 2000; Chmielewski 2008; Włodarczak 2017; Zastawny 2022; Kadrow 2023
12	Łoniowa 18 (LNW18)	9	settlement pit	Ia?	charcoal (undet.)	Poz-15978	5880 ±40	Bc2	Valde-Nowak 2009; Zastawny 2022; Kadrow 2023
13	Racibórz-Ocice (RCO)	9[5]	settlement pit	x	charcoal (undet.)	KN-I.357	5690 ±55[6]	Dc3	Breunig 1987; Kamieńska, Kozłowski 1990; Kulczycka-Leciejewiczowa 1993; Czarniak 2012; Chmielewski 2020
14	Rozbórz 42 (RZB41)	2645	posthole (timber house)	Ib	charcoal (undet.)	MKL-799	5820 ±90	Ac3	Sznajdrowska, Mazurek 2015; Zastawny 2022; Kadrow 2023
15	Rzeszów 31 (RZW31)	18	settlement pit	II	charcoal (undet.)	Poz-16473	5480 ±40	Ac2	Dębiec, Pelisiak 2008; Zastawny 2022; Kadrow 2023
16	Rzeszów 31 (RZW31)	18	settlement pit	II	charcoal (undet.)	Poz-16474	5450 ±40	Ac2	Dębiec, Pelisiak 2008; Zastawny 2022; Kadrow 2023
17	Sandomierz 6 (SWZ6)	26	settlement pit	II	charcoals (undet.)	Gd-2909	5930 ±130	Bd4[7]	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017
18	Sandomierz 6 (SWZ6)	24	settlement pit	II	charcoals (undet.)	Gd-4322	5740 ±130	Bd4[8]	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017
19	Sandomierz 6 (SWZ6)	49	settlement pit	II	charcoals (undet.)	Gd-4459	5680 ±140	Bd4[9]	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017
20	Sandomierz 6 (SWZ6)	16	settlement pit	II	charcoal (undet.)	Poz-57913	5590 ±40	Bc2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023
21	Sandomierz 6 (SWZ6)	42	settlement pit	II	charcoal (undet.)	Poz-57916	5590 ±40	Bc2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023

No.	Site	Feature no.	Type of feature	Phase	Material dated	Laboratory no.	Radiocarbon age (BP)	Date quality	References
22	Sandomierz 6 (SWZ6)	25	settlement pit	II	charcoal (undet.)	Poz-60513	5580 ±35	Bc2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023
23	Sandomierz 6 (SWZ6)	43	settlement pit	II	charcoal (undet.)	Poz-57917	5565 ±35	Bc2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023
24	Sandomierz 6 (SWZ6)	3	human burial	II	tar (undet.)	Poz-60512	5545 ±35	Ac2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023
25	Sandomierz 6 (SWZ6)	1	human burial	II	charcoal (undet.)	Poz-62480	5525 ±35	Bc2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023
26	Sandomierz 6 (SWZ6)	2	settlement pit	II	animal bone (undet.)	Poz-505596	5520 ±40	Bb2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023
27	Sandomierz 6 (SWZ6)	7	settlement pit	II	animal bone (undet.)	Poz-505595	5490 ±40	Bb2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023
28	Sandomierz 6 (SWZ6)	50	settlement pit	II	charcoal (undet.)	Gd-2910	5450 ±100	Bc3	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023
29	Sandomierz 6 (SWZ6)	18	settlement pit	II	charcoal (undet.)	Poz-63725	5452 ±35	Bc2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023

30	Sandomierz 6 (SWZ6)	50	settlement pit	II	charcoal (undet.)	Poz-62494	5420 ±35	Bc2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023
31	Sandomierz 6 (SWZ6)	67	settlement pit	II	charcoal (undet.)	Poz-57821	5360 ±35	Bc2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023
32	Sandomierz 6 (SWZ6)	26	settlement pit	II	charcoal (undet.)	Poz-62493	5300 ±35	Bc2	Kowalewska-Marszałek, Cygnot 2017; Włodarczak 2017; Zastawny 2022; Kadrow 2023
33	Sandomierz-Kruków 20 (SKR20)	11	settlement pit	II?	charcoal (undet.)	Gd-1944	5030 ±50	Cd2	Michalak-Ścibior, Taras 1995
34	Smroków 4 (SRW4)	H16	human burial	Ic	human bone (sex undet., 10-11 yrs; ulna)	Poz-91125	5585 ±35	Ab2	Piotrowska *et al.*, in press; unpublished burial
35	Smroków 4 (SRW4)	H26	human burial	Ic	human bone (sex undet., 12-15 yrs; humerus)	Poz-91126	5605 ±35	Ab2	Piotrowska *et al.*, in press; unpublished burial
36	Smroków 4 (SRW4)	H17	human burial	Ic	human bone (sex indet., 18-35 yrs; femur)	Poz-91094	5230 ±50	Ad2[10]	Piotrowska *et al.*, in press; unpublished burial
37	Smroków 4 (SRW4)	H29	human burial	Ib	human bone (♀, ca 22 yrs; os longum)	Poz-127152	5640 ±40	Ab2	Piotrowska *et al.*, in press; unpublished burial (Fig. 4)
38	Smroków 4 (SRW4)	J57	human burial	Ib	human bone (sex undet., ca 10 yrs; os longum)	Poz-127153	5670 ±40	Ab2	Piotrowska *et al.*, in press; unpublished burial
39	Smroków 4 (SRW4)	G22	human burial	Ib	human bone (sex undet., ca 6 yrs; os longum)	Poz-127156	5610 ±40	Ab2	Piotrowska *et al.*, in press; unpublished burial
40	Smroków 4 (SRW4)	O45?	human burial	II	human bone (os longum)	Poz-127154	5470 ±40	Ab2	Piotrowska *et al.*, in press; unpublished burial

No.	Site	Feature no.	Type of feature	Phase	Material dated	Laboratory no.	Radiocarbon age (BP)	Date quality	References
41	Świerszczów Kolonia 28 (SWK28)	4 (grave 2)	human burial	II?	human bone (♂, adultus; bone undet.)	Ki-4193	5430 ±60	Bd3[11]	Kadrow, Zakościelna 2000; Kadrow 2009; Kadrow *et al.* 2009; Zastawny 2022; Kadrow 2023
42	Świerszczów Kolonia 28 (SWK28)	5 (grave 3)	human burial	II?	human bone (sex undet., infans I; bone undet.)	Ki-4189	5350 ±50	Cd2[xi]	Kadrow, Zakościelna 2000; Kadrow 2009; Kadrow *et al.* 2009; Zastawny 2022; Kadrow 2023
43	Targowisko 10-11 (TRG10-11)	2271	settlement pit	Ia	charcoal (Quercus sp.)	Poz-71637	5800 ±35	Cc2	Zastawny 2022; Kadrow 2023
44	Targowisko 14-15 (TRG14-15)	1	settlement pit	Ib	charred plant macro-remains (undet.)	MKL-A5167	5821 ±23	Cc1	Kadrow *et al.* 2021; Zastawny 2022; Kadrow 2023
45	Targowisko 14-15 (TRG14-15)	1A	settlement pit	Ib	charred plant macro-remains (undet.)	MKL-A5166	5779 ±24	Cc1	Kadrow *et al.* 2021; Zastawny 2022; Kadrow 2023
46	Targowisko 14-15 (TRG14-15)	1	settlement pit	Ib	charred plant macro-remains (undet.)	MKL-A5165	5755 ±23	Cc1	Kadrow *et al.* 2021; Zastawny 2022; Kadrow 2023
47	Targowisko 14-15 (TRG14-15)	1	settlement pit	Ib	charred plant macro-remains (undet.)	MKL-A5162	5741 ±23	Cc1	Kadrow *et al.* 2021; Zastawny 2022; Kadrow 2023
48	Targowisko 14-15 (TRG14-15)	1C	settlement pit	Ib	charred plant macro-remains (undet.)	MKL-A5163	5737 ±23	Cc1	Kadrow *et al.* 2021; Zastawny 2022; Kadrow 2023
49	Targowisko 14-15 (TRG14-15)	1	settlement pit	Ib	charred plant macro-remains (undet.)	MKL-A5168	5737 ±23	Cc1	Kadrow *et al.* 2021; Zastawny 2022; Kadrow 2023
50	Targowisko 14-15 (TRG14-15)	10	settlement pit	Ib	charred plant macro-remains (undet.)	MKL-A5164	5705 ±24	Cc1	Kadrow *et al.* 2021; Zastawny 2022; Kadrow 2023
51	Targowisko (TRG core)	x	sediment core	Ia	biogenic sediments	MKL-4183	5960 ±80	Dd3	Forysiak *et al.* 2021; Kadrow 2023
52	Tworkowa 20 (TKW20)	10	settlement pit	x	charcoal (undet.)	Poz-47533	5200 ±40	Dc2[12]	Valde-Nowak 2020; Zastawny 2022; Kadrow 2023
53	Zakrzowiec 8 (ZKC8)	359	well	Ib	charcoal (Betula sp.)	Poz-45435	5760 ±40	Aa2	Jarosz 2012, after Zastawny 2022; Kadrow 2023

54	Zakrzowiec 8 (ZKC8)	359	well	Ib	charcoal (Betula f sp.)	Ki-13694	5690 ±90	Aa3	Jarosz 2012, after Zastawny 2022; Kadrow 2023
55	Zawada 14 (ZWD8)	3	settlement pit	Ic	unspecified organic matter on the inner surface of a pot (tar?)[13]	Poz-96806	5570 ±40	Ab2	Szeliga et al 2023

1 The relative chronology of this context is based on the assessment of ceramic finds performed by Jadwiga Kamieńska and Anna Kulczycka-Leciejewiczowa (Jacek Lech, personal communication, March 9, 2024).

2 The dated charcoal was taken from remains of a fireplace.

3 According to Sławomir Kadrow (2023, table 1), the context should be related to the Rzeszów phase (II), whereas the pottery published by Albert Zastawny (2022, Fig 8: 1-8) is stylistically older (phase I) Nevertheless, the controversy appear to be of no importance as the stratigraphic and contextual relationships between these finds and the radiocarbon dated animal bone cannot be determined (see footnote iv).

4 The dated bone has apparently been discovered in a secondary position – in the pit of the Baden culture (see Zastawny 2015, tab. 5-6) The alleged contemporaneity of the dated bone and pottery finds of the Malice culture from a pit intersected by feature 7 is based solely on the presumption that the bone has been redeposited from the older pit.

5 Krzysztof Czarniak (2012, 69) connects the date calculated on the basis of the obtained radiocarbon age to the Malice culture However, according to Janusz K Kozłowski who explored the pit that yielded the radiocarbon-dated charcoal, this feature is related to the Lengyel culture (Kamieńska and Kozłowski 1990, 51).

6 Unlike all Polish scholars (Kamieńska and Kozłowski 1990, 51; Kulczycka-Leciejewiczowa 1993, tab 1; Czarniak 2012, 69), Peter Breunig (1987, 156) provides the radiocarbon age with an uncertainty of ±75 conventional years.

7 The LSC measurement was performed on a mixture of charcoals from five different anthracological samples (Kowalewska-Marszałek and Cygnot 2017, 73).

8 The LSC measurement was performed on a mixture of charcoals from six different anthracological samples (Kowalewska-Marszałek and Cygnot 2017, 71).

9 The LSC measurement was performed on a mixture of charcoals from three different anthracological samples (Kowalewska-Marszałek and Cygnot 2017, 108).

10 The low collagen yield (0.6%) of the original bone sample was indicative for a strong diagenesis of the bone, and consequently – possible contamination of the sample with foreign materials such as humic and fulvic acids (see Piotrowska *et al.* in press, supplementary material 2, for more details) This suspicion was then confirmed by measuring the C:N ratio, the value of which exceeded the threshold value of 3.343 (*cf.,* Schwarcz, Nahal 2021).

11 The samples were classified as class „d" due to the fact that the measurements were almost certainly performed on non-ultrafiltrated collagen, which increases the risk of leaving contamination in the dated organic matter (*cf., eg.,* Brown 1988; Bronk-Ramsey *et al.* 2004; Higham *et al.* 2006) Technically, ultrafiltration can be applied only for milligram-sized samples, radiocarbon age of which can be measured using non-radiometric methods (such as AMS; *cf., eg.,* Linick *et al.* 1989) During that time, the Kiev laboratory was using exclusively a radiometric method of measuring radiocarbon age (LSC) what requires larger organic samples.

12 Paweł Valde-Nowak (2020, 174) provided no information about traditional (chrono-typological) dating of the pit from which the radiocarbon dated sample was taken Seemingly, it was just the ^{14}C date that made him connect the context with the Malice culture.

13 Dating of carbonized organic residues from inner surfaces of walls of vessels (most likely – charred food remains) is generally burdened with the risk ofa reservoir effect Thus, they may result in very inaccurate radiocarbon age determinations (cf eg Pesonen 1999; Miyata *et al.* 2011) In this case though, assuming that the dated matter is indeed tar (which was commonly used in the Neolithic and Eneolithic in the Vistula-Oder interfluve; *cf., eg.,* Pietrzak 2010), the obtained date should be considered accurate (*cf., eg.,* Pesonen 1999; Kotova *et al.* 2021, 20-21; Manninen *et al.* 2021, 848).

and Lech 1976, 79; personal communication with Jacek Lech on March 9, 2024). In this division, based on the taxonomic and chronological findings of Jadwiga Kamieńska and Janusz K. Kozłowski (1970), two phases were distinguished, the first of which was divided into two subphases. Currently, the first of them (Ia) is referred to as the Early Classic or – more fitly – Pre-Classic one, the second (Ib) – as the Classic phase, and the third (II) – as the Rzeszów or simply Late phase of the Malice culture. During further research (Kadrow 1990, 70), a Late Classic or Post-Classic (Ic) subphase has been distinguished (for a different historical perspective on this research see: Kadrow and Zakościelna 2000, 194-197; Kadrow 2006, 63; 2009, 59; 2023, 59, 60). It must be pointed out that in the present study, the Samborzec-Opatów group was considered a regional group of the early Malice culture that is distinct with a strong Lengyel component (*cf.*, Michalak-Ścibior 1996, 47; Zápotocká 2004, 38-41). At the same time, we uphold the opinion (Chmielewski 2008, 82, 83) that the postulated division of the Rzeszów phase into two subphases (*cf.*, Kadrow 1988; 1996; Kadrow and Zakościelna 2000, 204-208) had never been convincingly justified. Despite dissent on the two points, the stylistic phasing of the Malice culture applied in the present study corresponded to the generalised divisions used in both reference studies (*cf.*, Zastawny 2022, 168; Kadrow 2023, 59-61).

Information directly relating to the dated organic samples and measurements of their radiocarbon age has been complemented wherever possible. These additional pieces of data were partly obtained from the literature, and partly from the personal communication with a number of scholars. The resulting description is still somewhat simplified and does not meet all current requirements for publishing radiocarbon dates (*cf.*, Millard 2014; Bayliss 2015, 681-690). Undoubtedly though, the specification of dates provided in our paper was intended to be as close to these standards as possible.

As already stressed, one of the main reasons for undertaking this study, and at the same time the very starting point of the statistical chronometric analyses carried out herein, was the necessity of a qualitative assessment of all the hitherto performed measurements of radiocarbon ages of organic remains that can be associated with the Malice culture. This evaluation was made in terms of precision and accuracy of the measurements in accordance with the criteria proposed only a few years before (Chmielewski 2020a, 55-69).

And so, considering the precision given by a value of uncertainty(σ) for every ^{14}C age measurement, the measurements were divided into four classes:

– class 1 (of very high precision: $\sigma \leq \pm 25$ conv. yrs);
– class 2 (of high precision: $\pm 25 < \sigma \leq \pm 50$ conv. yrs);
– class 3 (of low precision: $\pm 50 < \sigma \leq \pm 100$ conv. yrs);
– class 4 (of very low precision: $\sigma > \pm 100$ conv. yrs).

The accuracy of each measurement was defined on the basis of a definite or assumed chronological relationship between the target 'depositional event' (*i.e.* deposition of a given ceramic set) and the age of radiocarbon dated organic material that is contextually associated with the dated pottery assemblage. In this regard, the reliability of the archaeological context and the organic substance of every sample was subject to an independent assessment. In order to evaluate the samples in the former aspect, each of them was attributed to:

– class A (of unquestionable contextual reliability);
– class B (of conditional contextual reliability);
– class C (of uncertain contextual reliability);
– or class D (of questionable contextual reliability).

Depending on the organic material dated, every sample was categorised as belonging to one of four analogical classes:

– class a (of unquestionable substance reliability);
– class b (of conditional substance reliability);
– class c (of uncertain substance reliability);
– or class d (of questionable substance reliability).

Ultimately, on the basis of the foregoing dual assessment of accuracy, each measurement could be assigned to one of four (I–IV) quality groups in accordance with the weakest link rule. If then any measurement was classified as belonging to the 'double a' (Aa) class, the ^{14}C date was considered to be of the highest quality (group I). The lower its reliability, the more declassed it became. When any of the two attributes of the measurement was classified as 'B/b', the resulting date was assigned to the quality class II, when classified as 'C/c' – to the third (III) class, and when classified as 'D/d' – to the lowest one (IV).

Only the samples belonging to quality groups I and II were considered as coeval with the associated assemblages of the Malice culture. Consequently, the resulting ^{14}C dates were inserted into the corresponding 'ceramic phases' without any prior corrections as equally reliable elements of the proposed chronometric models.

The subset of dates classified under quality group III was a derivative of radiocarbon age measurements made mainly for anatomically undetermined or anatomically and species-wise undetermined charcoals. Their radiocarbon age was *a priori* treated as biased by the so-called old wood effect (see Bronk Ramsey 2009a, 1028, 1030-1032). As such, these dates were introduced into all the models as certain t-outliers, under the assumption that long-lived trees, whose charred remains occur commonly at Central European archaeological sites, can live up to a thousand years of age.

In accordance with the initially adopted principle (Chmielewski 2020a, 71), measurement results assigned to qualitative group IV, either due to the lack of any specification or non-homogenous character of dated organic remains (*e.g.*, mixed samples of charcoals), or due to justified doubts regarding the relationship of the obtained ^{14}C date to the targeted 'depositional events', were excluded from modelling.

After being classified and pre-selected accordingly, the radiocarbon age measurements related to the subsequent stylistic phases of the Malice culture were modelled with the use of Bayesian statistics. All the calculations and their visualisations were completed using the IntCal20 calibration curve (Reimer *et al.* 2020) with the OxCal 4.4 package (Bronk Ramsey 2009b).

The statistical modelling assumed that the distribution of these dates within individual phases is stochastic and uniform (uniform phase; see Bronk Ramsey 2009b, 342-347). Unlike the modelling performed by Sławomir Kadrow (2023, 56-58), which was based on the assumption of subsequent stylistic phases following each other consecutively, these analyses also tested an alternative contiguous sequence of the stylistic phases in which the transitions between them are assumed to be smooth (the trapezoid model according to Lee and Bronk Ramsey 2012). For comparative purposes, the latter model was run twice, once solely on the basis of the ^{14}C dates that were collected in the reference studies, and then using the set of dates extended with the newly obtained ones. CQL codes for both the models based on the updated data are presented (Appendices 1 and 2).

RESULTS AND DISCUSSION

At the outset, the analysed pool consisted of 54 radiocarbon age determinations produced with the use of the same number of samples from 41 archaeological features. An additional date was obtained for unspecified biogenic sediments from a drill core located near one of the sites where remains of the Malice culture settlement were recorded. Half of the entire corpus of measurements was related to the Late phase, and one third – to the Classic phase of the Malice culture. Only seven dates (13%) were associated with the Early phase, and five of them (9%) – with the Post-Classic phase. All the ^{14}C age determinations as well as their characteristics are listed in Table 1.

Although the unified tabular description provides some new important information both on the samples used for dating as well as the results of their radiocarbon ages' measurements, it is not standardised in full compliance with modern requirements in this regard (Millard 2014; Bayliss 2015, 681-690). It is still just a chronometric data puddle, though certainly a less muddy one. Despite this, the collected information allows for a comprehensive and consistent qualitative and quantitative analysis of radiocarbon dates currently available for the Malice culture.

The quality of the entire initial dataset was verified by an elemental analysis of all the constituent radiocarbon determinations, with a particular emphasis put on the nature of the ^{14}C-dated material and the reliability of the archaeological contexts that the relevant samples came from (Fig. 1). It transpires that in only 15 instances could the date obtained on the basis of radiocarbon age measurement be considered as unconditionally or conditionally corresponding to the given depositional event of interest, viz the archaeological context with an assemblage representing a definable stylistic phase of the Malice culture. Exactly half of the gathered set consisted of inaccurate measurements, most of which were made for unspecified charred wood. All the dates obtained on their basis, as implicitly affected by the 'old wood effect', were assumed to precede the targeted events. These radiocarbon dates were inserted into the sequential models as t-type outliers and corrected

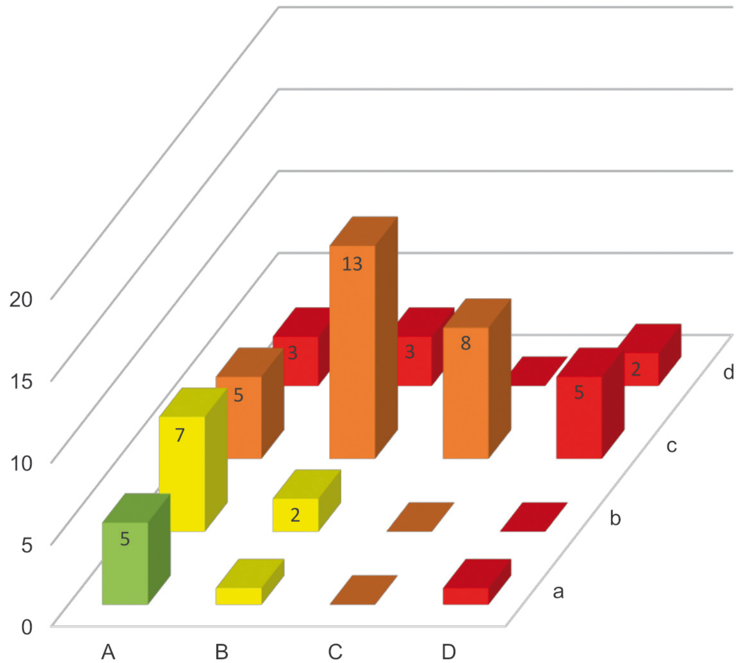

Fig. 1. Quantitative distribution of all gathered radiocarbon age determinations for the Malice culture in regard to reliability of archaeological contexts /classes A-D/ and samples of organic substances dated /classes a-d/ (illustration by T. J. Chmielewski)

accordingly. Due to the questionable substantive reliability of the samples used (category d) or their archaeological context (category D), as many as 14 radiocarbon age measurements (25%) were assigned to the lowest quality class and eliminated from the modelling.

As a result of this categorisation and pre-selection, a set of 41 radiocarbon age determinations was obtained, 37% of which can be considered as closely corresponding to the relevant phases of the Malice culture, while the rest should be treated as providing just a *terminus post quem* of a given event of interest. It should be emphasised that 8 out of 15 dates classified under quality class I and II (almost 20% of the entire collection) are either newly obtained or positively verified ones. The reliability of the latter was confirmed thanks to additional information regarding the nature of the dated prehistoric organic substance or the archaeological context from which these samples were taken. Particularly valuable among them are the dates for graves of the Malice culture recently discovered at the sites of Smroków 4 (Przybyła and Fabiszak 2021) and Kraków-Nowa Huta-Zesławice 88 (Chmielewski 2023). All of them contained very well-preserved skeletons buried with ceramic goods that are very distinctive taxonomically and chronologically (Figs 2-7). These are a few of the very scarce radiocarbon-dated graves of the Malice culture in general, and the first published ones from western Lesser Poland (see Zastawny 2022, 168, fig. 9).

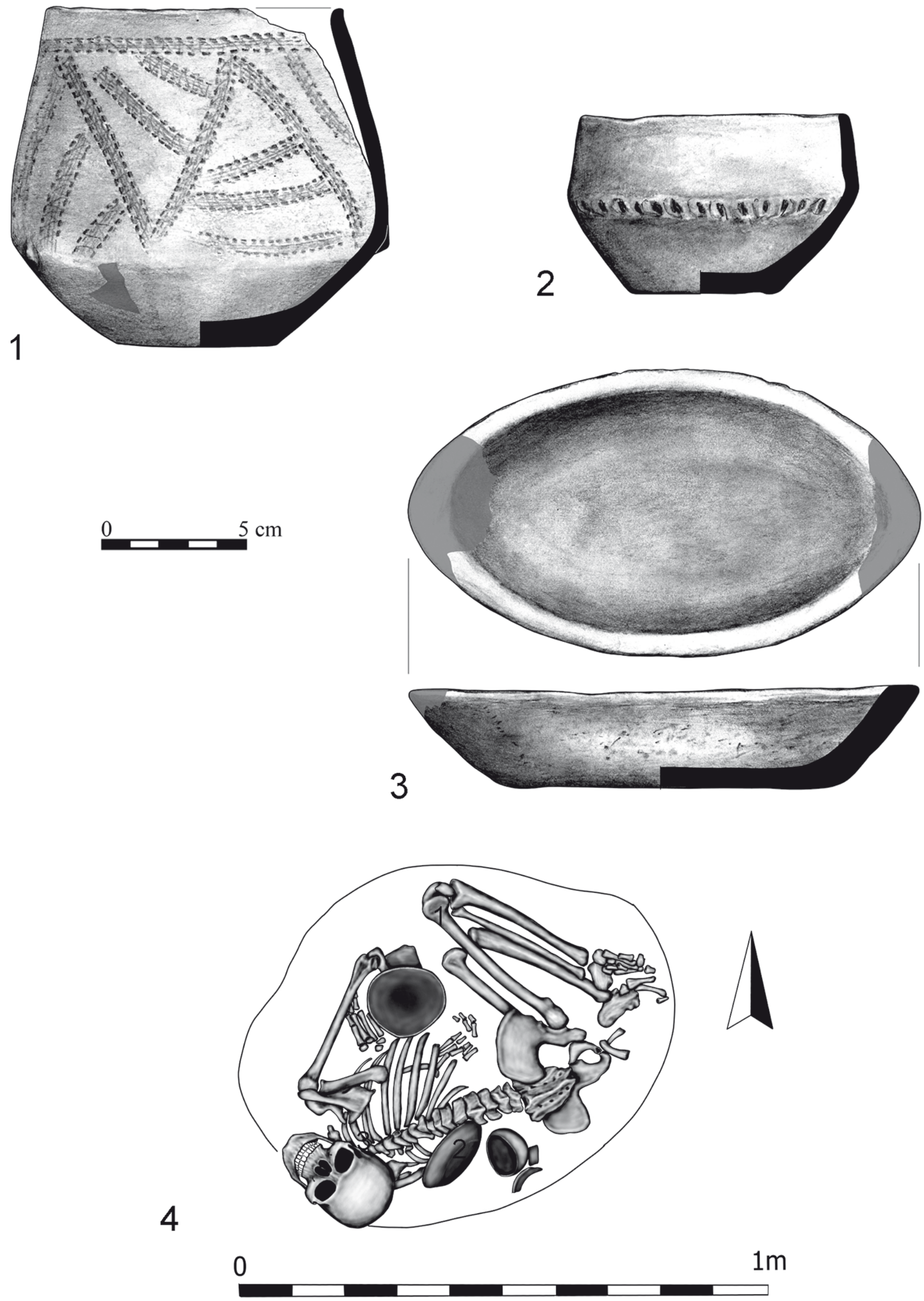

Fig. 2. Feature B820 at Kraków-Nowa Huta-Zesławice 88: 1-3 – ceramic grave goods (illustrations by N. Lenkow); 4 – arrangement of the burial (illustration by M. Podsiadło)

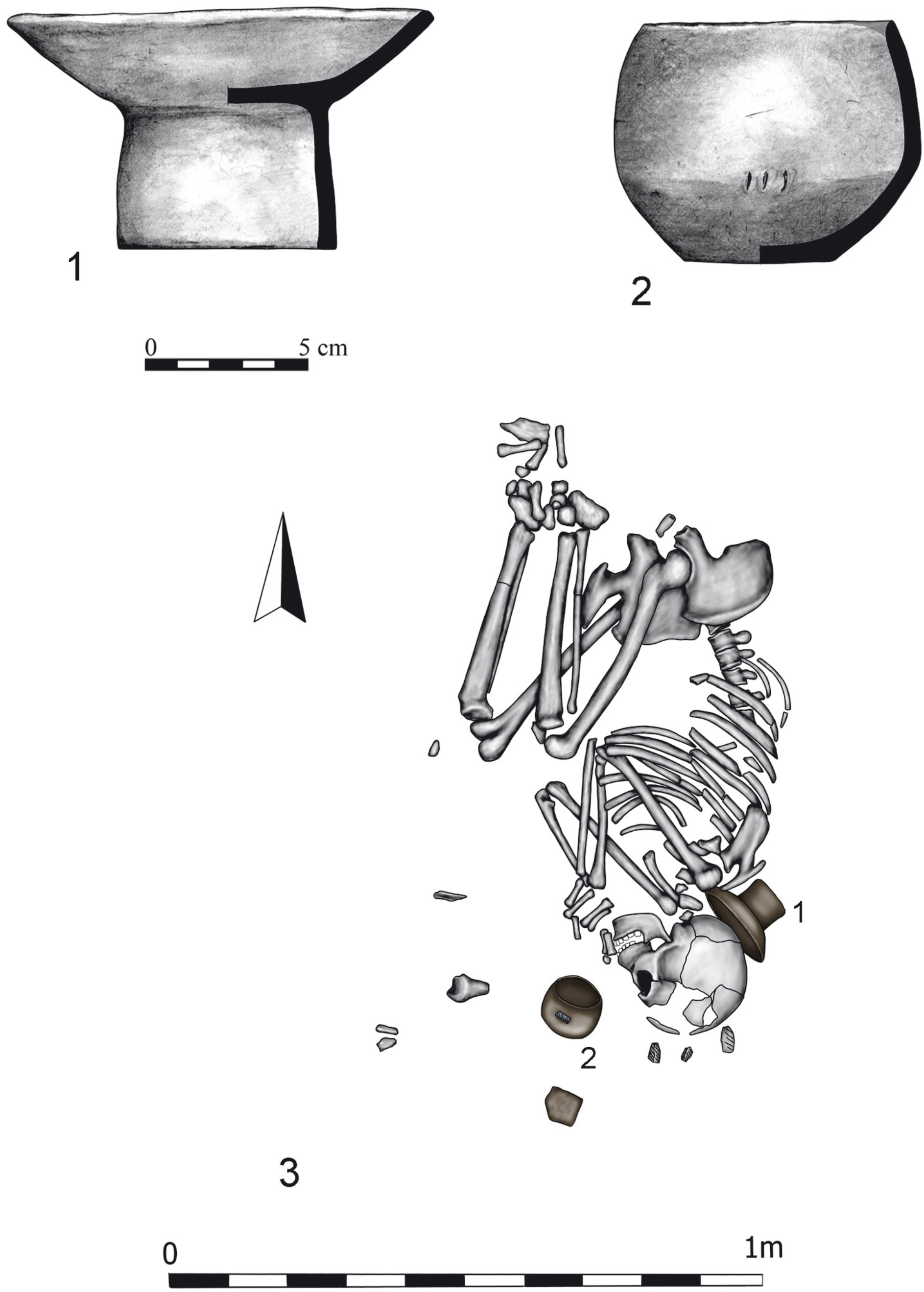

Fig. 3. Feature C150 at Kraków-NowaHuta-Zesławice 88: 1-2 – ceramic grave goods (illustrations by N. Lenkow); 3 – arrangement of the burial (illustration by M. Podsiadło)

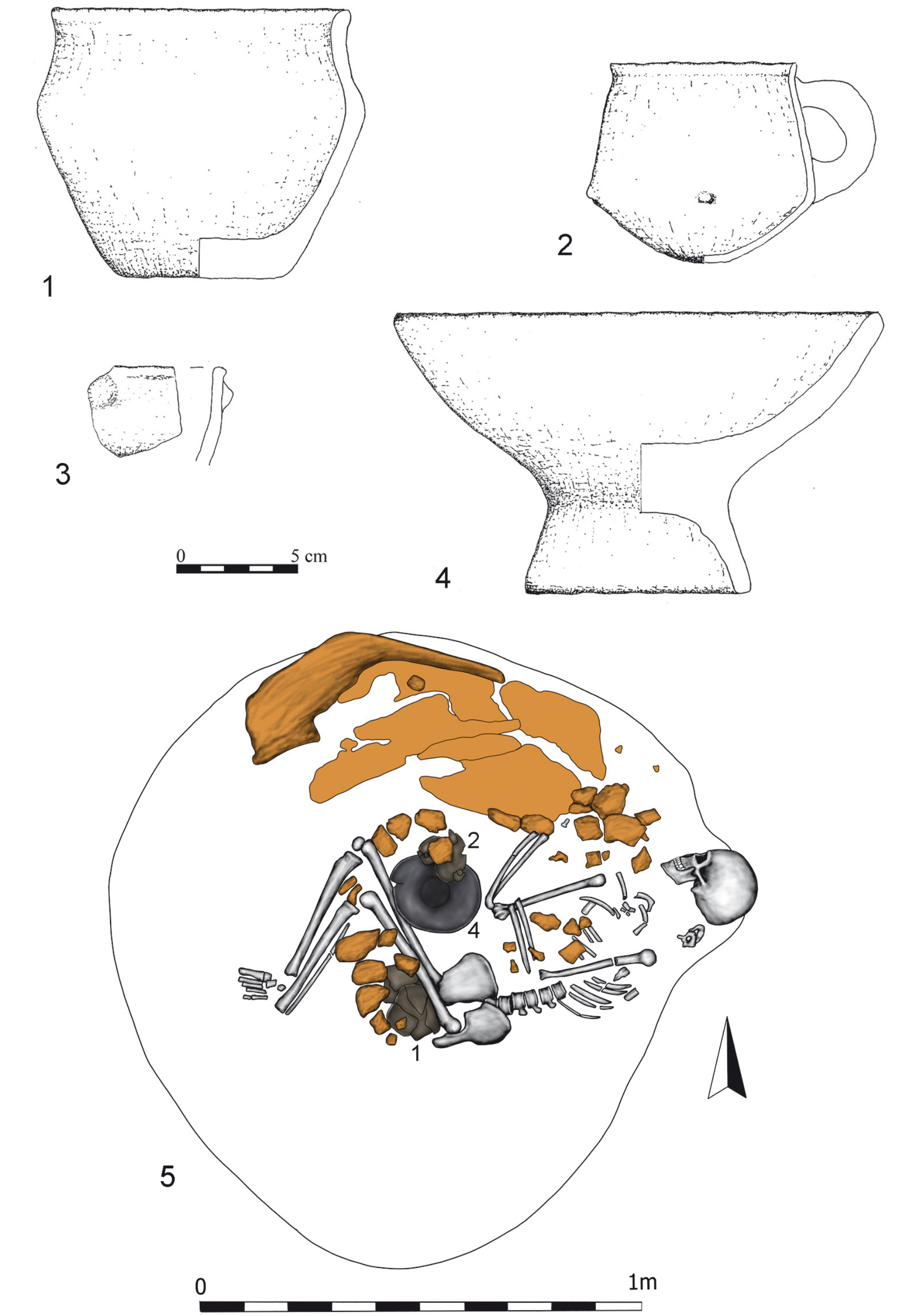

Fig. 4. Feature H29 at Smroków 8: 1-4 – ceramic grave goods (Ilustrations by I. Fabiszak); 5 – arrangement of the burial (illustration by M. Podsiadło)

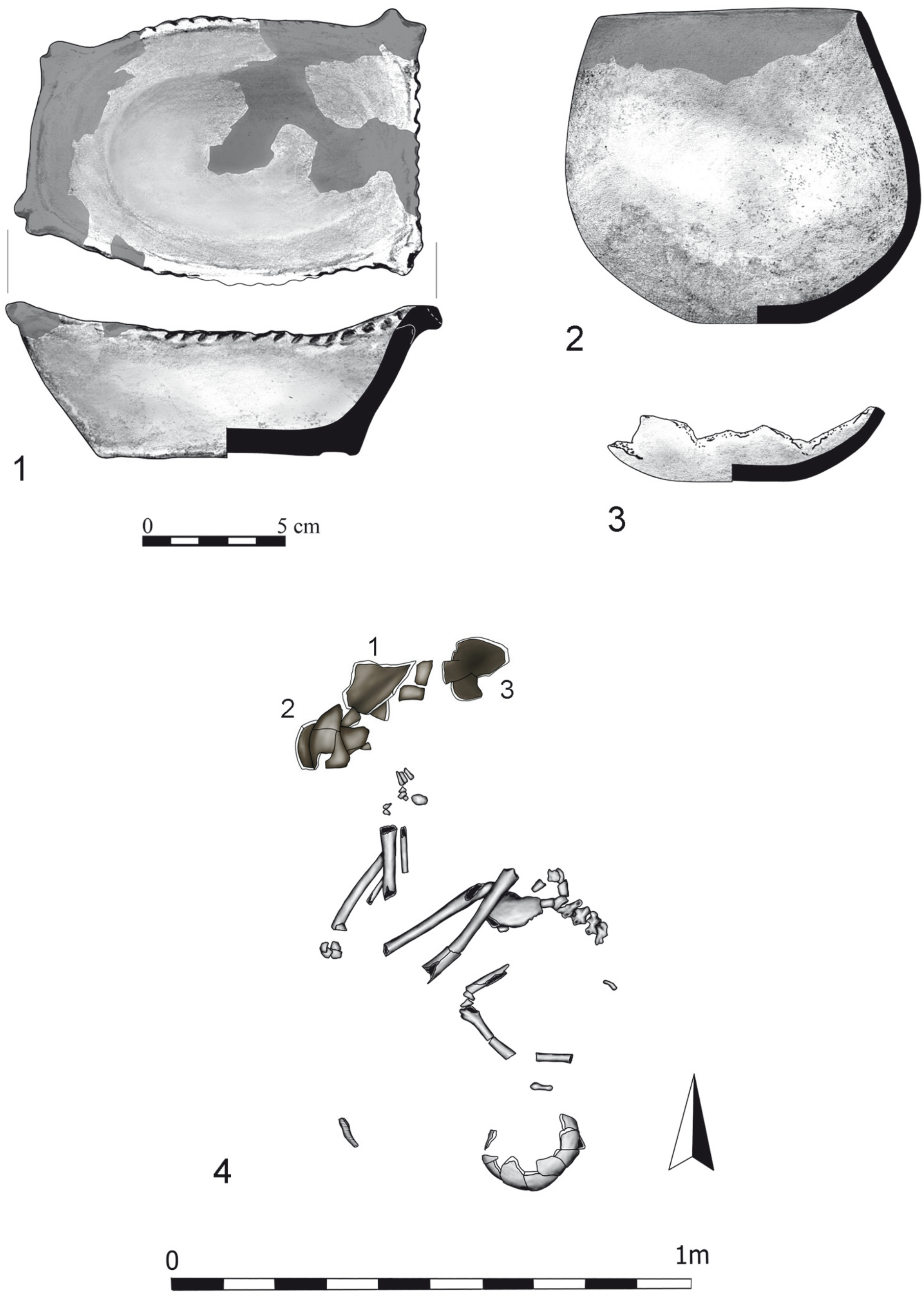

Fig. 5. Feature Y421 at Kraków-Nowa Huta-Zesławice 88: 1-3 – ceramic grave goods (illustrations by N. Lenkow); 4 – arrangement of the burial (illustration by M. Podsiadło)

1

2

Fig. 6. Photographs of the Malice culture burials at Kraków-Nowa Huta-Zesławice 88:
1 – feature B820 (photo by M. Kuś); 2 – feature C150 (photo by I. Fabiszak)

1

2

Fig. 7. Photographs of the Malice culture burials at Smroków 8 and Kraków-Nowa Huta-Zesławice 88: 1 – Smroków 8, feature H29 (photo by I. Fabiszak); 2 – Kraków-Nowa Huta-Zesławice 88, feature Y421 (photo by M. Kuś)

It is also worth noting that the modelled set of dates included mainly those obtained on the basis of radiocarbon age measurements of high or very high precision. Although a low or very low precision cannot be considered as suitable exclusion parameter in Bayesian statistics (see *e.g.*, Hamilton and Krus 2018, 191), it just occurred that most of the analysed dates of low or very low precision (8 out of 11) were discarded due to their questionable accuracy (Fig. 6).

The analysis of the gathered radiocarbon age measurements as a codomain of a function assigning them to the subsequent development phases of the Malice culture revealed other strengths and weaknesses of the discussed pool of dates (Fig. 7). First of all, it turned out that most of them can be connected with the Classic and Late phases, while the Post-Classic phase is underrepresented. In terms of quality, the weakest phase-defined subset of radiocarbon ages was the one related to phase Ia. In this case, only one ^{14}C date corresponds closely to the targeted 'depositional event'. The most significant difference between the currently collected set of radiocarbon age measurements and those gathered at the stage of completing the reference studies is the presence of accurate and precise dates for the Post-Classic (Ic) phase of the Malice culture (*cf.*, Kadrow 2023, 56).

The results of the statistical analyses carried out for both proposed models – the one assuming that the subsequent stylistic phases transited stepwise (contiguous uniform phases), and another, wherein the phases transited smoothly (contiguous trapezoid phases) – turned out to be convergent (Fig. 8). Nevertheless, considering the apparently continuous stylistic evolution of the Malice culture pottery, the second model seems to be more adequate. Thus, phase Ia should be dated to *ca.* 4770-4600 (rounded up to 10 years, at a confidence level of 1 sigma), beginning from around 4810 to around 4710 BCE. The transition between phases Ia and Ib took place between ca. 4650 to c. 4550 BCE, spanning no more than 50 calendar years. Phase Ib falls within the widest interval of approximately 4630-4440, whereas phase Ic occurred to be the shortest, lasting from c. 4460 to c. 4390 BCE. The probability distribution representing the boundary for the interstage between the two phases fell within the approximate interval of 4490-4420 BCE. The next transition period (Ic/II) was no longer than 30 years, with the distribution falling into c. 4400-4350 BCE. The pottery style typical of phase II of the Malice culture replaced the older one around 4390 and certainly lasted for some one hundred years, although a single measurement (with the lowest agreement index) indicates that it continued to about 4260/4250 BCE. The development of the Malice culture ended at around 4330-4270/4250 BCE.

Accordingly, the Early phase of the Malice culture can be considered contemporaneous with phase II of the development of the tell settlement at Polgár-Csőszhalom (Raczky *et al.* 2007, 64; Raczky and Anders 2010), an early part of phase I of the Lengyel culture in western Slovakia, Lower Austria and southern Moravia, as well as phase IVa (or the very end of phase III) of the Stroked Pottery culture in the Bohemian-Moravian-Silesian area (*cf.*, Stadler and Ruttkay 2007, 118-131; Riedhammer 2018, 91-109; Chmielewski 2020a). This is consistent with the cross-dating of all the cultural sequences (see for example Kaczano-

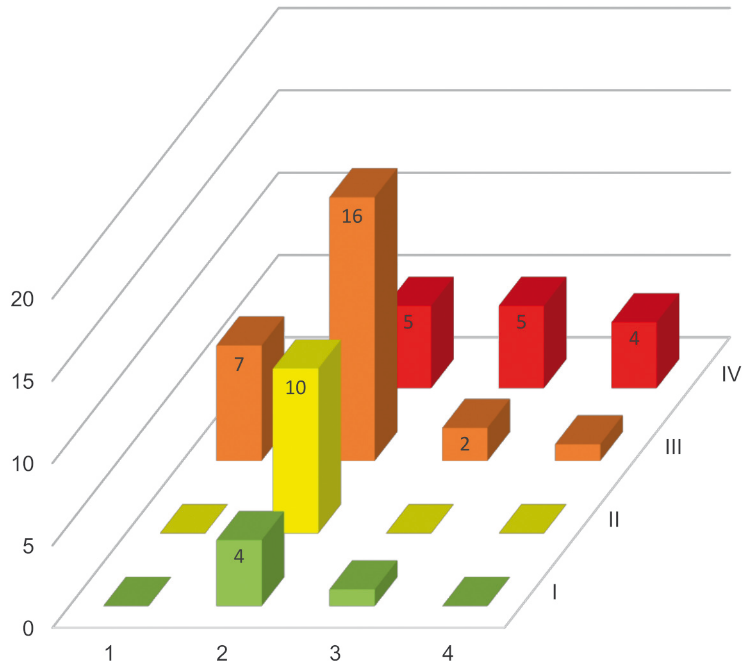

Fig. 8. Quantitative distribution of all gathered radiocarbon age determinations for the Malice culture in regard to measurements' accuracy /classes I-IV/ and precision /classes 1-4/ (illustration by T. J. Chmielewski)

wska *et al.* 1986, 112-118; Zápotocká 2004, 34-44; Kaczanowska and Kozłowski 2006, 35; Raczky *et al.* 2007, 54). The resulting absolute dates also allow us to synchronise the Classic phase of the Malice culture with phase III at Polgár-Csőszhalom (Raczky *et al.* 2007, 64; Raczky and Anders 2010) and the final stage of the Late Neolithic named Proto-Tiszapolgár (*cf.*, Horváth 2014, 310-316; Raczky and Anders 2016, 113-116). This complies with the presence of certain stylistic borrowings from the northern part of the Carpathian Basin in assemblages of the Malice culture dated to its Classic phase (Kaczanowska 1996, 24, 25). Consequently, its next phase (Ic) turns out to be younger than the Proto-Tiszapolgár phase (or Tiszapolgár A according to Dragoş Diaconescu – 2013; 2014) and contemporaneous with the Classical phase (B1) of the Tiszapolgár culture, whereas the Rzeszów phase turns out to be coeval with the Late phase (B2) of the Tiszapolgár culture as well as the Transitional and Early phases (A1/A2) of the Bodrogkeresztúr culture (see Chmielewski 2019; 2020b). The results obtained also allow us to synchronise phases Ic and II of the Malice culture with phases II and III of the Lengyel culture (respectively) in reference to its phasing proposed by Juraj Pavúk (*cf.*, Stadler and Ruttkay 2007, 118-131; Riedhammer 2018, 95-109; Chmielewski 2020a).

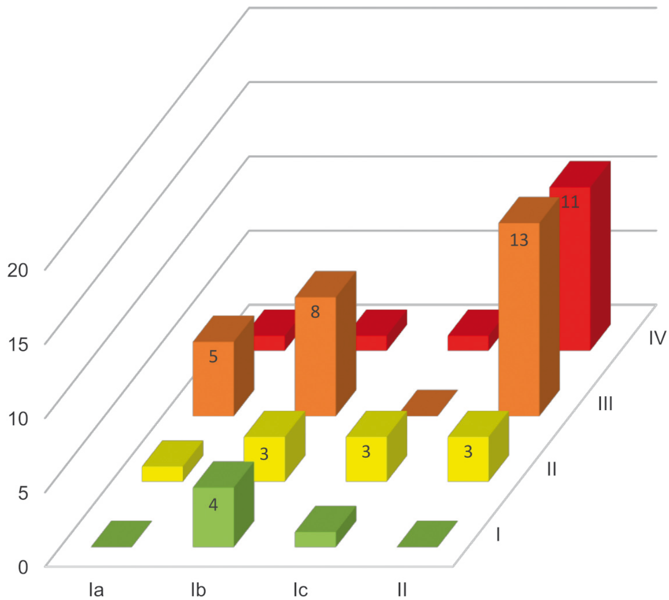

Fig. 9. Quantitative distribution of all gathered radiocarbon age determinations for the Malice culture in regard to their accuracy /classes I-IV/ and relative chronology of their archaeological contexts /phases Ia-II/ (illustration by T. J. Chmielewski)

There is an apparent dissonance between the results of modelling performed in this study and those presented in the reference work by Sławomir Kadrow (Fig. 9). The largest and most important differences concern the transitory border between phases Ia and Ib and the initial and final borders of phase II. In the first and second cases, the obtained results are mutually exclusive, with the lower levels of the probability ranges of the limits determined in the reference model corresponding to the upper limits obtained as a result of the analyses carried out presently. The difference is even several dozen calendar years. Similarly incompatible and distant on the scale of calendar years are ranges of phase II. In this case, however, the Rzeszów phase appears to end much later than inferred with the use of the reference model.

Due to different absolute chronologies of ceramic stylistic sequence of the Malice culture, there occurred serious discrepancies in the synchronisation of its phases with chronological units distinguished in neighbouring and closely related cultural areas. In the reference study by Sławomir Kadrow, a special emphasis was placed on linking the subsequent phases of the development of the former with the cultural and chronological sequence of the Polgár complex (no such attempts were made by Albert Zastawny in his earlier work). Our conclusions regarding the Early phase of the Malice culture turns out to be quite the same. The first controversy concerns the chronological correlation of the Classic phase of the Malice culture with the Proto-Tiszapolgár phase (Tiszapolgár A), which has already been proven above. In the opinion of Sławomir Kadrow, the latter was contemporaneous with the Post-Classic phase of the Malice culture. The second point of contention is related to the synchronisation of the Tiszapolgár culture (phase B) with phase II of the Malice culture. According to the reference study, they fully overlap, whereas the current analyses revealed that the duration of the latter was parallel only with the late stage (B2) of the Tiszapolgár culture. The earlier subphase of the Tiszapolgár culture (B1) is contemporaneous with the Post-Classic phase of the Malice culture. All in all, considering the new results and taking the sequence of stylistic phases of the Polgar circle as the point of reference, the Post-Classic and Late (Rzeszów) phases of the Malice culture must be moved one step down the scale. Consequently, the stylistic development of the Malice culture at the turn of the Neolithic and Eneolithic and at the beginning of the Eneolithic occurs to harmonise rather with the rhythm of evolution of the Lengyel and Stroked pottery cultures than with the pace of cultural changes taking place in the Upper Tisza basin.

The presented discrepancies stem not so much from the general architecture of the confronted models (both were based on the assumption of consecutiveness of stylistic phases), but rather from differences in the 'chronometric building material' used for their construction. These differences are not only quantitative (in the present study additional measurements could be used, including previously absent ones related to phase Ic), but also qualitative (the accuracy of all the ^{14}C age determinations used was verified and some of them were rejected). The significant effect of the assessment of the accuracy of measurements on the results can be clearly demonstrated by performing an additional modelling with the use of only those ^{14}C determinations that were already available for earlier studies, yet preceded by a verification of their accuracy. This remodelling was based on one more prior assumption that should have already been included in the reference model, *i.e.*, the existence of the intermediate stage (Ic) between the Classic and Rzeszów phases of the Malice culture, as explicitly postulated by Sławomir Kadrow himself (2023, 58). In the syntax of the new model the presence of such a separate stage in the stylistic evolution of the Malice culture pottery was declared as two non-shared boundaries – one at the end of phase Malice Ib and another at the beginning of phase Malice II (Fig. 10). The discrepancy between results obtained on the basis of the 'rebuilt' reference model and the current one (including, among other things, the previously unavailable dates for phase Ic of the Malice culture) are apparently smaller (Fig. 11). Expressed in calendar years, they generally do not exceed some three to four decades. The only serious difference concerns the end of phase Ib (by default also considered to be the beginning of phase Ic), which – according to the results of this chronometric exercise – falls into the timespan from around 4580 to 4490 BCE. In the light of the new statistical analyses, the Classic phase occurs to come to an end about a hundred years later. However, since radiocarbon age measurements for the contexts ascribed to this phase in the reference study were made almost exclusively for charcoals of indeterminate 'inbuilt age', resulting dates should be considered too old. Consequently, the end boundary of phase Ib, as calculated with the use of the 'rebuilt' reference model,

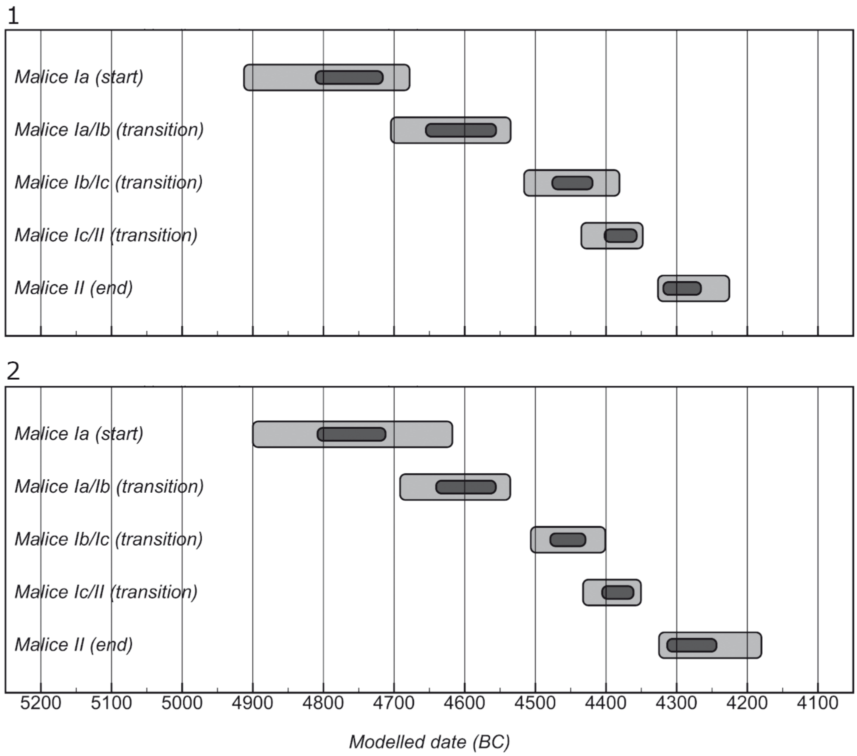

Fig. 10. 1 and 2σ confidence ranges for start and end boundaries as well as transitory boundaries (at 1 and 2σ) of subsequent stylistic development stages of the Malice Culture for: (1) contiguous phases, and (2) contiguous trapezoid phases. Agreement indexes of the models were 155.6 and 157.4% respectively, whereas individual agreement indexes were 158.1 and 159.6% (illustration by T. J. Chmielewski)

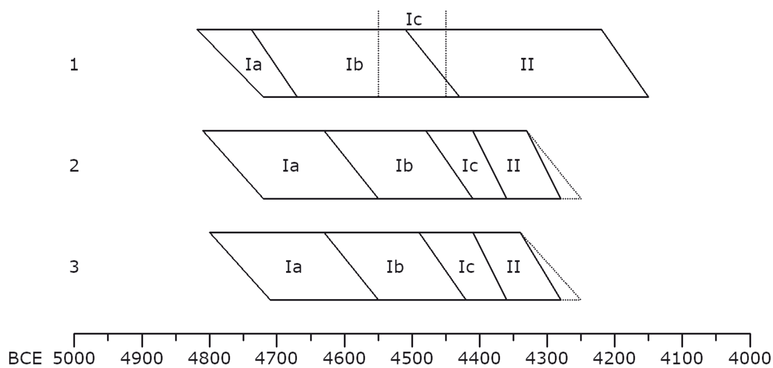

Fig. 11. Chronological sequences of subsequent stylistic development stages of the Malice Culture for: (1) contiguous phases, according to the original model presented in the reference study (Kadrow 2023); (2) contiguous phases, according to the current model; (3) contiguous trapezoid phases, according to the current model (illustration by T. J. Chmielewski)

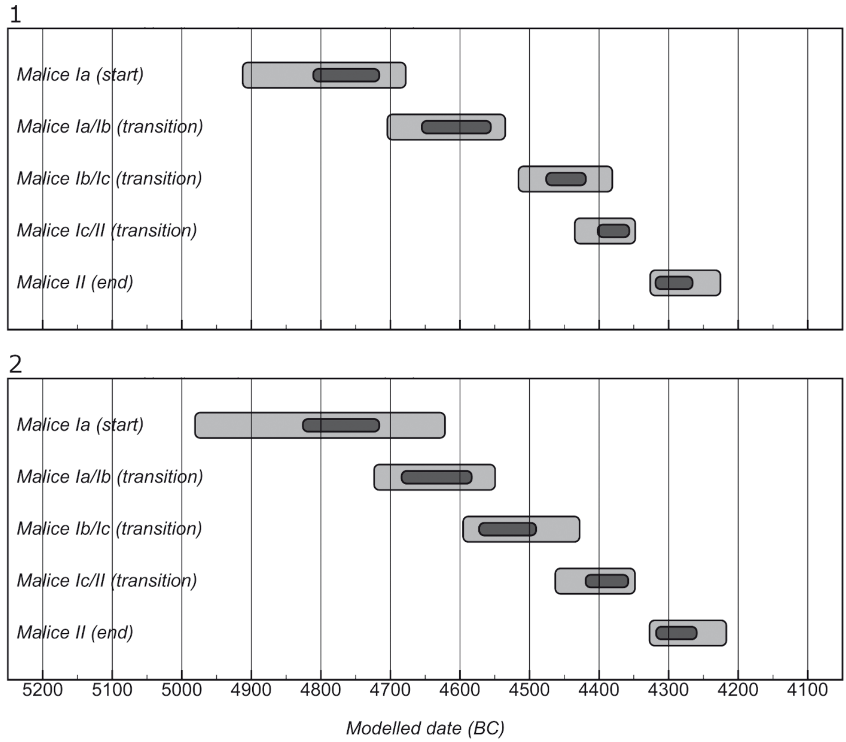

Fig. 12. 1 and 2σ confidence ranges for start and end boundaries as well as transitory boundaries of subsequent stylistic development stages of the Malice Culture for contiguous phases, based on: (1) currently available radiocarbon age measurements, and (2) measurements used in the reference study (Kadrow 2023). Agreement indexes of the models were 155.6 and 148.4% respectively, whereas individual agreement indexes were 158.1 and 150.7% (illustration by T. J. Chmielewski)

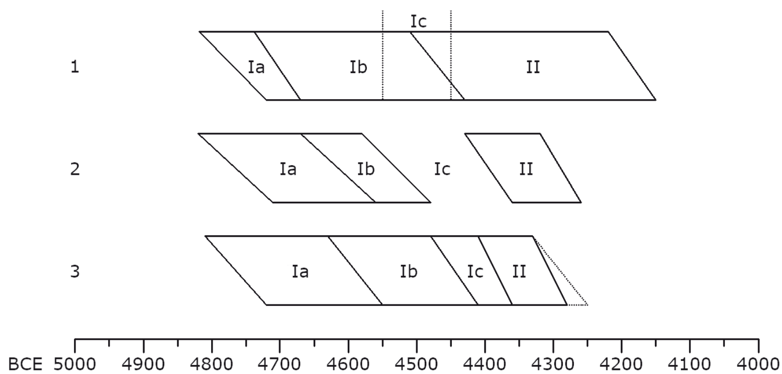

Fig. 13. Chronological sequences of subsequent stylistic development stages of the Malice Culture for: (1) contiguous phases, according to the original model presented in the reference study (Kadrow 2023); (2) contiguous phases, according to 'rebuilt' model from the reference study; (3) contiguous phases, according to the current model (illustration by T. J. Chmielewski)

provides only the *terminus post quem* for the beginning of phase Ic. Still, the previously available radiocarbon dates, if only proper 'chronometric hygiene' had been maintained, could already have served as the basis for a more accurate model.

All the arguments seem to resolve the controversy in favour of the statistical approach adopted in this study. Such a conclusion is strongly corroborated by the consistency of the eventual results of the analyses performed. The coherence of radiocarbon dates within the set modelled by Sławomir Kadrow (2023, 57) was low and barely exceeded the acceptance threshold of 60% (A_{model} = 60.4 and $A_{overall}$ = 66.5), while the consistency calculated on the basis of verified measurements and models proposed in this study is remarkably high (see captions to Figures 8 and 10).

CONCLUSIONS

Thanks to newly obtained accurate and precise radiocarbon age measurements as well as the verification of the previously published ones, a firm basis for establishing a robust absolute chronology of the Malice culture has been created. The larger and more carefully selected set of ^{14}C dates allowed us to perform more accurate chronological modelling, the outcomes of which proved to be more precise and coherent. However, can these be considered fully satisfactory? And if 'not', then what else can and should be done to achieve better results?

At present, there are 41 radiocarbon dates related to the Malice culture contexts that can be effectively modelled. Taking into account that this cultural formation evolved for several hundred years, the number is high enough only for establishing a robust chronology. However, the closer examination of the currently available radiocarbon age measurements revealed three fundamental weaknesses of this pool. These are: 1) the generally low accuracy of the measurements resulting from the fact that almost two thirds of them were produced either using samples with a questionable contextual attribution or wrongly selected or poorly defined organic remains; 2) the under-representation of high-quality dates related to the Early and Post-Classic phases of the Malice culture; 3) the uneven spatial distribution of the dated contexts, with a clear dominance of the measurements obtained for the finds coming from western Lesser Poland.

In a longer-term perspective, the diagnosed chronological problems will be solved by obtaining more precise and accurate radiocarbon age measurements referring to all the phases and the entire spread area of the Malice culture. This will take time and money. However, certain steps can be taken faster and without the additional expenses. In the short-term perspective, the most desired response to this diagnosis would be a democratisation and standardisation of all relevant data. As Daniel Keys Moran aptly put it, 'you can have data without information, but you cannot have information without data'.

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