Do ^{14}C dates always turn into an absolute chronology? The case of the Middle Neolithic in western Lesser Poland

Marek Nowak
Institute of Archaeology, Jagiellonian University, Kraków, PL
mniauj@interia.pl

ABSTRACT – *In the late 5th, 4th, and early 3rd millennia BC, different archaeological units are visible in western Lesser Poland. According to traditional views, local branches of the late Lengyel-Polgár complex, the Funnel Beaker culture, and the Baden phenomena overlap chronologically in great measure. The results of investigations done with new radiocarbon dating show that in some cases a discrete mode and linearity of cultural transformation is recommended. The study demonstrates that extreme approaches in which we either approve only those dates which fit with our concepts or accept with no reservation all dates as such are incorrect.*

KEY WORDS – *western Lesser Poland; Middle Neolithic; absolute chronology; ^{14}C dating*

Ali ^{14}C datumi vedno predstavljajo tudi absolutno kronologijo? Primer iz srednjega neolitika na zahodu Malopoljske

IZVLEČEK – *V obdobju poznega 5., 4. in zgodnjega 3. tisočletja pr. n. št. lahko na območju zahodne Malopoljske prepoznamo različne arheološke enote. Glede na tradicionalne poglede se v tem času kronološko prekrivajo enote poznega kompleksa Lengyel-Polgár, kulture zvončastih čas in badenskega fenomena. Novi radiokarbonski datumi kažejo, da je v nekaterih primerih potreben diskreten pristop z linearnimi kulturnimi spremembami. V članku pokažemo, da so ekstremni pristopi, pri katerih uporabimo oz. izključimo bodisi tiste datume, ki sodijo v naše koncepte, bodisi vse datume brez zadržkov, pri razlagah datumov nepravilni.*

KLJUČNE BESEDE – *Malopoljska; srednji neolitik; absolutna kronologija; ^{14}C datiranje*

Introduction

Radiocarbon dating is the basic method for elaborating the absolute chronology of prehistoric events in the Younger Stone Age (*Walanus, Goslar 2009; Taylor* et al. *2014*). Certainly, this is not an ideal method. It is characterised by a number of limitations, faults, and imperfections. Awareness of their existence varies among archaeologists and other scientists using this method. However, no method that would be a viable alternative for radiocarbon dating has been invented so far[1]. This is why it is very important to approach the results of radiocarbon dating correctly. These results must undergo multi-dimensional analyses and interpretations, which take into account many internal factors (*i.e.* arising from the me-

1 This inevitably connotes Winston Churchill's famous saying about democracy: "*Democracy is the worst form of government except for all those others that have been tried*". In fact, it perfectly reflects the place of the discussed method in archeology (and not only in archaeology), *i.e.* to paraphrase this saying, we could say that radiocarbon dating is the worst form of dating except for all those others that have been tried.

DOI: 10.4312/dp.44.15

thod itself) as well as external (*i.e.* arising from the context of a sample, and even from the specificity of a given laboratory).

Perhaps, above all, we must remember that, the result of radiocarbon dating and calibration, is a wider or narrower time range, and not, contrary to a common view, a specific point in time. Particular segments of the range are usually characterised by varying probability.

In our analyses, we may consider dates at face value, and determine the timeframe formally covered by ranges resulting from calibration procedures. Alternatively, we can add up the probabilities of each calibrated distribution. The result will usually be similar to the previous one. If we rely on individually calibrated date ranges or sum-calibrated distributions, we usually obtain longer timeframes than expected (*Marsch* et al. *2017.120*), when based on typological premises. Consequently, it appears that many archaeological units, contrary to conventional patterns, develop partially or completely in parallel.

However, ^{14}C dates treated in this way could be misleading. Natural imperfections and the risks connected with ^{14}C method, compounded by the laws of statistics, can result in the emergence of extreme values. These extreme values will deviate from the most typical and ordinary ones, and therefore will not reflect the actual chronology of the context from which they originate. In other words, the actual chronological diversity is not as advanced as it could appear. In terms of the prehistoric chronology, a good illustration of this matter is the comparison of radiocarbon and dendrochronological dates, with the latter giving clearly narrower intervals (*Włodarczak 2008c.Fig. 7*). In the quoted author's opinion (*Włodarczak 2008c.125–126*), uncritical acceptance of formal indications of radiocarbon dating results in an apparent lengthening of chronology and an apparent synchronicity of archaeological groupings. Based on such premises and thoughts, a 'reductionist' approach in the interpretation of radiocarbon dates may be suggested, in which extreme values are considered to be fictitious (*e.g., Domboróczki 2009. 80–91; Müller 2002; Włodarczak 2008c*). Therefore, modelling procedures can also be executed which will verify whether the available set of dates is characterised by internal cohesiveness (grouping) and, in effect, may designate a compact period of time. Undoubtedly, Bayesian modelling has become the most prevalent in recent years (*Bayliss 2015; Bayliss* et al. *2007; Bronk Ramsey 2009a; 2009b*), and we will use it in this contribution.

Admittedly, this approach is only an assumption, particularly when dates do not come from the same site or context. However, the concept of a phase can be applied to many sites combined, as dates can be related to an "*unordered group of events/parameters*" and to "*a random scatter of events between a start and an end boundary*" (*Bronk Ramsey online*). Moreover, the supposition of continuity of development within an archaeological unit is not an illogical idea. One can conclude that the vast majority of prehistoric phenomena were characterised by a consistent continuation and cohesiveness of development (*e.g., Marsch* et al. *2017*). Bayesian models have great potential to improve chronologies, but they have to be connected with critically analysed external circumstances (prior assumptions), *i.a.* with stratigraphic and typological contexts, as well as with already existing dating schemes of phenomena important for the issue investigated. The outcome of such procedures will quite frequently be a shortening of the timeframes of archaeological units under consideration. Chronologically, they will become more discrete units once again, and 'traditional', typological data will regain its importance. There may also be shifts in the dating of some prehistoric and historic events with respect to the common views.

To analyse problems of this kind, we decided to take into account the region of western Lesser Poland in a period that, in the local circumstances, can be called 'Middle Neolithic' (or alternatively 'Early Eneolithic'). Additionally, the 'Late Neolithic' Corded Ware culture will be utilised as a kind of 'upper' chronological boundary (Fig. 1). The timeframe under scrutiny is the period from the late 5th to the early 3rd millennium BC. In this period, significant changes to settlement and economic patterns took place, but probably also within the ideological and social spheres. These changes can be described as 'Eneolithisation'. Therefore, a comprehensive chronological interpretation of archaeological facts is also important and helpful for correct anthropological and historical interpretations of these processes.

Archaeological setting

Loess uplands covered by fertile soils predominate in western Lesser Poland, so it was and still is a very favourable area for agriculture. Hence, since the beginning of the Neolithic until today the area is characterised by very dense human settlement. What is more, this area was and is located at a crossroads of main communication routes, intersecting basins of the Vistula and Oder rivers. In the Neolithic, cultu-

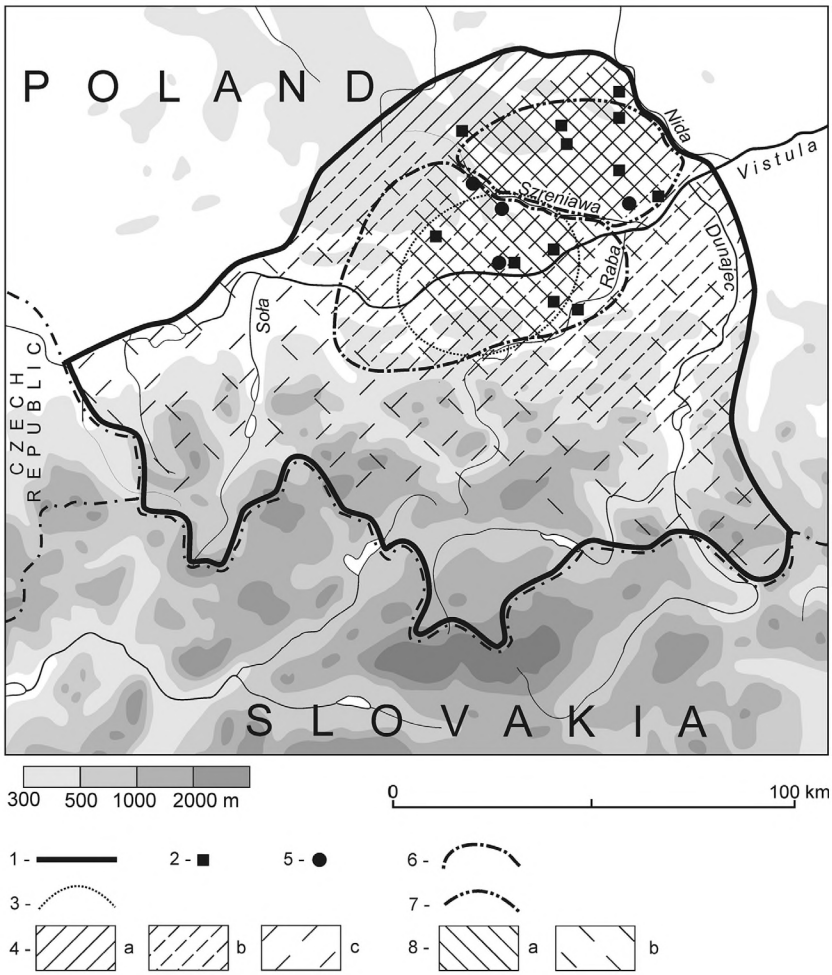

Fig. 1. Territory of western Lesser Poland and the main archaeological units in the late 5th, 4th and early 3rd millennia BC: 1 borders of the area discussed in the paper; 2 sites of the Lublin-Volhynian culture; 3 the Wyciąże-Złotniki group; 4 the Funnel Beaker culture (a dense settlement typical of 'loess' upland; b more dispersed settlement typical of foothills, alluvial plains/basins and 'jurassic' zones; c highly dispersed settlement typical mainly of mountainous zone); 5 sites with the Wyciąże/Niedźwiedź materials; 6 the Baden culture, 7 the Beaker/Baden assemblages; 8 Corded Ware culture (a relatively dense settlement typical mainly of 'loess' upland; b highly dispersed settlement typical of other ecological zones).

ral transmissions and human migration met and mingled here; they came from virtually all directions. As a result, the formation of specific, syncretic units took place fairly frequently. It was also the output area of a number of transmissions and migrations, also in virtually all directions.

Within the defined space and time, a number of archaeological units have been recorded (Fig. 1), almost all of which are local components of large groupings belonging to different Central-European cultural traditions. As is usual in the case of the Neolithic, especially in the 'continental' (cultural-historical) approach, these units and traditions were discerned long ago on the basis of pottery. From the perspective of the Anglo-American literature they would be described rather as pottery styles, not separate entities. Indeed, there are some shared elements of 'non-ceramic' material culture. However, there also are some other elements of material culture as well as patterns of settlement systems and, particularly, of burial practices which fit with the pottery classification very well (compare *Włodarczak 2017*). Thus, we are entitled to assume that in great measure this pottery classification reflects actual past divisions and categorisations.

In the early part of the period considered we are dealing with entities that belong to the last stage of the so-called Lengyel-Polgár complex (L-PC). The term is applied to groups that developed in the 5th millennium and in the first half of the 4th millennium BC, in the basins of the Vistula and Oder rivers (*e.g., Kamieńska, Kozłowski 1990*). These groups were subjected to very strong influences from the Carpathian Basin, reflected primarily in pottery. However, from the perspective of other elements of material culture, settlement, economy, and the as yet few genetic analyses (*Lorkiewicz* et al. *2015; Juras* et al. *2017*), they show evident connections with the first Neolithic culture in central Europe, the Linear Band Pottery culture (LBK). For this reason, they are thought to have formed a later part of the same cultural continuum, denoted as so-called Danubian Neolithic, to apply Gordon Childe's (*1929.220*) terminology. In Polish regions, apart from the Linear Band Pottery culture and Lengyel-Polgár complex, the Stroke Band Pottery culture is also usually in-

cluded in the Danubian Neolithic. However, it is not represented in the region under consideration. Therefore, the ultimate disappearance of the Lengyel-Polgár complex in Lesser Poland is in fact the ultimate disappearance of the continuous development of the Danubian Neolithic, which lasted from approx. the mid-6th millennium BC to approx. the mid-4th millennium BC.

The late Lengyel-Polgár units in western Lesser Poland comprise the Wyciąże-Złotniki group (W-ZG) (Fig. 2) and the Lublin-Volhynian culture (L-VC) (Fig. 3), or rather its westernmost extent, to be more precise (Fig. 1) (*Kadrow, Zakościelna 2000; Nowak 2009; 2014; Zakościelna 2010*).

The central part of our timeframe is characterised by the presence of the Funnel Beaker culture (TRB) (Figs. 4–5). This culture constitutes a quite new cultural tradition, being the outcome of complicated interactions between the later Danubian Neolithic and still 'non-Neolithised' late Mesolithic societies, which took place in the south-western Baltic zone in the late 5th millennium BC (*e.g., Kabaciński* et al. *2015*). In lowland parts of central Europe, it indicates the further development of the Neolithic, connected on the one hand with Eneolithisation processes, but on the other, with the inclusion of late hunter-gatherer populations in the Neolithic way of life ('second stage of neolithisation' – *Nowak 2009*). The Funnel Beaker culture differs from the Danubian Neolithic not only in pottery. Sites of this culture are dispersed more evenly in the landscape, *i.e.* communities of this culture settled and utilised almost all ecological zones (Fig. 1). A number of other factors also make a difference from the Danubian Neolithic, such as: i) the emergence of big settlements with an area of 20–40 hectares, ii) the appearance of monumental burial structures, and iii) the extensive pattern of agriculture of the slash-and-burn type (*Kruk, Milisauskas 1999; Milisauskas, Kruk 1984*). As a consequence of the latter factor, we have clear signs of the human transformation of the environment, mainly of deforestation. Certainly, the emergence of this culture in western Lesser Poland was associated with an impact from the Polish Lowland zone. The balance between cultural transmission and migration within this impact remains a matter of speculation.

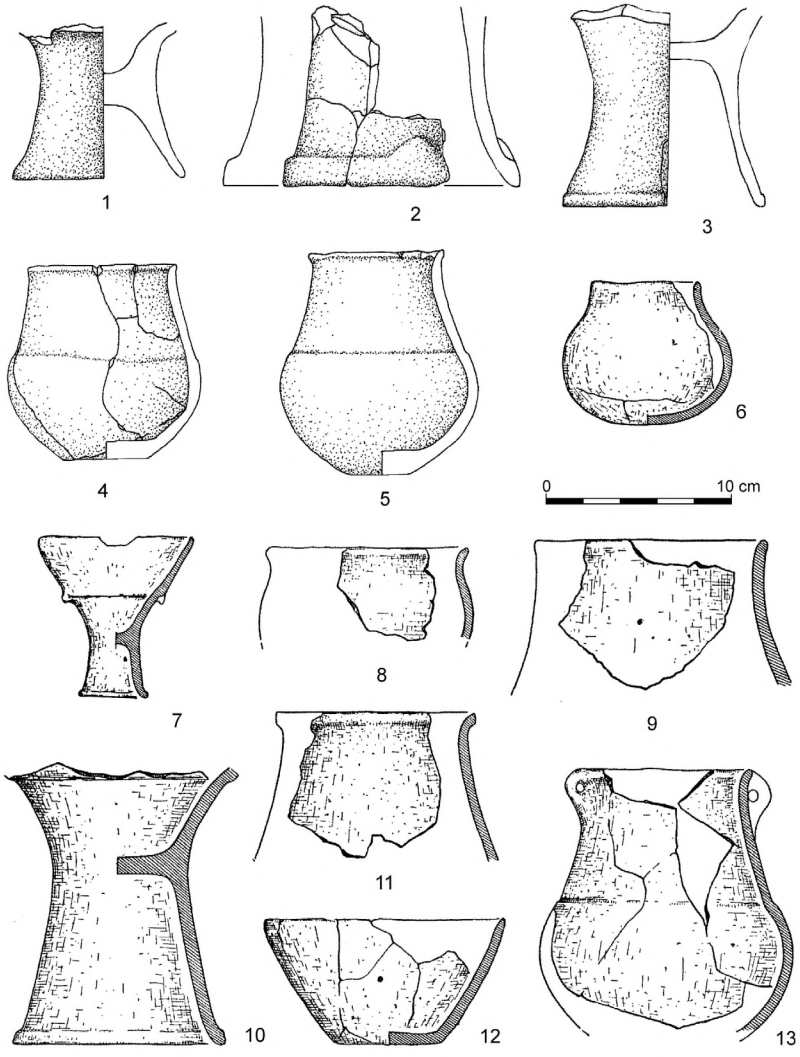

Fig. 2. Selected pottery of the Wyciąże-Złotniki group: 1–5 Podłęże 17 (from* Nowak *et al.* 2007*); 6–13 Złotniki (from* Dzieduszycka-Machnikowa 1966*).

The last part of the period under discussion is characterised by phenomena connected with the Baden culture (BaC) (Fig. 6), which was a unit covering basically the whole of the middle Danube basin. The Baden phenomena have an important position in the Late Eneolithic of east-central Europe, and not only because of their new ceramics. There are many new elements in settlement and economic patterns and in funeral rites; these can be linked to new social structures, both in the horizontal and vertical dimensions. For many reasons, the Baden cultural model must have

been attractive. This factor makes it is possible to explain the relative cultural unification of almost the whole Carpathian Basin and some of the surrounding areas in the period *c.* 3600–2900 cal BC. This had also to be the reason for the enthusiastic acceptance of Baden patterns in regions situated far to the north of the middle Danube basin. This is visible in the new fashion in pottery, but also in other elements, such as the enlargement of some settlements, fortifications and collective burials.

The term 'Baden phenomena' is used here because – as a matter of fact – at least three versions of the 'Badenian' materials can be distinguished in Lesser Poland (Fig. 1). Firstly, we are dealing with the Baden culture proper (Fig. 6) in a small area in and around Kraków (*Zastawny 2015a*). Secondly, features of the Baden culture can easily be noticed within the late Funnel Beaker materials. This is evident primarily in ceramics, but not only in western Lesser Poland. However, only there did the Baden ceramic style became extremely popular within local late Funnel Beaker communities. This fashion was accepted so enthusiastically and en masse that at least some archaeologists have discerned a quite separate local cultural unit called Beaker/Baden assemblages (TRB/BaC, B/BA on Figs. 18, 21) (Fig. 7), in the more eastern part of the area under consideration (*Kruk, Milisauskas 1999; Milisauskas, Kruk 1989*). Thirdly, we are also dealing with materials that combine some late Lengyel-Polgár, Baden and possibly Funnel Beaker features. They are referred to by different terms; there is no universal agreement on this matter (*Burchard 1977; Godłowska 1979.305–306; Kozłowski 1971; 1989b; Włodarczak 2008b; 2013; Zastawny 2011*). The notion of 'materials of the Wyciąże/Niedźwiedź type' (in a shorter, more convenient, version: 'Wyciąże/Niedźwiedź materials') will be used in this contribution (Fig. 8)

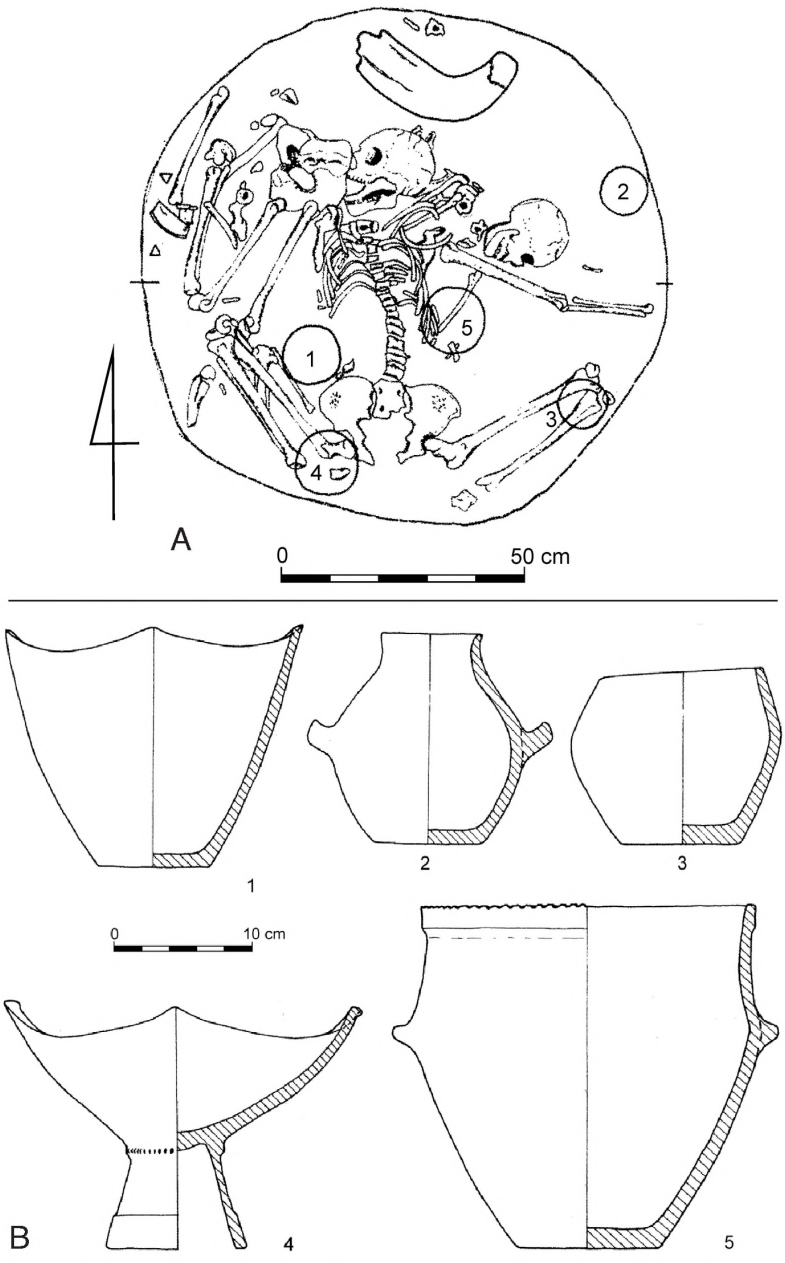

Fig. 3. Collective grave of the Lublin-Volhynian culture at Bronocice (A) and pottery found there as grave goods (B) (from* Kruk, Milisauskas 1985*).

The development of Funnel Beaker culture and Baden phenomena (the Middle Neolithic development) seems to end with the appearance of the Corded Ware culture (CWC). It is obviously defined again by new ceramics, but frequently appear in unprecedented forms of funeral rites (barrows and niche graves). This culture, including its branch known from southern Poland, is quite commonly considered to be evidence of nomadic, pastoral populations. In contrast to previous Neolithic communities, their social structure was distinguished by a greater social stratification. The ruling social stratum, endowed with privileges, would have

been a stratum of adult men, warriors, who were buried under barrows (*Włodarczak 2006a*). There are more and more indications, including genetic ones (*Allentoft* et al. *2015; Haak* et al. *2015*), that the genesis of the Corded Ware culture in central Europe was associated with western migrations from the steppe and forest-steppe zone of eastern Europe.

Until around 2005, views on the absolute chronology of Middle Neolithic units in Lesser Poland were defined rather vaguely. Fairly general terms were in use, such as first or second half of the millennium, the beginning of the millennium, the middle part of the millennium, *etc*. These views were based first and foremost on typological premises and around 40 radiocarbon dates. Available ^{14}C dates were unevenly distributed between archaeological groupings. Actually, most originated from one site of the Funnel Beaker culture and Beaker/Baden assemblages, *i.e.* from Bronocice (*Kruk, Milisauskas 1983; 1990*). Hence, it was difficult to make a reasonable, both detailed and more holistic description of absolute chronology.

However, in recent years there has been a significant increase in the number of radiocarbon dates of the Middle (and Late) Neolithic in western Lesser Poland (Fig. 9). At present, there are over 150 dates (Tab. 1 is available at http://dx.doi.org/10.4312/dp.44.15). More importantly, the first series of dates have been obtained for units previously almost deprived of absolute dates, such as the Wyciąże-Złotniki group, Lublin-Volhynian culture, and Baden culture, as well as Wyciąże/Niedźwiedź materials. For this reason, it seems necessary to make a new estimate of the absolute chronology of this segment of the Neolithic in western Lesser Poland, making use of Bayesian modelling, among other things.

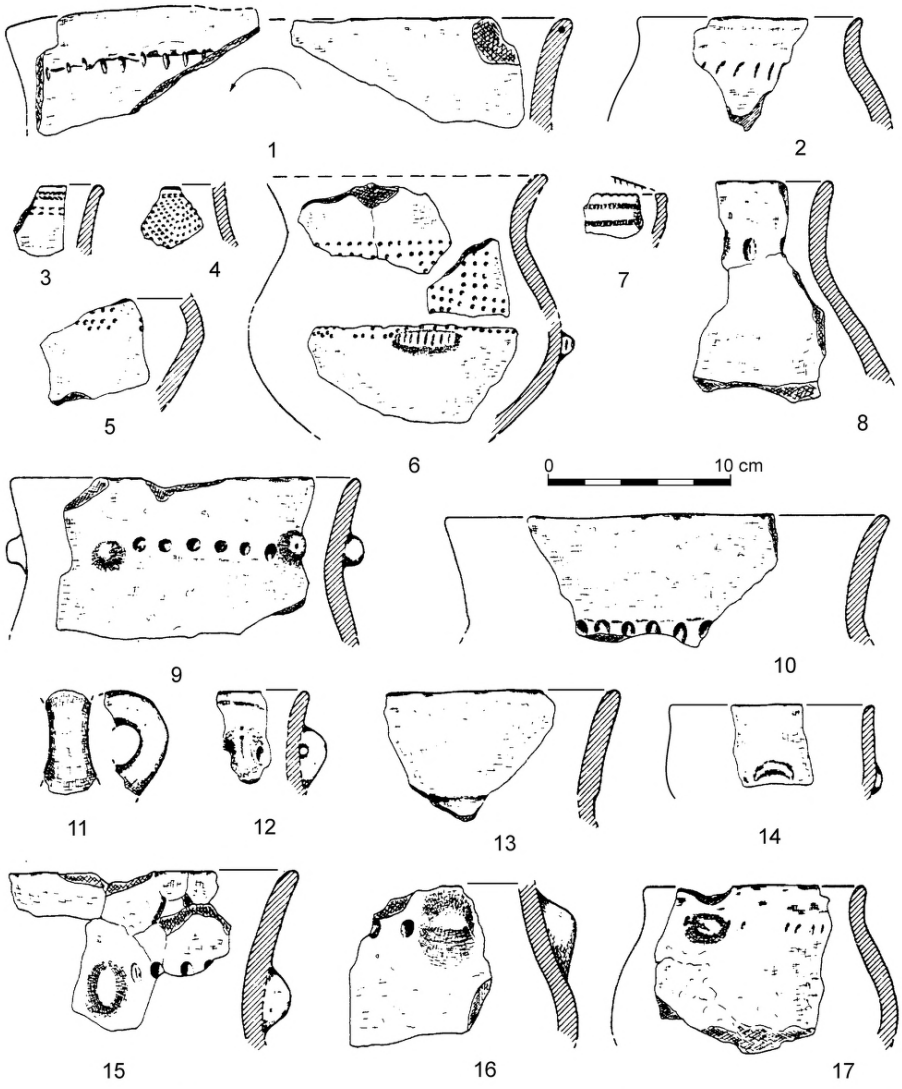

Fig. 4. Pottery of the earliest Funnel Beaker culture at Bronocice (phase BR I) (from* Kruk, Milisauskas 1990*).

Descriptions of all the dates used for their credibility are demonstrated in Table 1, available online at http://dx.doi.org/10.4312/dp.44.15. Of course, these dates are very different in this regard. Those obtained by the early 1980s usually have large standard errors and come from not very evident contexts. However, some newer dates do have the same drawbacks. On the other hand, quite a lot of our collection has a high degree of credibility, *i.e.* dates with small standard deviations obtained from bones or short-lived plants from a certain cultural context. Taking all of this into account, it was decided to conduct chronological analysis in three variants. The first is based on all dates; the second is based on dates with standard deviations of less than 100 years which originate from a confirmed context; this group of dates is denoted as group B (see Table 1, available online at http://dx.doi.org/10.4312/dp.44.15). The third variant is based exclusively on dates originating from the same confirmed context, but obtained only on bones and short-lived plants; such dates are labelled as group A (see Table 1, available online at http://dx.doi.org/10.4312/dp.44.15).

Direct dating

In the case of the Lublin-Volhynian culture in western Lesser Poland, we had until recently only one radiometric date from the Bronocice site (Tab. 1.4, available online at http://dx.doi.org/10.4312/dp.44.15), with a very broad standard deviation of 240 years (*Kruk, Milisauskas 1985*). Fortunately, three other dates (Tab. 1.1–3, available online at http://dx.doi.org/10.4312/dp.44.15) obtained on bones from the same site were published in 2016 (*Kruk* et al. *2016; Milisauskas* et al. *2016*). Overall, all these dates formally cover a time range from *c.* 3950 to 3350 cal BC (Tab. 2; Fig. 10). For three dates of group B and also A, this range is almost the same: *c.* 3950–3380 cal BC.

Similarly, for the Wyciąże-Złotniki group, only one ^{14}C date had been obtained before 2009, from the site of Złotniki (Tab. 1.15, available online at http://dx.doi.org/10.4312/dp.44.15), of not very high value.[2] This unit could also be associated with a date obtained from the palynological profile at Kraków-Pleszów (Tab. 1.5, available online at http://dx.doi.org/10.4312/dp.44.15) (*Wasylikowa* et al. *1985.53; Godłowska* et al. *1987.137*). However, the number of radiocarbon dates of this group has recently increased due to archaeological investigations on road works (Tab. 1.6–14, available online at http://dx.doi.org/10.4312/dp.44.15). All these dates formally cover a time range from *c.* 4300 to 3500 cal BC (Tab. 2; Fig. 11). The range for six dates included in group B has the same lower limit, while the upper is about 350 years earlier (Tab. 2). No date met group A requirements.

To the Funnel Beaker culture in western Lesser Poland, we can attribute 59 radiocarbon dates (Tab.

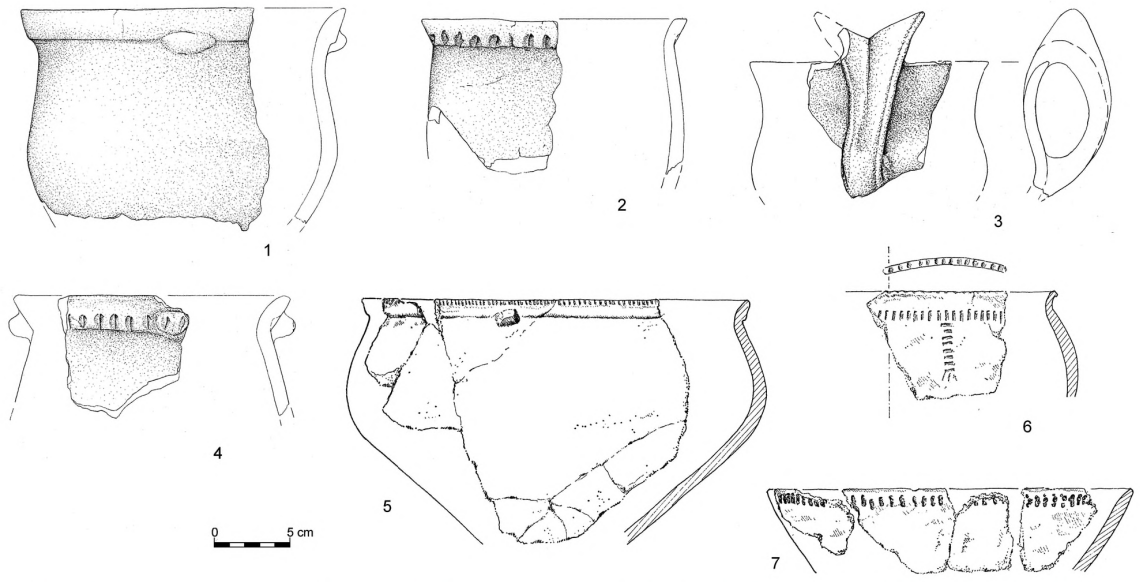

Fig. 5. Selected pottery of the Funnel Beaker culture: 1–4 Mozgawa (unpublished, drawn by M. Korczyńska); 5–7 Kraków-Prądnik Czerwony (from* Rook, Nowak 1993*).

2 In addition, this date is, unfortunately, often quoted with an incorrect standard deviation as 4810±120 BP (*e.g., Kozłowski 1989a. 198; Kamieńska, Kozłowski 1990.85; Nowak 2009.137 – mea culpa*). Its actual value is 4810±200 BP (*Crane, Griffin 1970.177*).

1.16–74, available online at http://dx.doi.org/10.4312/dp.44.15). Formally, all of them outline the time span of *c.* 3700–3250 cal BC (Tab. 2; Fig. 12). The dates of groups B and A provided results with upper limit slightly moved down to 3280 and 3270 cal BC, respectively.

At this point, an important issue must be explained. In the case of the site at Bronocice, some of the radiocarbon dates attributed in the literature to the Funnel Beaker culture are from graves. However, identifying the cultures of most of these graves found there is very difficult due to a complete absence of grave goods. For this reason, we cannot be sure whether such graves should be associated with the Funnel Beaker or with Beaker/Baden phases of the settlement. If we compare consecutive publications, we see differences in this classification. There are even differences between the chapters of the same publications (compare, for example, Table 4 on p. 51 and Table 1 on p. 57 in *Milisauskas* et al. *2016*). For this reason, a chronological evaluation of nine graves in which grave goods were not found, including Bayesian modelling (see below for a description) was performed (Tab. 2, Fig. 13). It follows that we are dealing here with three chronological horizons. The first is placed around 3700 cal BC and is represented by grave no. XX. The second is situated between *c.* 3500 and 3350 cal BC and is represented by graves no. XIV and XVIII. Finally, the third horizon is dated to *c.* 3350–2900 cal BC; graves no. VII, VIII, XV, XVI, XXIII and XXIX should be included in it. On the basis of this classification, the last group of graves was added to the Beaker/Baden assemblages, while graves XIV, XVIII and XX were rated as connected with the Funnel Beaker culture. We are aware that this categorisation does not fully accord with the proposals of Kruk and Milisauskas (*Kruk* et al. *2016; Milisauskas* et al. *2016*), especially the transfer of graves VIII and XV to the Beaker/Baden assemblages. Nevertheless, we believe that the presented modelling gives the proposed categorisation a good basis. Accordingly, dates from grave XIV, XVIII and XX were included in the group of all dates of the Funnel Beaker culture, while the remaining dates are from graves with Beaker/Baden assemblages. This arrangement will also be valid in the Bayesian modelling for all dates in other parts of the contribution.

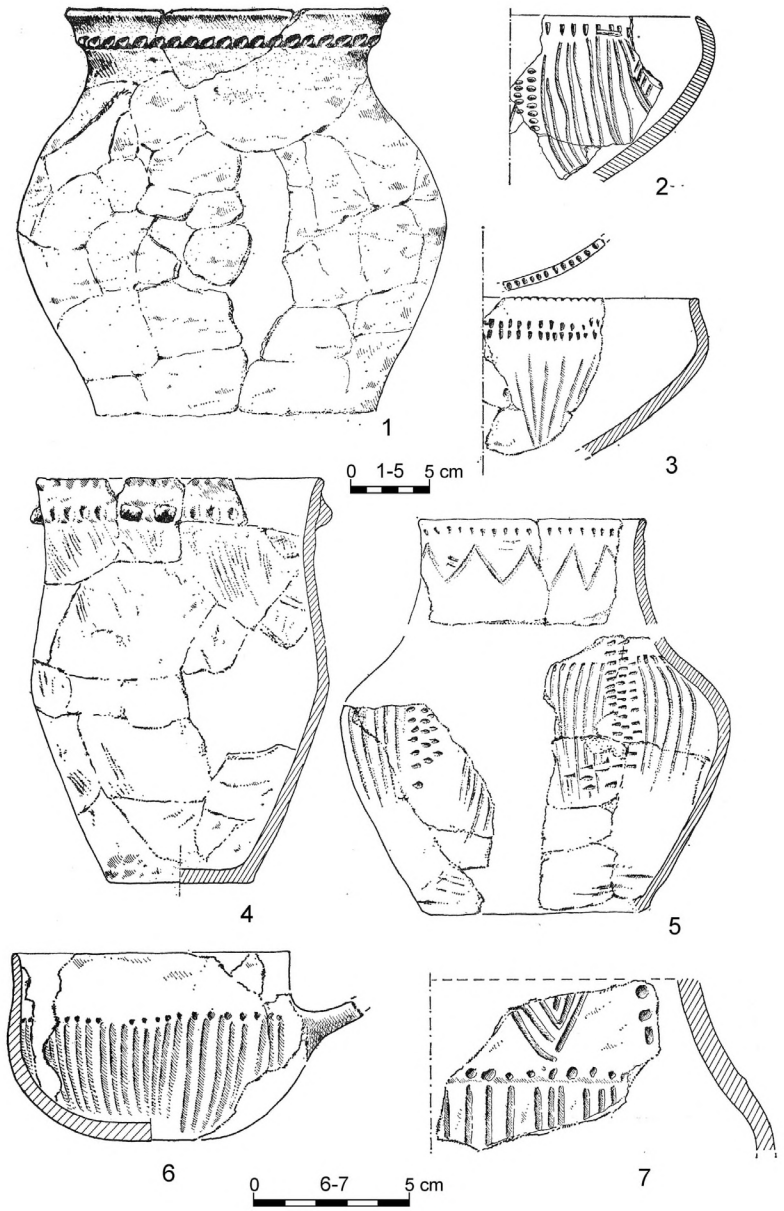

Fig. 6. Selected pottery of the Funnel Beaker culture (1) and Baden culture (2–7) at Kraków-Prądnik Czerwony (from* Rook, Nowak 1993*).

On the other hand, all nine dates were excluded from groups B and A, despite the fact that they were obtained from human bones. After all, we have to bear in mind that the above modelling of dates from these nine graves is merely an indirect indication of their cultural context.

Three dates, which can be linked to the Wyciąże/Niedźwiedź materials (Tab. 1.75–77, available online at http://dx.doi.org/10.4312/dp.44.15), indicate the interval of *c.* 3500–3000 cal BC (Tab. 2; Fig. 14); these dates meet the requirements of both group B and A.

Until recently, because of the scarcity of radiocarbon dates one could encounter quite diverse views on the absolute chronology of the Baden culture in western Lesser Poland. However, quite a large number of dates obtained in the past few years (Tab. 1.78–103, available online at http://dx.doi.org/10.4312/dp.44.15) (*Zastawny 2015b*) allow us to set it in a relatively reliable way. The time span formally covered by all 26 dates should be estimated to *c.* 3100–2800 cal BC (Tab. 2; Fig. 15). Interestingly, the same timeframes have been obtained in the case of 24 dates connected to group B and 19 dates classified as group A.

The absolute chronology of the Beaker/Baden assemblages can be analysed first and foremost on the basis of data from one site, Bronocice (Tab. 1.104–127, available online at http://dx.doi.org/10.4312/dp.44.15) (*Kruk, Milisauskas 1990; Kruk* et al. *2016; Milisauskas* et al. *2016*). To this set we should pos-

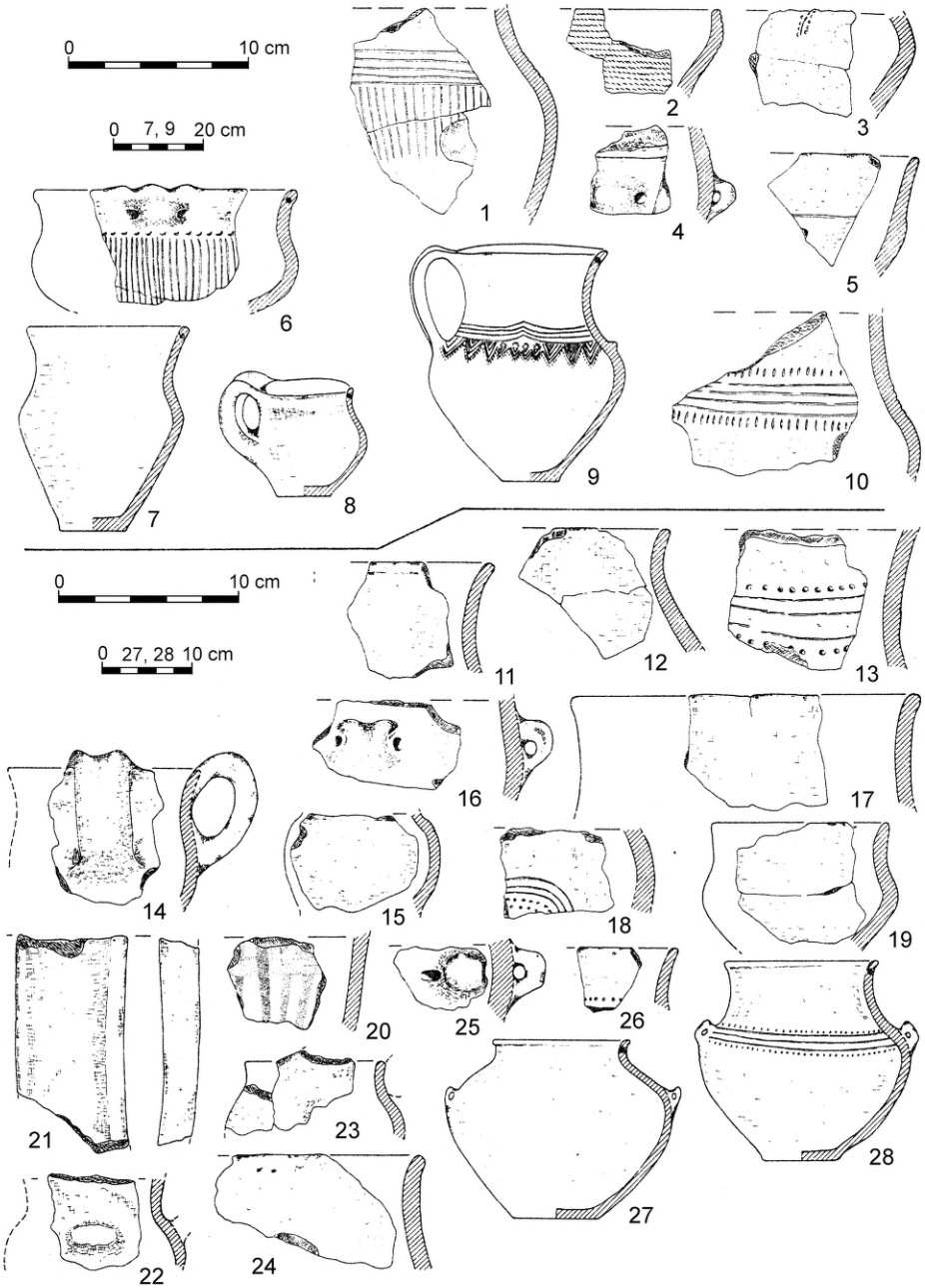

Fig. 7. Selected pottery of the Beaker/Baden assemblages at Bronocice: 1–10 feature 2-B2; 11–28 feature 1-A5 (from* Kruk, Milisauskas 1990*).

sibly add two dates from Szarbia, a site located nearby (Tab. 1.128, 129, available online at http://dx.doi.org/10.4312/dp.44.15) (*Włodarczak 2013.379*). Formally, all these 26 dates define a fairly wide interval of *c.* 3350–2650 cal BC (Tab. 2; Fig. 16). On the other hand, the intervals based on dates included in groups B and A are shorter, being *c.* 3350– 2790 cal BC and *c.* 3370–2900 cal BC, respectively. In both cases, the upper limit moved down, by 140 and 250 years.

Regarding the Corded Ware culture, we are interested mainly in dating its origins and early stages as a background to the declining development of the previously discussed units. But to do so, we must use all the dates from this culture. The absolute chronology can be determined on the basis of 24 radiocarbon dates (Tab. 1.130–153, available online at http://dx.doi.org/10.4312/dp.44.15) (*Jarosz, Włodarczak 2007; Tunia, Włodarczak 2002; Włodarczak 2006a*). Formally, all these dates cover the period between *c.* 2700 and 2280 cal BC (Tab. 2; Fig. 17). The timeframes for groups A and B are *c.* 2650–2330 cal BC and 2630–2300 cal BC, respectively.

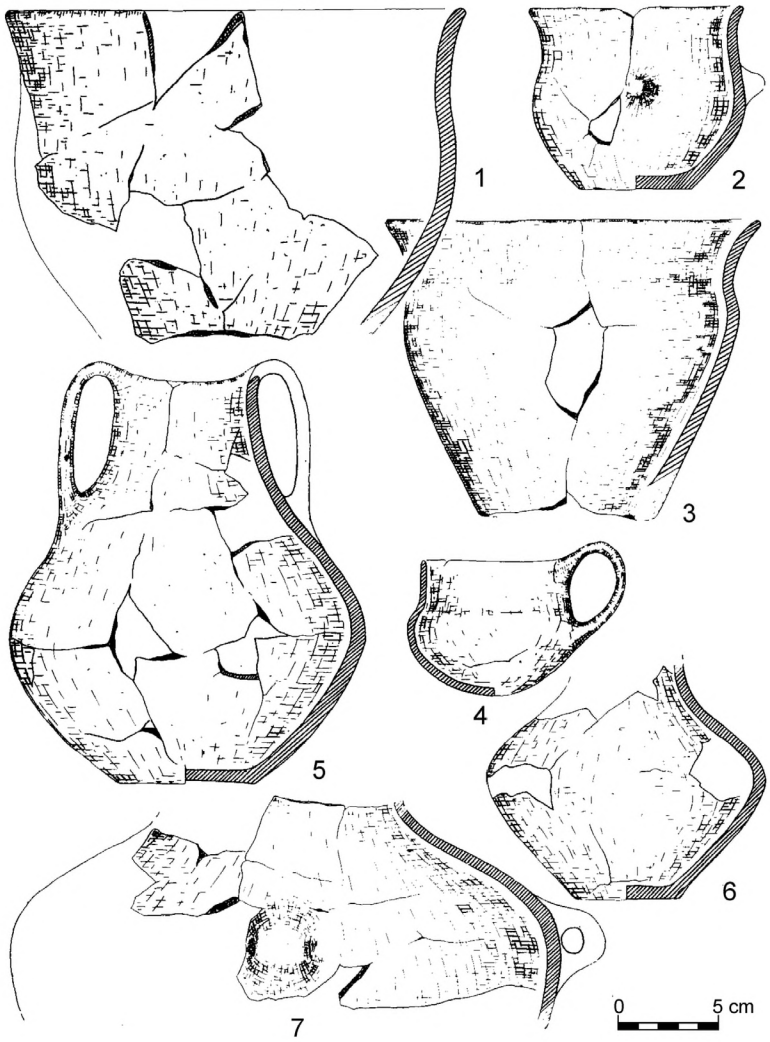

Fig. 8. Selected pottery of the Wyciąże/Niedźwiedź materials at Niedźwiedź (from* Burchard 1977*).

By and large, radiocarbon dates, treated directly, with no modelling, support views in light of which local branches of the late Lengyel-Polgár complex, the Funnel Beaker culture and the Baden phenomena overlap chronologically to a great extent. Admittedly, they are not always consistent with views based on individual (the earliest and/or the latest) dates or results from typological premises and stratigraphic observations.

Separate modelling

In order to determine the most precise chronological frameworks of the discussed archaeological units possible, Bayesian model simulations were performed in which dates obtained for discussed archaeological units (in three groups specified above) were treated as if they constitute one phase (see 'Intrduction'). The chronological data obtained from all of these procedures were analysed and compared. As a result, we decided to discern four kinds of interval based on the properties of generated boundaries (Tab. 2): i) as the interval based on median values; ii) as the widest possible interval, based on extreme points of the 95.4% ranges; iii) as the 'probable'[3] interval, based on extreme points of the 68.2% ranges; and iv) as the narrowest possible interval, based on the end point of the 95.4% start boundary and the start point of the 95.4% end boundary. However, the last version may be impossible to calculate.

3 After, for example, *Krus* et al. *2015.971*, who use this term for 68.2% probability – "*Activity associated with Group 1 on the site is estimated to have ended in calAD 1295–1465 (95% probability; Figure 6; End: SunWatch: Group 1), and probably in calAD 1305–1405 (68% probability)*".

The model for the Lublin-Volhynian culture based on four dates from Bronocice is statistically significant, as are all the individual dates (Fig. 10), but gives a very broad time range (Tab. 2). At maximum span it gives 4460–2760 cal BC. 'Probable' values are 4000 and 3290 cal BC, whereas the 'median' interval is 3890–3400 cal BC. The shortest version of the chronology amounts to only 20 years, *i.e.* 3650–3630 cal BC. Somewhat surprising is the fact that the intervals for three dates of group A and – simultaneously – B turned out to be even longer by several dozen years.

Modelling of the 11 dates of the Wyciąże-Złotniki group also proved to be statistically significant, as did all the particular dates (Fig. 11). Again, this modelling allows us to accept a very large time interval, maximally 4530–3300 cal BC, and in the 'probable' version 4400–3480 cal BC. The narrowest version is demarcated by 4120 and 3640 cal BC, and the 'median' by 4310 and 3530 cal BC (Tab. 2). The above values obtained from direct dating are similar to the 'median' ones. The modelling of group B dates gives intervals shorter by several dozen to two hundred years. The upper limit moves down fairly significantly, to 3690/3940 cal BC, except the widest interval value.

Modelling of 59 dates of the Funnel Beaker culture (Fig. 12) gives the time interval of 3730–3230 cal BC, in the longest version, and the 'probable' interval of 3700–3270 cal BC. The shortest version is 3650–3330 cal BC, and the 'median' version is 3680–3290 cal BC (Tab. 2). None of the intervals differ significantly from direct dating. The model for the TRB is statistically significant, but the level of agreement drops below 60% in the case of the two earliest dates from Bronocice and the latest date from Mozgawa (Fig. 12). As a comment on this observation we quote a sentence from the classic paper by Christopher Bronk Ramsey (*2009b.1025*): *"[...] secondly, an overall agreement index is calculated A_{model} and if this is above 60% it probably indicates that there is no problem with the model as a whole (and therefore no samples need be rejected)"*.

The chronological limits modelled on 47 dates of group B do not indicate major differences; they

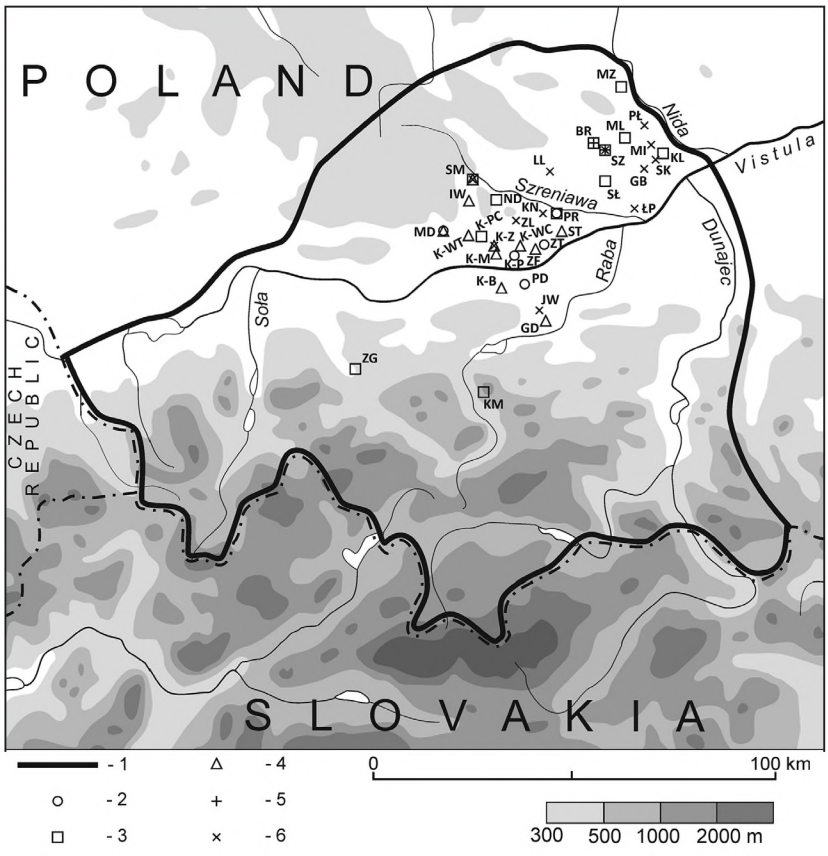

Fig. 9. Archaeological sites with ^{14}C dates used in the paper: 1 borders of the area discussed in the paper; 2 sites of the Wyciąże-Złotniki group and Lublin-Volhynian culture (only Bronocice); 3 sites of the Funnel Beaker culture; 4 sites of the Baden culture and Wyciąże/Niedźwiedź materials (only Kraków-Wyciąże and Smroków); 5 sites of the Beaker/Baden assemblages; 6 sites of the Corded Ware culture; BR Bronocice, GB Gabułtów, GD Gdów, IW Iwanowice, JW Jawczyce, KM Kamiennik, KL Kolosy, KN Koniusza, K-B Kraków-Bieżanów, K-M Kraków-Mogiła 55, K-P Kraków-Pleszów 17: settlement and palinological profile, K-PC Kraków-Prądnik Czerwony, K-WT Kraków-Witkowice, K-WC Kraków-Wyciąże 5, K-Z Kraków-Zesławice 21 and 22, LL Lelowice, ŁP Łapszów, ML Malżyce 30 and 31, MI Miernów, MD Modlnica 1 and 5, MZ Mozgawa, ND Niedźwiedź, PŁ Pełczyska, PD Podłęże, PR Proszowice, SK Sokolina, SŁ Słonowice, SM Smroków, ST Stręgoborzyce, SZ Szarbia, ZG Zagórze, ZL Zielona, ZT Złotniki, ZF Zofipole (for references see Table 1, available online at http://dx.doi.org/10.4312/dp.44.15).

Archaeological units; categories of ^{14}C dates (their amounts); agreement indices($A_{overall}$ and A_{model})	Sum[1]	Interval based on medians	The widest interval	The 'probable' interval	The narrowest interval
Lublin-Volhynian culture; all dates (4); 101.6%, 100.3%	*c.* 3950–3350	3890–3400	4460–2760	4000–3290	3650–3630
Lublin-Volhynian culture; dates of group B = dates of group A[2] (3); 97.6%, 97.4%	*c.* 3950–3380	3930–3390	4670–2590	4070–3260	3660–3630
Wyciąże-Złotniki group; all dates (11); 98.5%, 99.5%	*c.* 4300–3500	4310–3530	4530–3300	4400–3480	4120–3640
Wyciąże-Złotniki group; dates of group B (6); 88.3%, 88.0%	*c.* 4300–3850	4290–3770	4600–3460	4380–3690	4070–3940
Funnel Beaker culture; all dates (59) 76.2%, 74.2%	*c.* 3700–3250	3680–3290	3730–3230	3700–3270	3650–3330
Funnel Beaker culture; dates of group B (47); 80.9%, 70.7%	*c.* 3700–3280	3680–3280	3720–3200	3690–3260	3640–3330
Funnel Beaker culture; dates of group A (34); 79.6%, 79.6%	*c.* 3700–3270	3680–3290	3750–3210	3700–3260	3650–3340
Funnel Beaker culture; Bronocice graves (9); 91.8%, 92.0%	*c.* 3900–3650 and *c.* 3520–2850	3800–2870	4090–2580	3880–2790	3650–3080
Wyciąże/Niedźwiedź materials; all dates = dates of group B = dates of group A (3);104.2%, 104.1%	*c.* 3500–3000	3330–3130	3810–2700	3410–3030	–
Baden culture; all dates (26) 74.6%, 76.7%	*c.* 3100–2800	3070–2830	3130–2780	3100–2810	2990–2870
Baden culture; dates of group B (24); 72.9%, 70.8%	*c.* 3100–2800	3070–2830	3140–2780	3110–2810	2990–2870
Baden culture; dates of group A (19) 67.6%, 67.2%	*c.* 3100–2800	3060–2820	3130–2770	3100–2800	2980–2870
Funnel Beaker/Baden assemblages; all dates (26); 104.5%, 104.0%	*c.* 3350–2650	3280–2770	3400–2610	3360–2720	3150–2870
Funnel Beaker/Baden assemblages; dates of group B (15); 106.6%, 106.7%	*c.* 3350–2790	3250–2790	3420–2610	3320–2730	3120–2880
Funnel Beaker/Baden assemblages; dates of group A (6); 66.2%, 67.2%	*c.* 3370–2900	3310–3030	3560–2630	3390–2850	–
Corded Ware culture; all dates (24); 64.7%, 63.6%	*c.* 2700–2280	2670–2330	2800–2240	2720–2280	2580–2420
Corded Ware culture; dates of group B (21); 99.9%, 98.0%	*c.* 2650–2330	2630–2330	2710–2260	2660–2290	2580–2420
Corded Ware culture; dates of the A group (20); 84.4%, 81.3%	*c.* 2630–2300	2550–2360	2670–2270	2620–2310	2470–2460

1 Sum-calibrated intervals were delineated through excluding onset and tail sections of the very low probability density.
2 For characteristics of groups B and A and dates assigned to them see Table 1, available at http://dx.doi.org/10.4312/dp.44.15.

Tab. 2. Results of direct dating (sums) and of separate modelling of ^{14}C dates of the Middle and Late Neolithic units in western Lesser Poland (cal BC; rounded by 10 years).

amount to no more than 30 years. The same applies to group A (34 dates); in this case, the time differences do not exceed 20 years. Apart from the earliest date from Bronocice, which does not comply with the requirements of groups A or B, the same other two dates have agreement indices below 60%. In all versions, the differences from the sum-calibrated intervals are low; only in the case of the narrowest interval do they increase to 60/80 years.

Although we have only three dates which can be connected with the Wyciąże/Niedźwiedź materials, the agreement indexes of modelling are above 60% (Fig. 14). The widest time interval is 3810–2700 cal BC;

the 'probable' interval is 3410–3030 cal BC and the 'median' is based on 3330–3130 cal BC. The narrowest version cannot be calculated (Tab. 2). As may be recalled, these three dates fit groups A and B.

As a result of modelling (Fig. 15), the time span covered by the 26 dates from the Baden culture is consistent and relatively short (only one, the latest date, does not fit the model). It is delimited at 3130 cal BC and 2780 cal BC in the widest version, at 3100 and 2810 cal BC in the 'probable' version, at 2990–2870 cal BC in the narrowest version, and at 3070–2830 cal BC in the 'median' version. The values of direct dating are almost literally consistent with the 'probable' version (Tab. 2). The same can be said of the timeframes modelled on dates belonging to groups A and B; the differences amount to 10 years.

As we already know, the absolute chronology of the Beaker/Baden assemblages can be analysed on the basis of 24 dates from Bronocice and 2 dates from the nearby site of Szarbia. The model for all dates is characterised by high levels of significance (Tab. 2; Fig. 16). All these dates define the widest interval as 3400–2610 cal BC. The 'probable' interval covers 3360–2720 cal BC (and this is almost exactly the same interval as that resulting from direct dating), whereas the narrowest one is 3150–2870 cal BC, and the 'median' one 3280–2770 cal BC (Tab. 2). Some values in the model based on 15 group B dates differ by no more than 40 years. On the other hand, the model generated by 6 dates in group A yields larger differences. Moreover, the values of the 'median' (3310–3030 cal BC) and 'probable' (3390–2850 cal BC) intervals are generally older.

The possible dates of the beginning of the Corded Ware culture resulting from statistically significant modelling of all dates are: 2800, 2720, 2580 and 2670 cal BC (Tab. 2; Fig. 17). The corresponding values for groups B and A are clearly younger. They are respectively: 2710/2670, 2660/2620, 2580/2470 and 2630/2550 cal BC.

Our analyses give rise to the two basic interpretations of an extreme character (Fig. 18).

Firstly, we can accept the whole time or most of the time generated by the modelling procedures. In this case, all archaeological units more or less formally mesh together in time.

Secondly, we can take into account only the short segments of chronological range and reject the remaining parts of these ranges. In this case, the archaeological units would have been arranged roughly into two groups (consisting of contemporary units), and two single units. These four groupings would be ordered linearly, but there would be even breaks in the continuity of cultural development. This scenario goes to some extent back to the linear (traditional) vision of the development of archaeological units.

One group would consist of the Lublin-Volhynian culture, the Wyciąże-Złotniki group and Funnel Beaker culture. The Wyciąże-Złotniki group would perhaps appear earlier, around 4100 BC, while the Lublin-Volhynian culture would appear around 3700 cal BC. These two units would disappear around 3600 cal BC. The Funnel Beaker culture would appear at *c.* 3700/3650 cal BC, so it would (partly) overlap with former units in the 37th century BC. This culture would vanish around 3300/3250 cal BC.

Another group would comprise the Baden culture and Beaker/Baden assemblages, and would be generally dated to the 31st, 30th and part of the 29th cen-

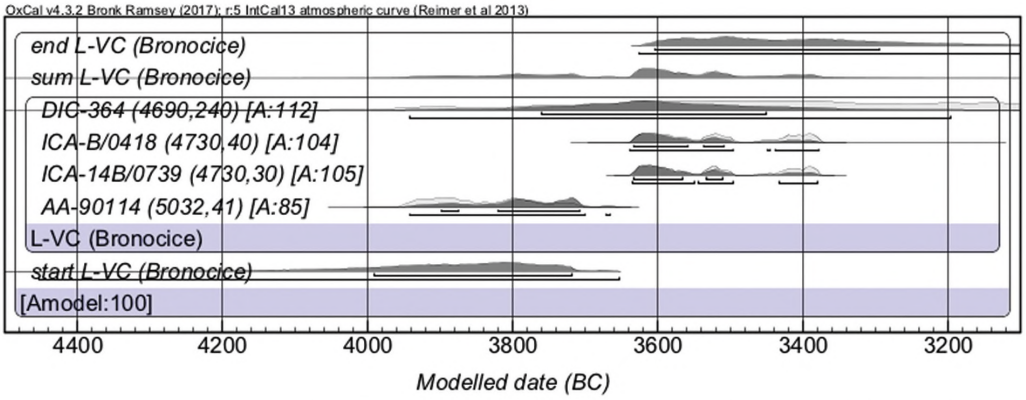

Fig. 10. Radiocarbon chronology (cal BC) of the Lublin-Volhynian culture (L-VC). The OxCal 4.3.2 package was used for all calibrations and models (*Bronk Ramsey 2009a; online; Reimer *et al.* 2013*).

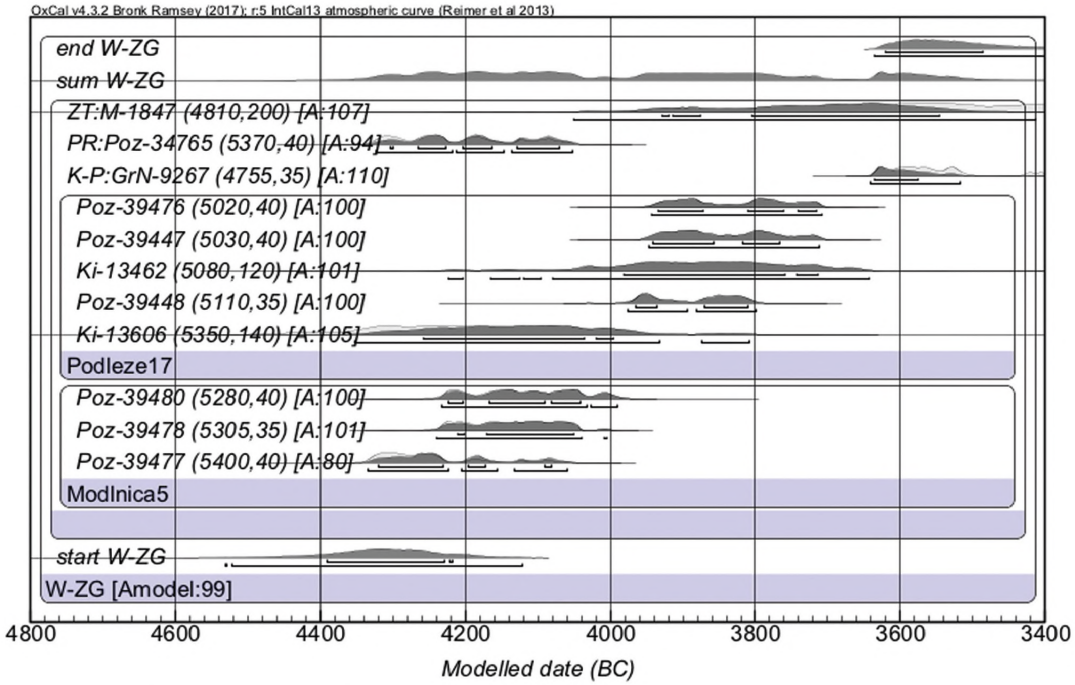

Fig. 11. Radiocarbon chronology (cal BC) of the Wyciąże-Złotniki group (W-ZG); K-P Kraków-Pleszów, palynological profile, PR Proszowice, ZT Złotniki.

turies BC, with possible earlier start of the latter unit (*c.* 3250 cal BC).

The Wyciąże/Niedźwiedź materials would be dated to *c.* 3350–3100 cal BC, which would fill the potential gap between the Funnel Beaker and the Baden cultures in the Kraków region in the late 33rd and in the 32nd centuries BC. A hiatus could also be postulated between the second group and the Corded Ware culture, around 2800–2650/2600 cal BC.

Combined modelling

In our next step, Bayesian models based on 153, 119 (group B) and 85 (group A) dates, were constructed using several relationships resulted from typological data, stratigraphic observations and general knowledge about Neolithic development in east-central Europe (priors). Holistic modelling is justified, because the archaeological units under considerations can depend on each other, both chronologically and territorially. Such dependencies do not appear in the separate modelling. In this arrangement, "*results must be seen as dependent on the assumptions built into the chronological framework*" (*Bronk Ramsey 2009b.348*).

The aforementioned relationships are as follows:

Firstly, some stratigraphic observations on a few sites indicate that Lengyel-Polgár units had to be at least partially coeval with, or even later than, the early stages of the Funnel Beaker culture (*Kaczanowska 1976; Kruk, Milisauskas 1985*). These observations, however, do not refer to radiocarbon dated features. Stratigraphic dependencies in Bronocice demonstrate that the earliest phase of the local Funnel Beaker culture (phase BR I) had to be older than the local Lublin-Volhynian culture (*Kruk, Milisauskas 1985*). Alas, this rule can be utilised only in modelling based on all dates, because the only date of the BR I phase does not meet the requirements of groups B and A. To be clear, there are also situations of an opposite kind in Bronocice, *i.e.* some Lublin-Volhynian features are older than Funnel Beaker features belonging only to phases BR II or BR III.

Secondly, a comparison of general chronologies of the Funnel Beaker culture and Baden culture (*Nowak 2009; Zastawny 2015a*) suggests that the relationship between them is non-linear and assumes parallelism in the second half of the 4th millennium BC.

Thirdly, in case of the beginnings of the Funnel Beaker culture, we decided to replace 'boundary' with 'sigma boundary'. This was done primarily so as to include the possible pattern of the local development of this unit, *i.e.* its quantitatively modest and conspicuously early beginnings (*Nowak 2009*).

Fourthly, some stratigraphic relations in Bronocice (see Table 1, available online at http://dx.doi.org/

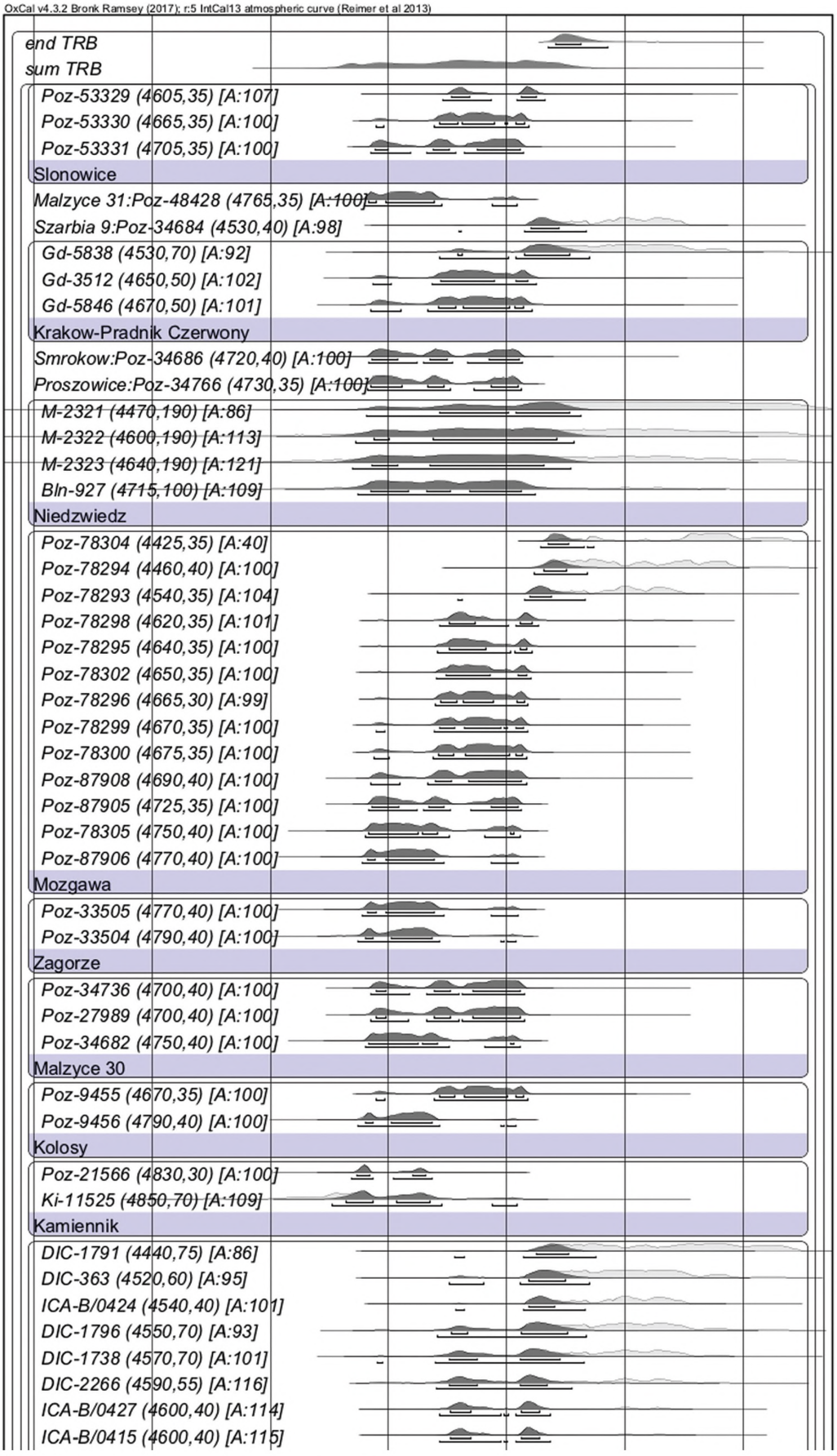

Fig. 12. Radiocarbon chronology (cal BC) of the Funnel Beaker culture (TRB).

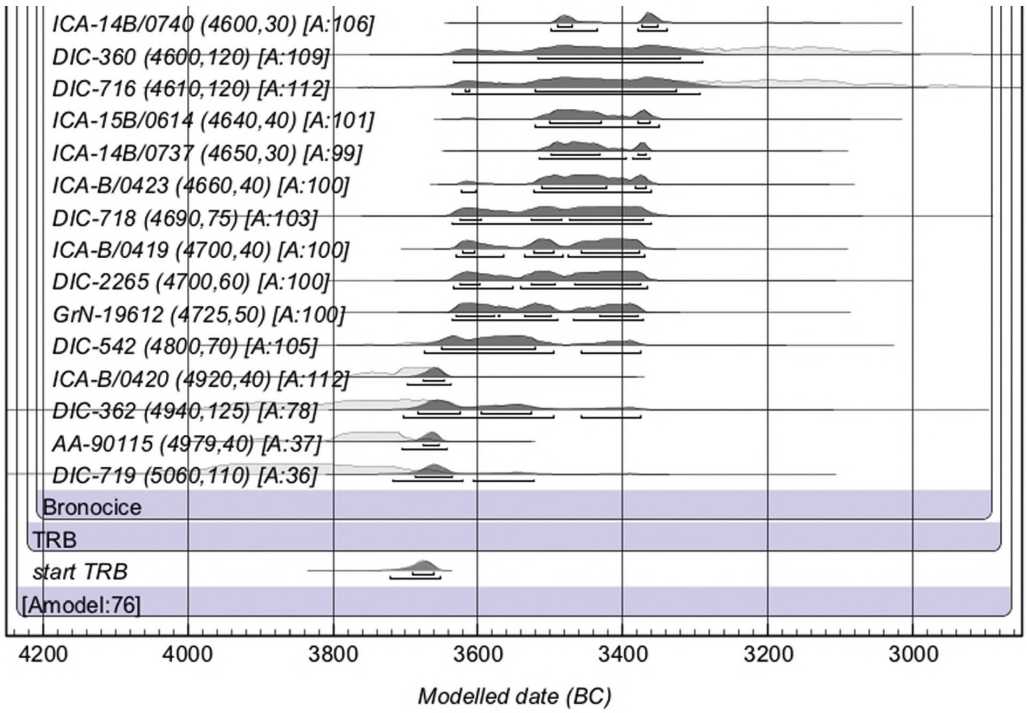

Fig. 12. Continue ...

10.4312/dp.44.15) demonstrate younger chronology of the Beaker/Baden assemblages when compared to the Funnel Beaker culture, as well as their typological continuity. The typological data also suggest close continuity between the Wyciąże-Złotniki group and Wyciąże/Niedźwiedź materials. Hence, a 'transitional boundary' was used in these positions.

Fifthly, no elements within the materials of the Corded Ware culture in western Lesser Poland can be derived from other units (*Włodarczak 2008b; 2011*). Consequently, we believe that this culture quite radically closed the earlier development and, therefore, is radically separated from earlier units.

In all models constructed under these assumptions, both indexes of agreement are over the threshold value of 60% (Tab. 3; Fig. 19). Three dates 'drop' below 60% in the case of the 'all dates model' and 'group B model'; in the case of the 'group A model' there are five such dates. Therefore, we can easily take these models as a basis for further analyses and interpretations. Their results have been presented in the same way as for separate modelling (Tab. 3).

For the Lublin-Volhynian culture, we obtained 3990–3100 cal BC in the widest version. The 'probable' values are 3870 and 3360 cal BC, whereas the 'median' ones are 3810 and 3470 cal BC. The narrowest interval covers only 3690–3630 BC. These values are shorter than those obtained in separate modelling, except for the narrowest one. In the modelling of group B, as expected, the origins are earlier, even by over 300 years for the widest interval. By contrast, in group A, the results are virtually identical to the modelling for all dates; differences do not exceed 30 years.

As for the Wyciąże-Złotniki group, modelling for all dates allows us to accept a very large time interval, the maximal version being 4460–3270 BC, and the 'probable' version 4370–3340 cal BC. The dates of 4110 and 3630 BC make the narrowest interval, and 4290 and 3440 cal BC the 'median' one. Modelling for the dates of group B gives similar values (a difference of no more than 50 years), except the narrowest interval, which ends 270 years earlier. There are some differences with separate modelling of several dozens or over one hundred years. Interestingly, the intervals generated in combined modelling are usually not shorter.

Regarding the Funnel Beaker culture, its earliest phase in Bronocice can be placed at the turn of the 5th and 4th millennia BC, or in the first quarter of the 4th millennium BC, as modelled on the basis of one date from the Bronocice phase BR I. Unfortunately, this is the only date of this phase, and is of relatively low reliability.

The other values for the Funnel Beaker culture are very similar in all three models. The widest intervals

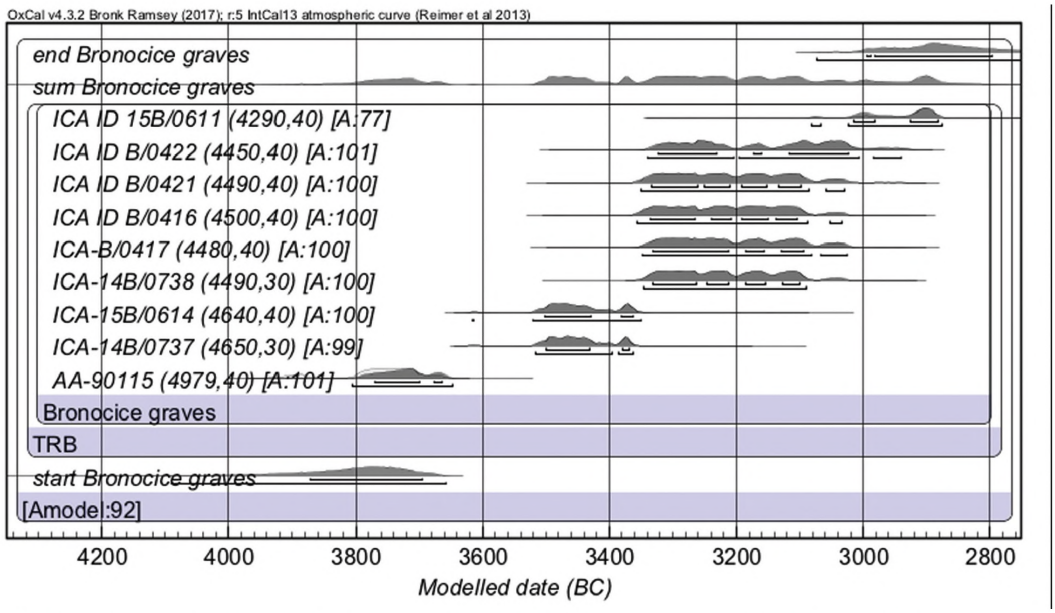

Fig. 13. Radiocarbon chronology (cal BC) of graves without grave goods at Bronocice.

covers the period of *c.* 3550/3530–3280/3270 cal BC, the 'probable' intervals 3510/3500–3300/3290 cal BC, the narrowest intervals 3490/3430–3340, and the 'median' intervals 3490/3480–3310 cal BC. Overall, consequently, the Funnel Beaker culture ends several decades earlier than in previous models, except the narrowest interval.

The values of the beginning of the Funnel Beaker culture should be calculated in a slightly different way due to the other type of distribution used, as we already know. In the 'sigma boundary'/'boundary' distribution start dating, *c.* 3500 cal BC should be considered as the beginning of more intensive development.

We have to bear in mind that the agreement indexes of the two earliest dates of the Funnel Beaker culture (DIC-719, AA-90115, see Table 1.16–17) in separate modelling (Fig. 12) were lower than 60%. A situation of this kind can be interpreted in two ways. Either these dates are typical deviations from the norm, appearing in numerous datasets due to the laws of statistics, or they reflect the earliest episode of the presence of a given phenomenon that was isolated in time in relation to the main, continued development. Since the whole model was statistically significant, we could in theory believe that the first alternative is more likely. Regardless, a date DIC-719, approach of this kind can also be defended for another reason. It has been proposed that in the pottery from feature 5-B6 at Bronocice (with the above-mentioned date) elements of the Lengyel-Polgár complex are visible (*Kruk, Milisauskas 1983. 267, 282*). If this is the case, it is possible even to accept the idea that the date should not be bound to the TRB at all.

On the other hand, in the combined modelling, the agreement indexes of these two dates were higher than 60%, so we can say that the pattern of quantitatively modest and conspicuously early beginnings was tested successfully. Therefore, it should be recognised that dates earlier than 4900 cal BP in posteriori version are close to reality (Fig. 20). In this case, the first Funnel Beaker culture occupation probably began around 3750 cal BC, due to the uncertainty of the date DIC-719.

The widest time interval for the Wyciąże/Niedźwiedź materials is 3630–2860 cal BC, the 'probable' interval is 3570–3040 cal BC, and the 'median' based interval gives 3440–3140 cal BC. It is not possible to calculate the narrowest interval. There are no bigger differences in the case of the group A modelling, whereas the start is placed 200/300 years earlier in the group B modelling. Differences appear with separate modelling, which are particularly visible in the group B modelling (over 100 years).

The Baden culture turned out to be delimited similarly in all models. We obtained 3130–2790/2780 cal BC in the widest versions, 3110/3100–2810 cal BC in 'probable' versions, 3000/2980–2870 cal BC in the narrowest versions, and 3070/3060–2830 cal BC in 'median' versions. The differences between separate models are negligible.

The models for the Beaker/Baden assemblages give the widest intervals, of 3340–2770/2690 cal BC, the 'probable' interval of 3330–2850/2750 cal BC, and the narrowest of 3280/3270–2880/2870 cal BC (for all dates and group B). The 'median' interval covers a period of 3310–3030/2790 cal BC, *i.e.* there is a significant difference as to the upper limit. We observe differences with separate modelling up to over one hundred years.

The possible dates of the beginning of Corded Ware culture are: 2740/2670, 2700/2620, 2590/2500 and 2660/2570 cal BC (Tab. 2). Except the values for the widest interval and all dates (2800 cal BC), they are quite similar to those modelled separately.

A summary of this modelling again gives rise to two basic interpretations of the type analogous to the separate modelling (Fig. 21).

Firstly, we can accept the whole period or most of the period generated by modelling procedures. In this case, archaeological units mesh together in time to a greater or lesser extent, but generally two concentrations of coeval units can be noticed. The Wyciąże-Złotniki group would appear at *c.* 4400 cal BC, and would coexist with the Lublin-Volhynian culture from *c.* 4300/4000 BC to *c.* 3250 cal BC. The latter unit would exist longer, until the 31st century BC. The Funnel Beaker culture would appear to a small extent between 4350 and 4100 cal BC, but would develop substantially from *c.* 3750 to 3250 cal BC. In the period *c.* 3900/3800–3250 cal BC we could postulate the co-existence of even four units, because Wyciąże/Niedźwiedź materials would join the remaining ones. The latter unit would exist until *c.* 2900/2800 cal BC.

At around 3350/3300 cal BC, the Beaker/Baden assemblages would appear, *i.e.* it would briefly coexist with the Funnel Beaker culture and Wyciąże-Złotniki group (approx. 100 years) and – for a longer time – with the Lublin-Volhynian culture and Wyciąże/Niedźwiedź materials. On the other hand, from *c.* 3150/3100 to 2800/2750 cal BC, Beaker/Baden assemblages would develop simultaneously with the Baden culture. The overlapping of the Beaker/Baden assemblages and Corded Ware culture would be limited only to the second half of the 28th century BC, but it could not have happened at all. If we accepted the long duration of the Lublin-Volhynian culture and Wyciąże/Niedźwiedź materials, to 3100/3000 and 2850 cal BC respectively, both these units would partially overlap with the Baden culture and Beaker/Baden assemblages.

Secondly, we could again take into account only short segments, 'hard cores', as it were, situated within the widest intervals, and reject their remaining parts. In such a case, archaeological units would be separated more distinctly than in the previous interpretation, and be arranged roughly into four groups consisting mostly of partly contemporary units. These four groupings would be arranged linearly, but there would be even breaks in the continuity of cultural development.

One group would consist of the Wyciąże-Złotniki group and Lublin-Volhynian culture. The former would appear at about 4200/4100 cal BC, and the latter only in the 38th century BC. The end of both units should be placed at *c.* 3550 cal BC.

The Funnel Beaker culture would come into existence at *c.* 3750 cal BC, it would exist simultaneously with previous units for no more than 200 years. The fundamental development of this culture would start at *c.* 3500 cal BC and would last until *c.* 3300 cal BC. Because there is only one ^{14}C date connected with phase BR I, the question of pos-

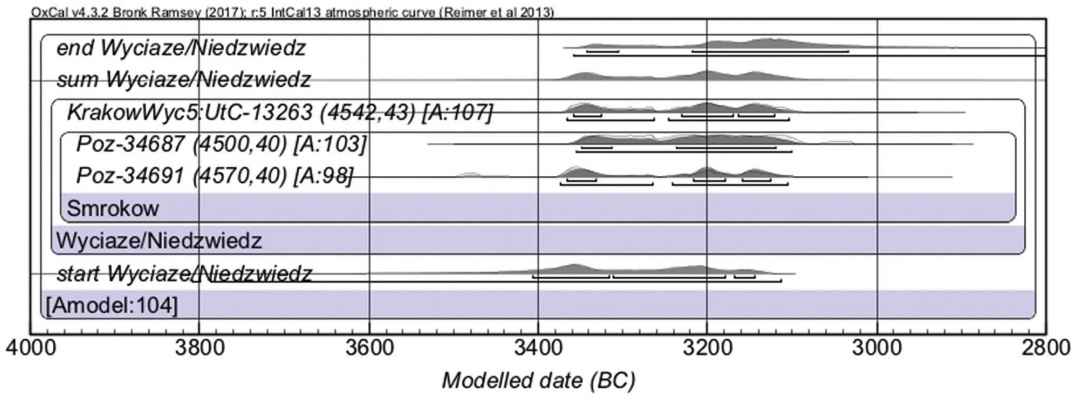

Fig. 14. Radiocarbon chronology (cal BC) of the Wyciąże/Niedźwiedź materials.

sible the earlier appearance of the Funnel Beaker culture should be considered as rather doubtful, because stratigraphic anteriority to the Lublin-Volhynian culture could mean nothing more than anteriority to the end of this culture, *c.* 3600/3550 cal BC.

The third group would comprise the Beaker/Baden assemblages and Baden culture, and would be dated to *c.* 3300–2850/2800 cal BC and *c.* 3050–2850 cal BC, respectively. The Wyciąże/Niedźwiedź materials would be placed between 3400 and 3150 cal BC, or rather somewhere within these borders.

A hiatus could be postulated between the Beaker/Baden assemblages and Baden culture on the one hand, and the fourth group, *i.e.* the Corded Ware culture, on the other, *c.* 2800–2650/2600 cal BC.

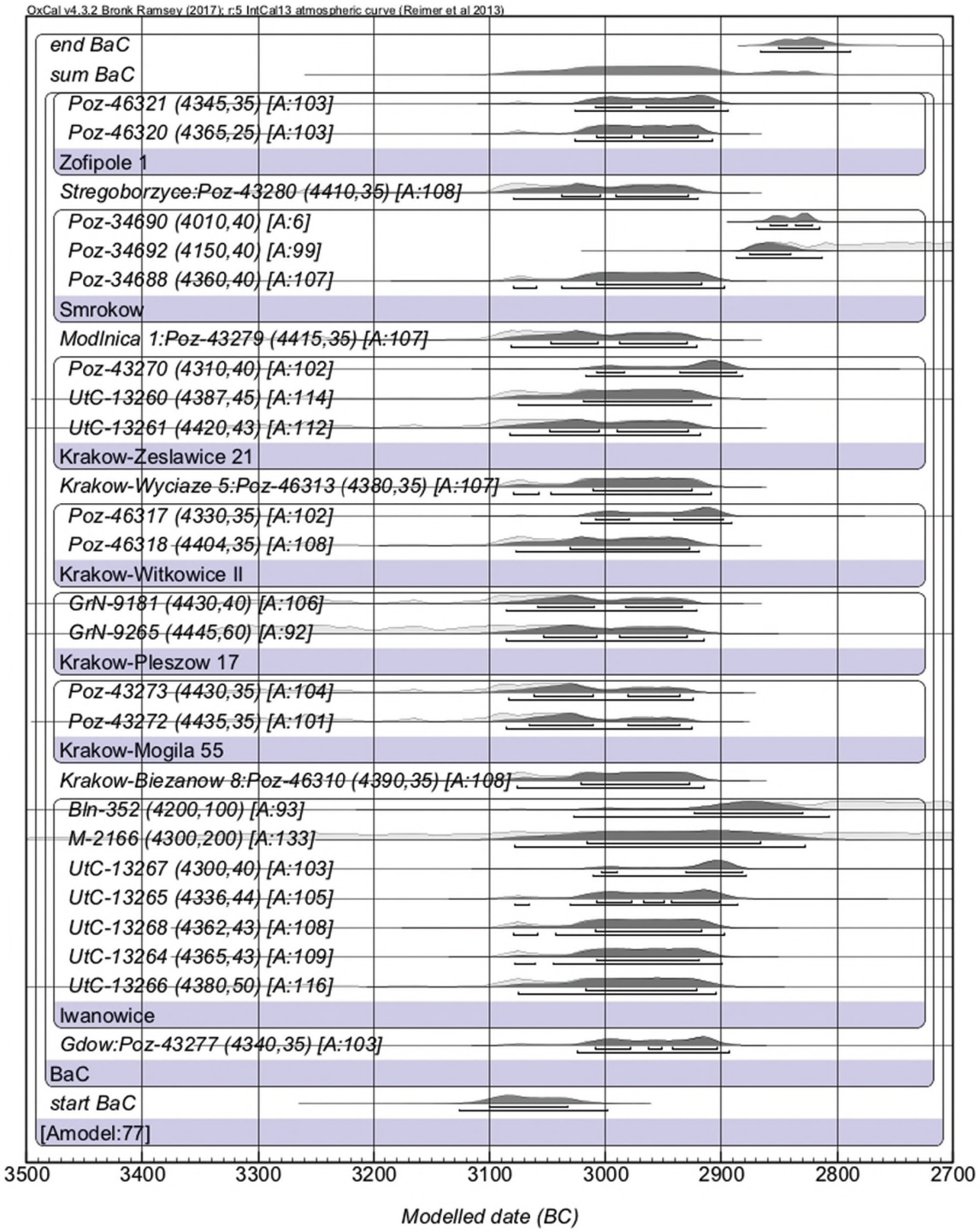

Fig. 15. Radiocarbon chronology (cal BC) of the Baden culture (BaC).

Discussion

While assessing which of the alternative chronological scenarios may be more akin to past reality, we should first highlight some observations and premises.

Firstly, it is very easy to notice that we are dealing with very broad chronological ranges only in the cases of those units which still have a relatively low number of dates (Lublin-Volhynian culture, Wyciąże-Złotniki group, Wyciąże/Niedźwiedź materials). On the other hand, the Funnel Beaker culture, Baden culture, Beaker/Baden assemblages and Corded Ware culture, where this is not the case, give much shorter, compact ranges. In these cultures, a good compromise seems to be values close to the 'probable' and median ones.

Secondly, it is worth noting that, while we are handling large datasets (in our case: radiocarbon dates) extreme values will almost always occur for various reasons (see Introduction). Certainly, Bayesian modelling considerably reduces this, but we cannot be sure that it does so completely.

Thirdly, we must remember that the above summaries of the direct dating, separate modelling and combined modelling are of a generalised and extreme nature. In fact, in every single case, we should take into account the specificity of local conditions. Consequently, one can also imagine some combinations of these two extremes. Thus, some units and phenomena would be limited only to 'hard cores' indeed, but some would not. In other words, in some cases, a discrete mode of cultural transformation should be

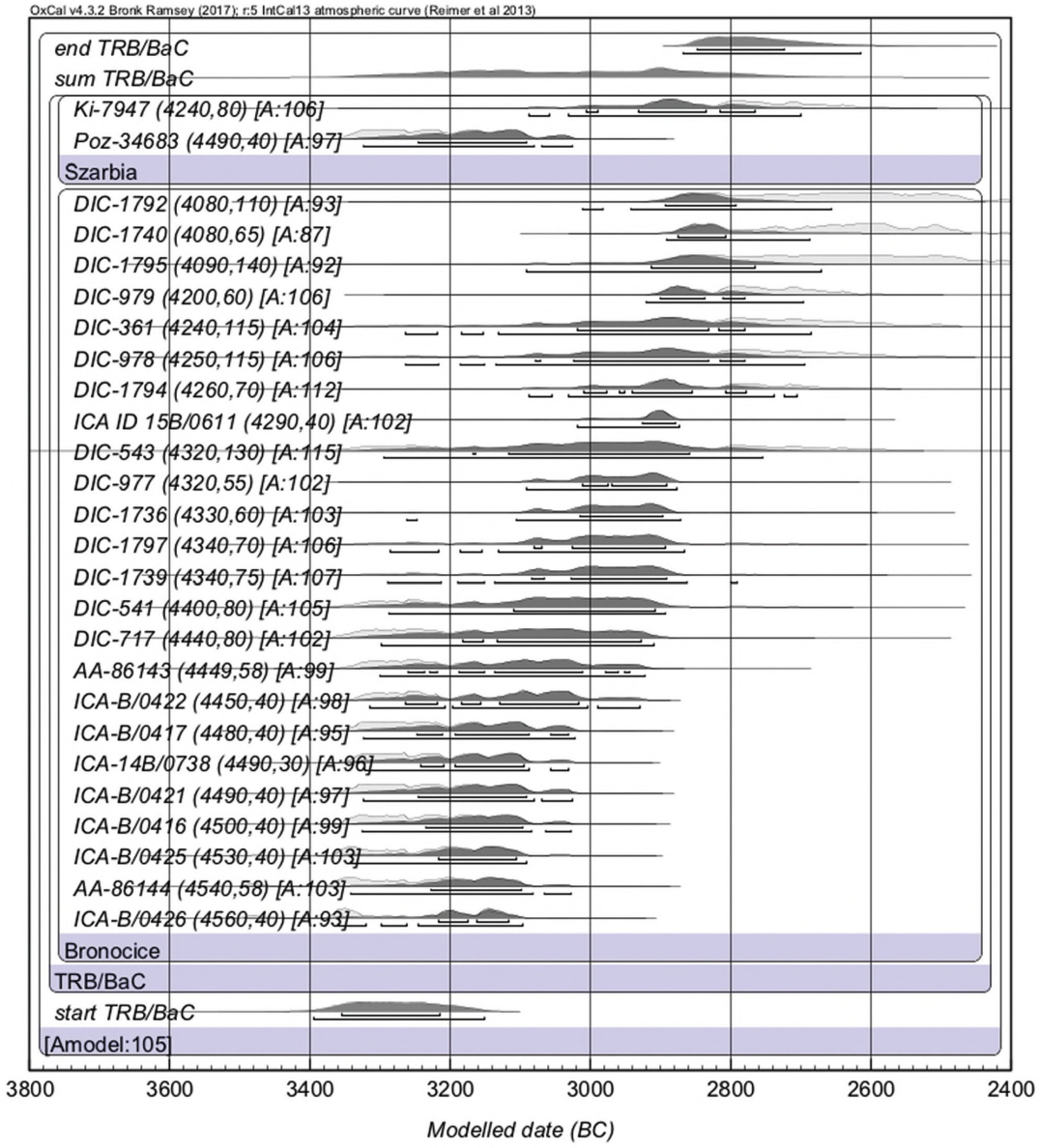

Fig. 16. Radiocarbon chronology (cal BC) of the Beaker-Baden assemblages (TRB/BaC).

Archaeological units and categories of ^{14}C dates (their amounts)	Interval based on medians	The widest interval	The 'probable' interval	The narrowest interval
Funnel Beaker culture, phase BR I; 1 date	3960–3810	4340–3690	4070–3720	–
Lublin-Volhynia culture; all dates (4)	3810–3470	3990–3100	3870–3360	3690–3630
Lublin-Volhynia culture; dates of group B (3)	3910–3410	4300–2940	4010–3300	3700–3630
Lublin-Volhynia culture; dates of group A (3)	3800–3470	4020–3040	3870–3360	3660–3630
Wyciąże-Złotniki group; all dates (11)	4290–3440	4460–3270	4370–3340	4110–3630
Wyciąże-Złotniki group; dates of group B (6)	4240–3630	4450–3280	4330–3560	4070–3900
Funnel Beaker culture; all dates (58)	3480–3310	3530–3280	3510–3300	3440–3340
Funnel Beaker culture; dates of group B (47)	3480–3310	3530–3270	3500–3290	3430–3340
Funnel Beaker culture; dates of group B (34)	3490–3310	3550–3270	3510–3290	3490–3340
Wyciąże/Niedźwiedź materials; all dates (3)	3440–3140	3630–2860	3570–3040	–
Wyciąże/Niedźwiedź materials; dates of group B (3)	3630–3120	3900–2820	3860–2990	–
Wyciąże/Niedźwiedź materials; dates of group A (3)	3320–3140	3630–2890	3410–3040	–
Baden culture; all dates (26)	3070–2830	3130–2780	3110–2810	2990–2870
Baden culture; dates of group B (24)	3070–2830	3130–2790	3110–2810	3000–2870
Baden culture; dates of group A (19)	3060–2830	3130–2780	3100–2810	2980–2870
Funnel Beaker/Baden assemblages; all dates (26)	3310–2790	3340–2700	3330–2750	3280–2870
Funnel Beaker/Baden assemblages; dates of group B (15)	3310–2800	3340–2690	3330–2750	3270–2880
Funnel Beaker/Baden assemblages; dates of group A (6)	3310–3030	3340–2770	3330–2850	–
Corded Ware culture; all dates (24)	2660–2330	2740–2250	2700–2280	2590–2410
Corded Ware culture; dates of group B (21)	2630–2330	2720–2250	2670–2290	2570–2420
Corded Ware culture; dates of group B (20)	2570–2350	2670–2260	2620–2300	2500–2440

– All dates: A_{model} = 64.3%, $A_{overall}$ = 64.5%; 3 dates with agreement index lower than 60%
– Modelling for dates of group B: A_{model} = 76.2%, $A_{overall}$ = 75.0%; 3 dates with agreement index lower than 60%
– Modelling for dates of group A: A_{model} = 62.1%, $A_{overall}$ = 60.1%; 5 dates with agreement index lower than 60%

Tab. 3. Results of combined modelling of ^{14}C dates of the Middle and Late Neolithic units in western Lesser Poland (cal BC; rounded by 10 years).

recommended, but in other cases continuous development should be proposed.

To these local conditions, as we already know, typological continuations between the Funnel Beaker culture and Beaker/Baden assemblages as well as between the Wyciąże-Złotniki group and Wyciąże/Niedźwiedź materials should be included. This means that these units had to come into contact, but on the other hand, they could not develop simultaneously for a long time. Besides, some stratigraphic observations suggest some contemporaneity between the Lublin-Volhynian culture/Wyciąże-Złotniki group and the Funnel Beaker culture. The remaining assumptions used in combined modelling (see above) are not local, but should of course also be taken into account.

Although these interdependencies had already been used in combined modelling, we are not concerned here with circular reasoning. The result of the combined modelling still gives quite a bit of uncertainty, which must still be interpreted with the application of the aforementioned local conditions. There are also no obstacles to taking these conditions into account in the falsification of direct dating and separate modelling.

Fourthly, reliable external data, referring to both absolute and relative chronology, should be included in our assessment.

Lastly, the shape of the relevant part of the calibration curve is also important for the final selection of timeframes of archaeological units under consideration.

External data are particularly important for the Lublin-Volhynian culture and Wyciąże-Złotniki group. Their extremely early beginnings, reaching almost the mid-5th millennium BC (Figs. 18–19), as well as late endings, reaching the early 3rd millennium BC

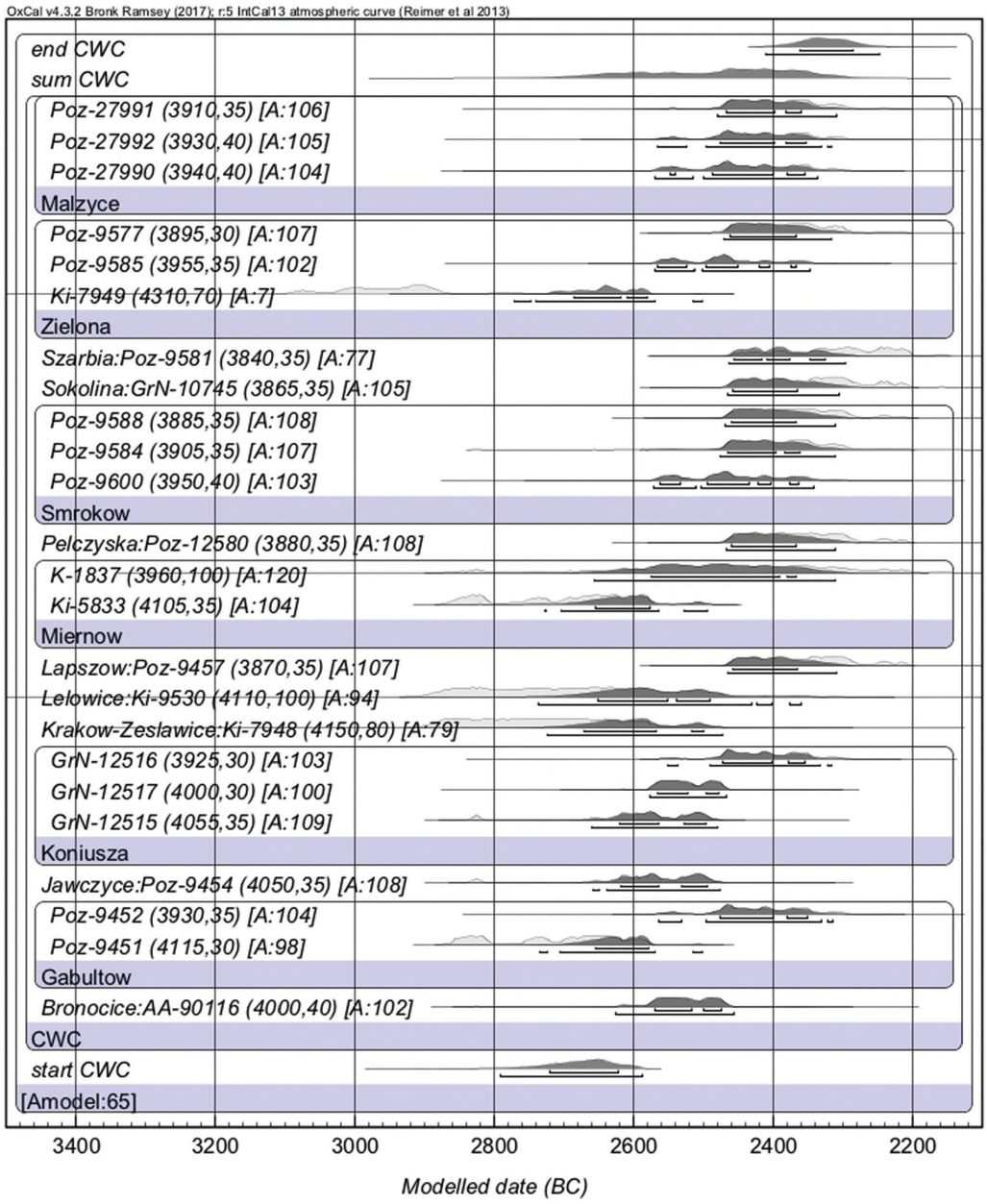

Fig. 17. Radiocarbon chronology (cal BC) of the Corded Ware culture (CWC).

in the case of the former and 3300/3200 cal BC in the case of the latter (Figs. 18, 21), are impossible to accept in light of our knowledge on chronology of the Lengyel-Polgár phenomena. For instance, in the recent assessments of the chronology of the Early and Middle Eneolithic in the Carpathian Basin (*Chmielewski 2008.72–76, 86; Nowak 2010.68–79, 82; Raczky, Siklósi 2013*), the timeframes of the Bodrogkeresztúr and Hunyadihalom cultures were placed around 4300/4200–3700 cal BC. This is of great significance, since both these cultures can be described as 'mother' units of the ceramic style of the Wyciąże-Złotniki group. Similarly, new views on the chronology of the Lublin-Volhynian culture (*Chmielewski 2008; Wilk 2014; 2016*), based on the dates from western Volhynia, Nałęczów Plateau and Sandomierz Upland, supported by new schemes from the Carpathian Basin, prove that the traditionally defined phase III of this culture (actually, this is rather pottery styles, not the phase as such) should be placed between *c.* 4200 and *c.* 3700 cal BC. Phase III is important for our subject, because Lublin-Volhynian materials from western Lesser Poland belong to it.

It seems, therefore, that the second approach proposed in the summaries of separate and combined models is more correct for units which provided fewer dates. The intervals delimited by complete ranges in both models and in direct dating should

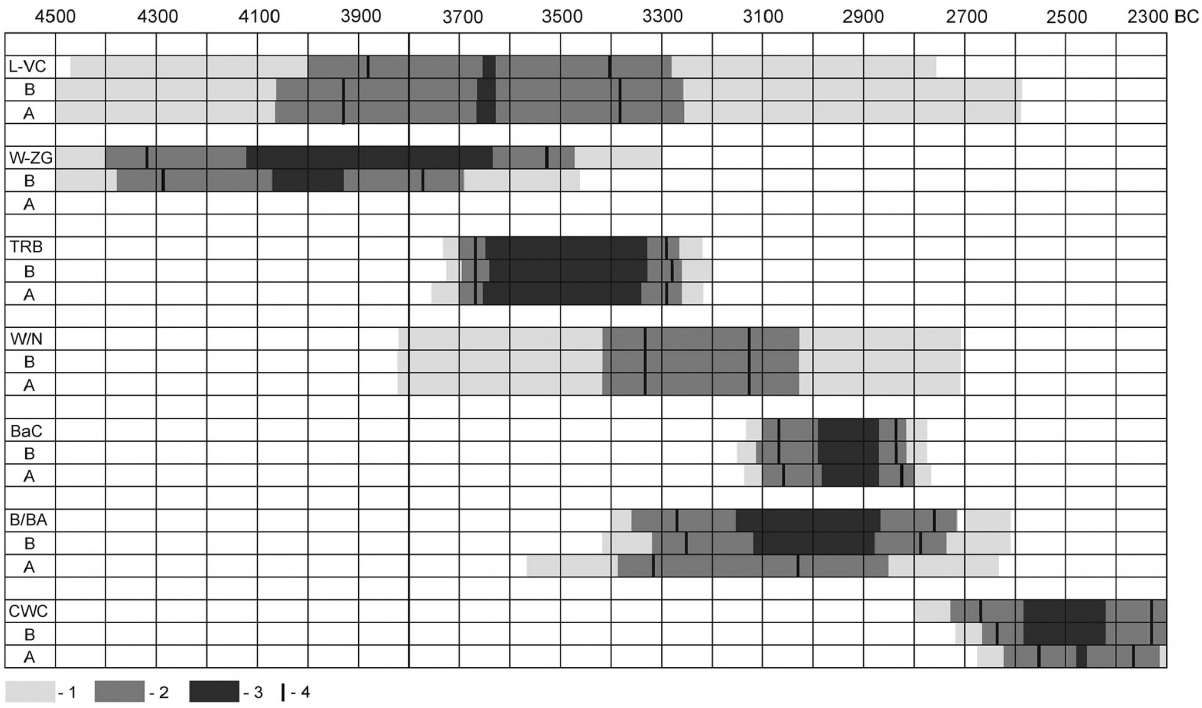

Fig. 18. Absolute chronologies (cal BC) of the Middle and Late Neolithic (Corded Ware culture) units in western Lesser Poland based on separate Bayesian modelling of all ^{14}C dates referring to these units (rows with abbreviations), of dates belonging to group B (B) and of dates belonging to group A (A); 1 the widest intervals, based on extreme points of the 95.4% ranges; 2 the 'probable' intervals, based on extreme points of the 68.2% ranges; 3 the narrowest intervals, based on the end point of the 95.4% start boundary and the starting point of the 95.4% end boundary; 4 medians. L-VC Lublin-Volhynian culture, W-ZG Wyciąże-Złotniki group, TRB Funnel Beaker culture, W/N Wyciąże/Niedźwiedź materials, BaC Baden culture, B/BA Beaker/Baden assemblages, CWC Corded Ware culture.

be considered as indicative of approximate intervals within a segment of which given units actually developed.

Therefore, we should eliminate the long 'onsets' and 'tails' of the Lublin-Volhynian culture and Wyciąże-Złotniki group. If we also take into consideration, the shape of the calibration curve between *c.* 5100 and 4900 cal BP, we can accept the idea that the Lublin-Volhynian culture appeared in western Lesser Poland between *c.* 3950 and 3700 cal BC (*c.* 3800 cal BC could be proposed as the most probable time), because some retardation of more western areas of this culture is highly probable. However, somewhat paradoxically, this does not necessarily refer to the Bronocice site. The Lublin-Volhynian settlement could have appeared later there. Due to stratigraphic relationships, we can assume that it was later than the first phase of the Funnel Beaker culture, which we finally placed around 3750/3700 cal BC (see below). Thus, the Lublin-Volhynian culture at this site can be placed around 3700–3650/3550 cal BC. Admittedly, this chronological position is later than in the schedule developed by Kruk and Milisauskas; they recently dated the Lublin-Volhynian culture at Bronocice to 3800–3700 cal BC (*Milisauskas* et al. *2016.36*). Overall, the end of this culture in western Lesser Poland should be placed within the period of *c.* 3650–3550 cal BC, due to the plateau visible in the calibration curve for 4800–4700 cal BP.

Regarding the absolute dating of the Wyciąże-Złotniki group, the series of nine new ^{14}C dates led to the transformation of previous opinions. Two 'old' dates from Złotniki and Kraków-Pleszów suggested the late chronological position, *i.e.* the first half of the 4th millennium BC, and particularly the second quarter of that millennium. It seemed even possible to extend this chronology slightly, by about 100/150 years, beyond the date of 3500 cal BC. However, new dates consequently point to an earlier period, *i.e.* at the second half of the 5th millennium and the first quarter of the 4th millennium BC. According to the results of both models (particularly the combined one), and in light of the cited external data, the start of the Wyciąże-Złotniki group should be established at between *c.* 4250 and 4050 cal BC, since a plateau of this length occurs in the calibration curve and retardation to the Tisza basin is reasonable. The value for the end would be within *c.* 3650–3550 cal

BC, at the very latest, *i.a.* some retardation of the cultural development, when compared to the Middle Eneolithic of the Tisza basin, is again acceptable. Moreover, the shape of the calibration curve plays a similar part as in the case of the end of the Lublin-Volhynian culture.

In case of the Wyciąże/Niedźwiedź materials, the very modest amount of data makes it difficult to reliably characterise this unit, including its chronology. We should again employ the above-mentioned 'segment' approach. If we assume the actual presence of Lengyel-Polgár elements there, which originated from the Wyciąże-Złotniki group (*Bober 2004; Furcholt, Machnik 2006.336, 339; Grabowska, Zastawny 2011.134–135*), as well as ther prevoiously mentioned shape of the calibrated curve, then its beginnings should be placed in the timeframes of *c.* 3650–3550 cal BC. The dating of the disappearance of these materials remains a mystery; the value of *c.* 3350–3100 BC can be proposed, based mainly on median values from both models confronted with a wide plateau for 4550–4450 cal BC. Nevertheless, it gives a surprisingly long period for quantitatively insignificant archaeological phenomena. It would mean that Lengyel-Polgár elements were still in use for 400 years even after their disappearance from the Carpathian Basin.

As regards other units, we have quite a different situation due to the larger sets of ^{14}C datings, which resulted in more compact ranges in all kinds of analyses. Therefore, it seems more probable that either the whole length of these ranges or most of them should be taken into account as the real timeframes of their existence.

As to the dawn of the Funnel Beaker culture, the combination of all analyses carried out above and the shape of the calibration curve indicate that the dates

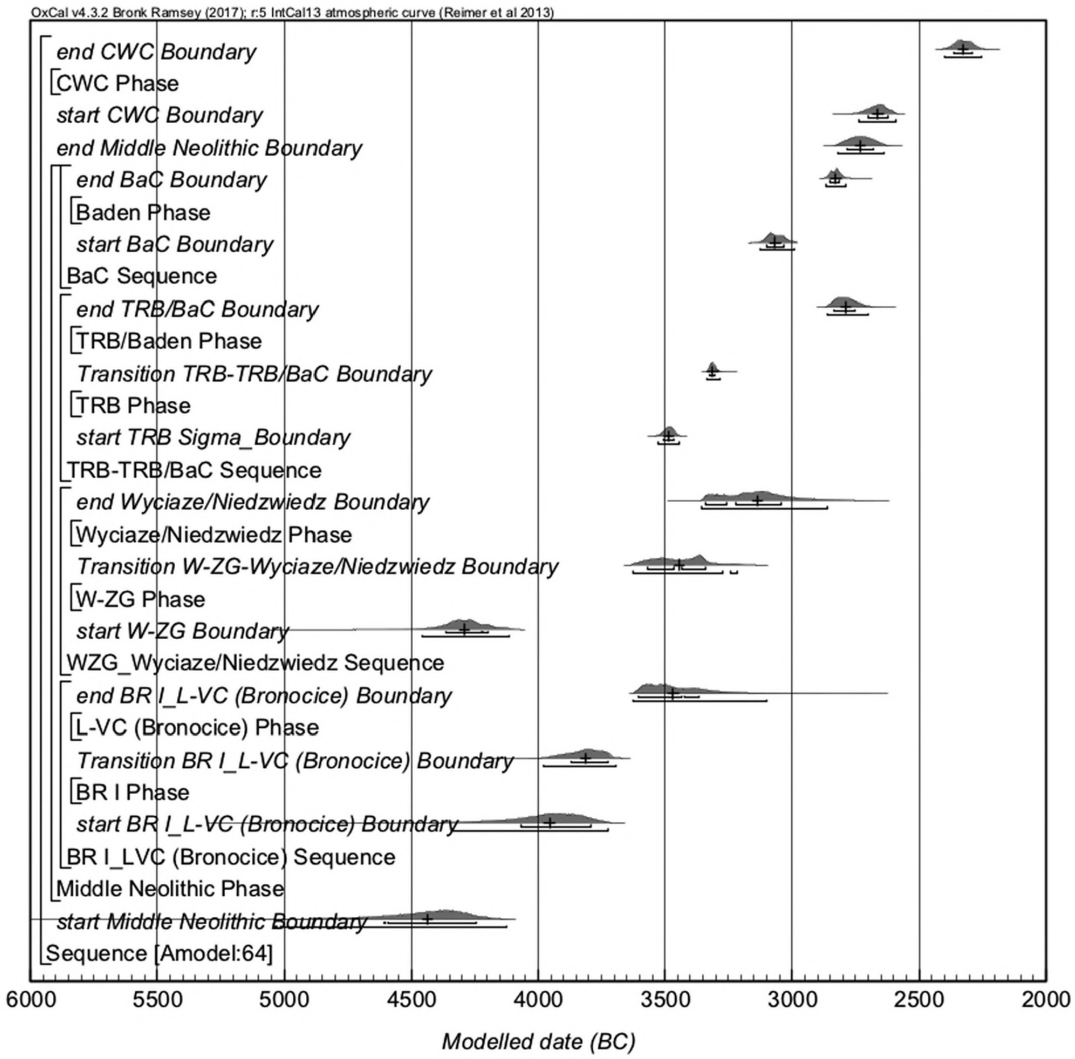

Fig. 19. Combined modelling of all ^{14}C dates of the Middle and Late Neolithic (Corded Ware culture) units in western Lesser Poland (cal BC); individual dates are not presented.

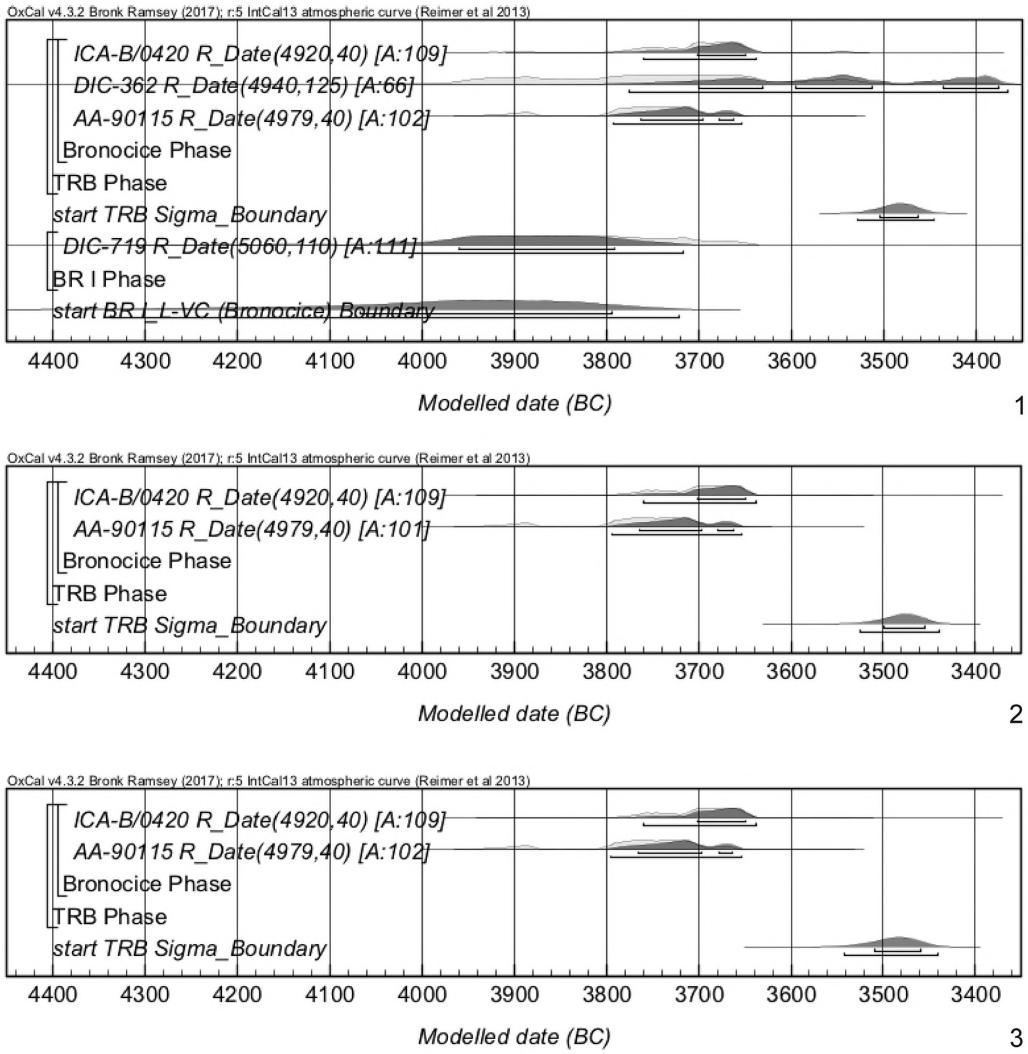

Fig. 20. Prior and posterior versions of the earliest ^{14}C dates of the Funnel Beaker culture at of Bronocice: 1 modelling of all dates; 2 modelling of group B dates; 3 modelling of group A dates. These diagrams are enlargements of segments of complete modelling diagrams; in the case of all dates, a simplified version of this is presented on Figure 19.

of *c.* 3750 and 3700 cal BC should be regarded as the most likely borders of its very beginning. The ceramic typology does not exclude this possibility (*Nowak 2009.334–336*, see further references), although this date is a bit later than the commonly suggested date of 3900/3800 cal BC (*Kruk* et al. *2016; Milisauskas* et al. *2016; Nowak 2009; Włodarczak 2006b*). However, the latter proposal was based only on single dates from 'our' area and other areas in Lesser Poland (*Nowak 2006; Rybicka 2017*) whose reliability can be challenged. The date of 3750/3700 cal BC does not contradict the above-mentioned stratigraphic relations recorded at Bronocice (see above).

The issue of the disappearance of the Funnel Beaker culture from western Lesser Poland and of the importance of the Baden influence on that process is complex. One way or another, it seems very likely that between this culture and the Beaker/Baden assemblages had to function a cultural (typological) continuity, which is well corroborated by separate and combined models. In other words, the Funnel Beaker culture proper, at least in the eastern part of the western Lesser Poland loess uplands, existed until the beginning of the Beaker/Baden assemblages. The value of 3300–3250 cal BC seems very reliable as to that transition (and remains roughly in line with the Bronocice chronology – *Kruk* et al. *2016; Milisauskas* et al. *2016*); however, we cannot exclude that the upper boundary of this interval of uncertainty should be moved up to *c.* 3100 cal BC, due to the shape of the calibration curve described in the case of the Wyciąże/Niedźwiedź materials.

The end of the Beaker/Baden can be situated at *c.* 2800 cal BC, based mainly on the values of medi-

ans obtained in both models. Taking into account the calibration curve, we could transform this date into *c.* 2850–2750 cal BC. The postulated period of *c.* 3300/3250/3100–2850/2750 cal BC roughly fits with recent dating of the BR IV and BR V phases at Bronocice (3300–2900/2800 cal BC – *Kruk* et al. *2016; Milisauskas* et al. *2016*).

The absolute dating of the Baden culture in western Lesser Poland should be delineated by a kind of average of all boundary values, which do not differ between each other very much. The high reliability of ^{14}C dating enforces such a construction. Most of these dates have been obtained recently in reliable laboratories, mainly from bones, and usually have small standard deviations (*Zastawny 2015b*). Thus, the proposed range could be *c.* 3100–2800 cal BC. The first date does not have to be changed due to the calibration curve (lack of wiggle or plateau); the second can again be stretched to *c.* 2850–2750 cal BC. Let us recall, however, that in A. Zastawny's opinion (*2015.202*), an even shorter slice of time, of *c.* 3100/3050–2900 cal BC, better reflects the Baden chronology, due to some typological constraints. Consequently, it is our belief that the range of *c.* 3100–2850 cal BC reflects the chronology of the Baden culture in the best way.

Admittedly, this is a shorter period than might be expected. Particularly surprising are the late origins of the Baden culture in Lesser Poland. However, credible dating indicates precisely this and no other situation. Also, the proposed time interval does not contradict the overall principles of typological development or current patterns of the absolute chronology of the Baden phenomena (*Horvath, Svingor 2015; Stadler* et al. *2001; Wild* et al. *2001; Zastawny 2008; 2011; 2015a*).

Such dating, especially the relatively late beginnings, convincingly confirm what we had long suspected, namely that the Baden culture proper in western Lesser Poland appeared as the effect of fast (a single wave?) migration from beyond the Carpathians. This migration was of groups coming from the developed (late classic) Baden culture. These people brought

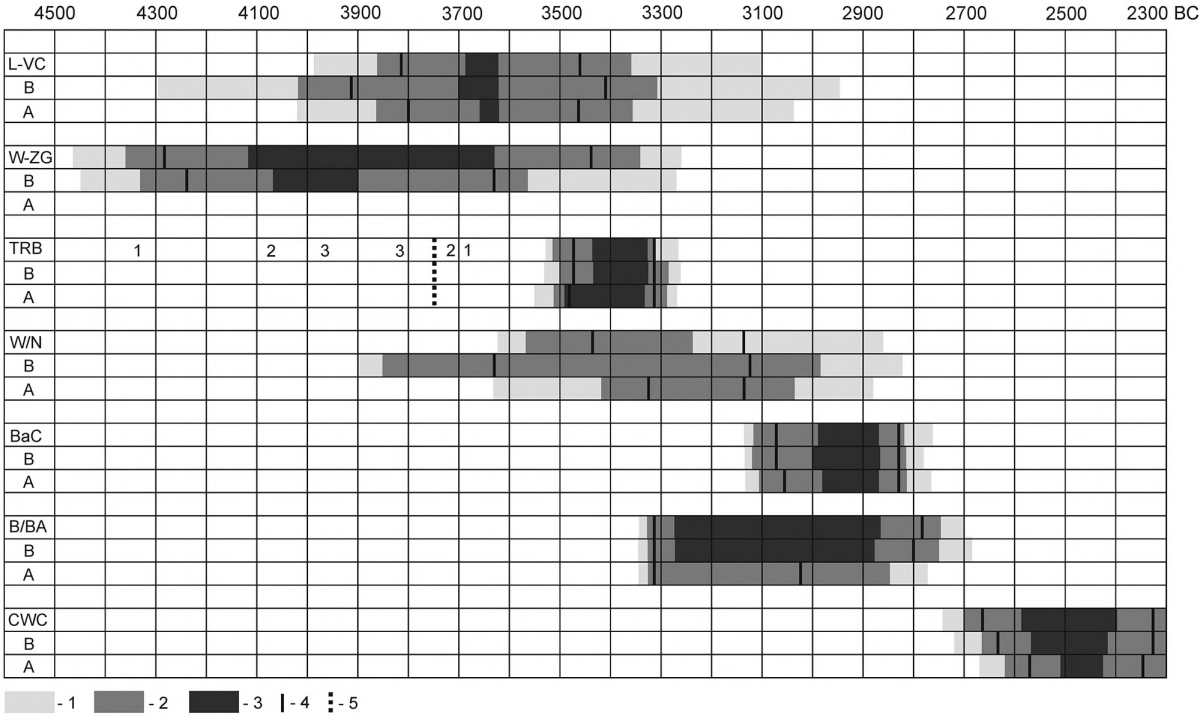

Fig. 21. Absolute chronologies (cal BC) of the Middle and Late Neolithic (Corded Ware culture) units in western Lesser Poland based on combined Bayesian modelling of all ^{14}C dates referring to these units (rows with abbreviations), of dates belonging to group B (B) and of dates belonging to group A (A); 1 the widest intervals, based on extreme points of the 95.4% ranges; 2 the 'probable' intervals, based on extreme points of the 68.2% ranges; 3 the narrowest intervals, based on the end point of the 95.4% start boundary and the starting point of the 95.4% end boundary; 4 medians; 5 evaluated beginning of the Funnel Beaker culture (see text). L-VC Lublin-Volhynian culture, W-ZG Wyciąże-Złotniki group, TRB Funnel Beaker culture (boundaries of the widest intervals (1), 'probable' intervals (2) and medians (3) of the phase BR I, based on the date DIC-719), W/N Wyciąże/Niedźwiedź materials, BaC Baden culture, B/BA Beaker/Baden assemblages, CWC Corded Ware culture.

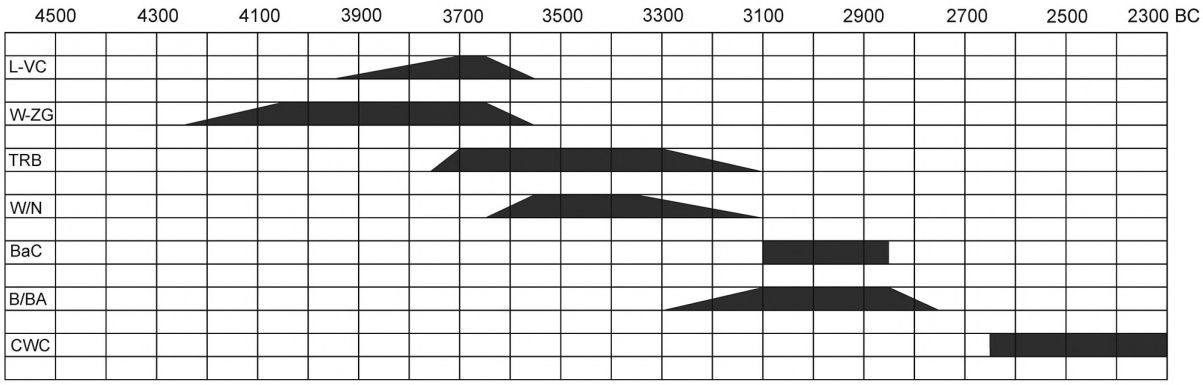

Fig. 22. The final scheme of the absolute chronology (cal BC) of the Middle and Late Neolithic (Corded Ware culture) units in western Lesser Poland.

here the model of the developed Baden culture in all its aspects. They settled in a small area within and around Kraków. Consequently, only this stage of development is represented in this area. Thus, we do not observe full cultural (typological) development, with early, developed (classic) and late phases. The cause of the sudden disappearance of Baden culture and the Beaker/Baden assemblages remains unclear. In any case, the results of analyses suggest the occurrence of a hiatus between this disappearance and the origins of the Corded Ware culture.

The possible dates of the beginnings of the Corded Ware culture, resulting from statistically significant modelling, fall within a rather broad interval between 2800 and 2500 cal BC. However, comparing the results of all analyses speaks, in our opinion, for the date of *c.* 2650 cal BC. We are aware that this date seems to be rather late when referring to general views on development of this unit in central Europe, including western Lesser Poland, which usually point to *c.* 2800 cal BC (*Włodarczak 2006a*). We are also aware that the calibration curve makes it possible to alternatively refer several dates earlier than *c.* 3100 to *c.* 2850–2800 cal BC. Nevertheless, we think that the presented results of separate and combined modelling allow us to evaluate the probability of such an option as lower than the probability of the 'later' option. This problem must be analysed in depth in the future.

Conclusions

The final, modelled scheme of the absolute chronology of the discussed archaeological units in the area under consideration is illustrated on Figure 22. This is the result of analyses which included radiocarbon, typological and contextual facts and their interpretations, as well as more or less arbitrary chronological constructions based on these facts and interpretations and on general knowledge, including the parameters of the calibration curve. It should be emphasised that this graph shows the chronology itself, not the dynamics of cultural processes. In other words, the rising and falling segments of bars reflect intervals of uncertainty in dating the beginning and end of a given unit. These bars do not necessarily mirror the 'birth', 'heyday' and 'decline' of the analysed phenomena.

This scheme unambiguously suggests both the overlapping and contiguous nature of cultural development in western Lesser Poland within the Middle Neolithic. The basic elements of this development are: 1) the Wyciąże-Złotniki group and the Lublin-Volhynian culture, until *c.* 3650–3550 cal BC; 2) the Funnel Beaker culture proper, which appeared *c.* 3750–3700c al BC, and existed until *c.* 3300–3250 cal BC, perhaps accompanied by the Wyciąże/Niedźwiedź materials from *c.* 3650–3550 cal BC; and 3) the Baden culture and the Funnel Beaker/Baden assemblages from 3100 and 3300–3100 cal BC, respectively, until 2850–2750 and 2850 cal BC, with – possibly – later Funnel Beaker culture and Wyciąże/Niedźwiedź materials, existing until *c.* 3100 cal BC.

There is an explicit suggestion in the final scheme that in some cases a discrete (radical) mode of cultural transformation could be proposed; and in other cases, continuous development and/or simultaneous functioning can be suggested. In the author's opinion, this arrangement (particularly the discrete one) means that some archaeological units (perhaps Baden culture and Corded Ware culture) should be considered as reflections of real units of a cultural, population, or even political nature, which were discernible to prehistoric people.

The final scheme shows that the Lublin-Volhynian culture could have coincided with the Wyciąże-Złot-

niki group. In view of the territorial relationship between them, relations from the point of view of material culture, primarily in the field of pottery, become particularly interesting. It is relatively easy to see clear similarities between these units. However, the most evident similarities apply only to some categories of ceramics, including, for example, vessels with Scheibenhenkel handles. What is more, in the period between the late 38th and early 36th centuries BC, the early Funnel Beaker and possibly early Baden influences are superimposed on this Lublin-Volhynian/Wyciąże-Złotniki 'mix'.

The lack of any Funnel Beaker elements in materials of the Baden culture proper is particularly pregnant with meaning. This directly suggests that the Funnel Beaker communities in the western part of the area under consideration could have been expelled or exterminated. A fairly sharp geographical boundary between areas of the Baden culture and Beaker/Baden assemblages (Fig. 1) (see *Zastawny 2008.Fig. 2*; but *cf.* a somewhat different opinion in *Włodarczak 2008b.252*) could also support an interpretation of this kind. As a result, as already mentioned, one can postulate that a substantial migration of Baden people from the south-west took place at about 3100 cal BC.

With reference to the next fundamental cultural change, *i.e.* the appearance of the Corded Ware culture, which we use only as a kind chronological frame, we should emphasise that currently it also is difficult to point to any common or transient characteristics in the pottery of the Funnel Beaker culture, Beaker/Baden assemblages and Corded Ware culture, not to mention the Baden culture (*Włodarczak 2008b.253; 2010.208, 210; 2011.215–220*), contrary to earlier hypotheses (*Machnik 1966.123; Włodarczak 2006a.90–95, 103, 105; Zastawny 2001*). As a kind of summary of this issue, we can quote the opinion by P. Włodarczak, according to which "*a short period of co-existence between the two groups is possible (*c. *2850–2700 BC), although not very likely*" (*Włodarczak 2008b.253*). Altogether, we take a the liberty to express the (unfashionable) view that processes connected with the disappearance of the Beaker/Baden and Baden groups and with appearance of Corded Ware groups were primarily historical (political?) processes.

"*All models are wrong, some models are useful*", as George Box says (*Box 1979.202* – after *Bayliss* et al. *2007*). Hopefully, the final model is useful for many issues, despite some controversial points. Particularly, the precise chronology of the Baden culture, and more precise chronology of the Funnel Beaker culture, Beaker/Baden assemblages, and of the beginning of Corded Ware culture should be highlighted. It is impossible to say this about the remaining units, but the proposed chronological limits can be useful for current knowledge and constitute a good starting point for further analyses and studies.

This scheme, of course, will be more or less changed if new radiocarbon and other data appear. A very recent, extremely surprising discovery of the spectacular collective grave of the Globular Amphorae culture in Koszyce (approx. 30km NE of Kraków) which is dated to *c.* 2900–2600 cal BC (*Przybyła* et al. *2013*) clearly proves that in western Lesser Poland many processes and events happened in the Neolithic period, about which we have so far not acquired any knowledge and which were not even expected.

Obviously, the question posed in the title of this contribution should be answered negatively. Radiocarbon dates as such usually do not determine the actual absolute chronology of a given phenomena. They must pass a rigorous contextual analysis and modelling in combination with other dates, whereby we might be able to come closer to past reality. Extreme approaches in which we either approve only those dates which fit into our concepts or accept without any reservations almost all dates are incorrect.

ACKNOWLEDGEMENTS

This work, particularly radiocarbon dating of the site at Mozgawa, was supported by grants of the National Science Centre of Poland: 2013/11/B/HS3/03822 and 2013/10/M/HS3/00537. My thanks go to the Heads of these projects: Magdalena Moskal-del Hoyo and Aldona Mueller-Bieniek.

References

Allentoft M. E. and 64 co-authors. 2015. Population genomics of Bronze Age Eurasia. *Nature 522: 167–172*. doi: 10.1038/nature14507

Baczyńska B. 2000. Obiekt gospodarczy kultury badeńskiej odkryty z pełnym wyposażeniem w Szarbii Zwierzynieckiej, gm. Skalbmierz. *Sprawozdania Archeologiczne 52: 113–129*.

Bayliss A. 2015. Quality in Bayesian chronological models in archaeology. *World Archaeology 47(4): 677–700*.

Bayliss A., Bronk Ramsey Ch., van der Plicht J. and Whittle A. 2007. Bradshaw and Bayes: towards a timetable for the Neolithic. *Cambridge Archaeological Journal 17(S1): 1–28*.

Bober J. 2004. Nowe materiały tzw. grupy Wyciąże-Książnice z Krakowa Ruszczy (stan. 128). *Materiały Archeologiczne Nowej Huty 24: 147–149*.

Box G. E. P. 1979. Robustness in scientific model building. In R. L. Launer, G. N. Wilkinson (eds.), *Robustness in Statistics*. Academic Press. New York: 201–236.

Bronk Ramsey Ch. 2009a. Bayesian analysis of radiocarbon dates. *Radiocarbon 51(1): 337–360*.

2009b. Dealing with outliers and offsets in radiocarbon dating. *Radiocarbon 51(3): 1023–1045*.

online. https://c14.arch.ox.ac.uk/oxcal/OxCal.html

Budziszewski J., Tunia K. 2000. A grave of the Corded Ware culture arrowheads producer in Koniusza, Southern Poland, revisited. In S. Kadrow (ed.), *A Turning of Ages. Jubilee Book Dedicated to Professor Jan Machnik on His 70th Anniversary*. Institute of Archaeology and Ethnology Polish Academy of Sciences. Kraków: 101–135.

Burchard B. 1973. Ze studiów nad chronologią kultury pucharów lejkowatych w zachodniej części Małopolski. In J. Machnik (ed.), *Z badań nad neolitem i wczesną epoką brązu w Małopolsce*. Ossolineum. Wrocław: 107–120.

1977. Wyniki badań wykopaliskowych na stan. 1 w Niedźwiedziu, gm. Słomniki, woj. Kraków, w latach 1965–1973. *Sprawozdania Archeologiczne 29: 59–81*.

Childe V. G. 1929. *The Danube in Prehistory*. Clarendon Press. Oxford.

Chmielewski T. 2008, Uwagi o chronologii względnej i absolutnej wczesnego i środkowego eneolitu na obszarze Polski południowo-wschodniej i zachodniej Ukrainy. *Przegląd Archeologiczny 56: 41–100*.

Crane H. R., Griffin J. B. 1970. University of Michigan radiocarbon dates XIII. *Radiocarbon 12: 161–180*.

Domboróczki L. 2009. Settlement structures of the Alföld Linear Pottery Culture (ALPC) in Heves County (northeastern Hungary): development models and historical reconstructions on micro, meso and macro levels. In J. K. Kozłowski (ed.), *Interactions Between Different Models of Neolithisation North of the Central European Agro-Ecological Barrier*. Polish Academy of Arts and Sciences. Kraków: 75–127.

Dzieduszycka-Machnikowa A. 1966. Wyniki badań osady kultury lendzielskiej na stanowisku w Złotnikach, pow. Proszowice, w roku 1964. *Sprawozdania Archeologiczne 18: 19–29*.

Furholt M., Machnik J. 2006. Iwanowice Babia Góra and the settlements with Baden ceramics in Little Poland. Questions concerning their duration. *Sprawozdania Archeologiczne 58: 325–354*.

Godłowska M. 1979. Plemiona kultury ceramiki promienistej. In W. Hensel, T. Wiślański (eds.), *Prahistoria Ziem Polskich, vol. II: Neolit*. Ossolineum. Wrocław: 301–318.

Godłowska M., Gluza I. 1989. Zespoły datowane metodą ^{14}C. Radial Ware Culture. Cracow-Nowa Huta-Pleszów. *Przegląd Archeologiczny 36: 251–254*.

Godłowska M., Kozłowski J. K., Starkel L. and Wasylikowa K. 1987. Neolithic settlement at Pleszów and changes in the natural environment in the Vistula valley. *Przegląd Archeologiczny 34: 133–159*.

Grabowska B., Zastawny A. 2011. Materiały kręgu lendzielsko-polgarskiego ze st. 5 w Modlnicy, pow. krakowski. In J. Kruk, A. Zastawny (eds.), *Modlnica, st. 5: Od neolitu środkowego do wczesnej epoki brązu*. Krakowski Zespół do Badań Autostrad. Kraków: 95–172.

Haak W. and 38 co-authors. 2015. Massive migration from the steppe was a source for Indo-European languages in Europe. *Nature 522: 207–211*. doi:10.1038/nature14317

Horváth T., Svingor É. 2105, The spatial and chronological distribution of the so-called "Baden Culture". In M. Nowak, A. Zastawny (eds.), *The Baden Culture Around the Western Carpathians*. Krakowski Zespół do Badań Autostrad. Kraków: 19–74.

Jarosz P., Tunia K. and Włodarczak P. 2009. Burial mound No. 2 in Malżyce, the district of Kazimierza Wielka. *Sprawozdania Archeologiczne 61: 175–231*.

Jarosz P., Szczepanek A. and Włodarczak P. 2013. Tomb no. 1 at Malżyce, site 31 (distr. Kazimierza Wielka) and the megalithic Funnel Beaker cemeteries in the loess region of western Małopolska. *Sprawozdania Archeologiczne 65: 293–309.*

Jarosz P., Włodarczak P. 2007. Chronologia bezwzględna kultury ceramiki sznurowej w Polsce południowo-wschodniej oraz na Ukrainie. *Przegląd Archeologiczny 55: 71–108.*

Juras A., Chyleński M., Krenz-Niedbała M., Malmström H., Ehler E., Pospieszny Ł., Łukasik S., Bednarczyk J., Piontek J., Jakobsson M. and Dabert M. 2017. Investigating kinship of Neolithic post-LBK human remains from Krusza Zamkowa, Poland using ancient DNA. *Forensic Science International: Genetics 26: 30–39.* doi: 10.1016/j.fsigen.2016.10.008

Kabaciński J., Hartz S., Raemaekers D. C. M. and Terberger T. (eds.) 2015. *The Dąbki Site in Pomerania and the Neolithisation of the North European Lowlands (c. 5000–3000 cal BC).* Archäologie und Geschichte im Ostseeraum/Archaeology and History of the Baltic 8. Marie Leidorf. Rahden/Westf.

Kaczanowska M. 1976. Pozycja stratygraficzna materiałów kultury pucharów lejkowatych na stanowisku Mogiła 62 w Nowej Hucie. *Sprawozdania Archeologiczne 28: 89–99.*

Kadrow S., Zakościelna A. 2000. An outline of the evolution of Danubian cultures in Małopolska and western Ukraine. *Baltic-Pontic Studies 9: 187–255.*

Kamieńska J., Kozłowski J. K. 1990. *Entwickung und Gliederung der Lengyel- und Polgar-Kulturgruppen in Polen.* Państwowe Wydawnictwo Naukowe. Warszawa-Kraków.

Kozłowski J. K. 1971. Niektóre aspekty genezy kultury ceramiki promienistej w Polsce. *Światowit 32: 27–60.*

1989a. Grupy kulturowe z lendzielską ceramiką niemalowaną i jednostki powstałe na podłożu wpływów późnopolgarskich. In J. Kmieciński (ed.), *Pradzieje Ziem Polskich, Vol. I, Part 1, Epoka kamienia.* Państwowe Wydawnictwo Naukowe. Warszawa-Łódź: 180–202.

1989b. Kultura ceramiki promienistej (badeńska). In J. Kmieciński (ed.), *Pradzieje Ziem Polskich, Vol. I, Part 1, Epoka kamienia.* Państwowe Wydawnictwo Naukowe. Warszawa-Łódź: 203–216.

Kruk J. 1980. *Gospodarka w Polsce południowo-wschodniej w V-III tysiącleciu p.n.e.* Ossolineum. Wrocław.

Kruk J., Lityńska-Zając M. and Milisauskas S. 2016. *Gospodarka roślinna w neolicie. Studium przypadku / Neolithic plant cultivation at Bronocice.* Institute of Archaeology and Ethnology, Polish Academy of Sciences. Kraków.

Kruk J., Milisauskas S. 1983. Chronologia absolutna osadnictwa neolitycznego z Bronocic, woj. kieleckie. *Archeologia Polski 28: 257–320.*

1985. *Bronocice. Osiedle obronne ludności kultury lubelsko-wołyńskiej (2800–2700 lat p.n.e.).* Ossolineum. Wrocław.

1990. Radiocarbon dating of Neolithic assemblages from Bronocice. *Przegląd Archeologiczny 37: 195–234.*

1999. *Rozkwit i upadek społeczeństw rolniczych neolitu.* Instytut Archeologii i Etnologii Polskiej Akadmii Nauk. Kraków.

Krus A. M., Cook R. and Hamilton D. 2015. Bayesian chronological modeling of Sunwatch, a Fort Ancient village in Dayton, Ohio. *Radiocarbon 57 (5): 965–977.* doi: 10.2458/azu_rc.57.18179

Lorkiewicz W., Płoszaj T., Jędrychowska-Dańska K., Żądzińska E., Strapagiel D., Haduch E., Szczepanek A., Grygiel R. and Witas H. W. 2015. Between the Baltic and Danubian worlds: The genetic affinities of a Middle Neolithic population from Central Poland. *PLOS ONE 10(2): e0118316.* doi:10.1371/journal.pone.0118316.

Machnik J. 1966. *Studia nad kulturą ceramiki sznurowej w Małopolsce.* Ossolineum. Wrocław.

Margielewski W., Krąpiec M., Valde-Nowak P. and Zernitskaya V. 2010. A Neolithic yew bow in the Polish Carpathians. Evidence of the impact of human activity on mountainous palaeoenvironment from the Kamiennik landslide peat bog. *Catena 80: 141–153.*

Marsh E. J., Kidd R., Ogburn D. and Durán V. 2017. Dating the expansion of the Inca empire: Bayesian models from Ecuador and Argentina. *Radiocarbon 59(1): 117–140.* doi:10.1017/RDC.2016.118

Milisauskas S., Kruk J. 1984. Settlement organization and the appearance of low level hierarchical societies during the Neolithic in the Bronocice microregion, southeastern Poland. *Germania 62: 1–30.*

1989. Economy, migration, settlement organization, and warfare during the Late Neolithic in southeastern Poland. *Germania 67: 77–96.*

Milisauskas S., Kruk J., Pipes M-L. and Haduch E. 2016. *Neolithic Human Burials Practices. The Interpretation*

of Funerary Behaviors at Bronocice. Institute of Archaeology and Ethnology, Polish Academy of Sciences. Kraków.

Müller J. 2002. Zur belegungsabfolge des Gräberfeldes von Trebur: Argumente der typologieunabhängigen Datierungen. *Journal of Neolithic Archaeology (JungsteinSite)*. http://www.jna.uni-kiel.de/index.php/jna/article/view/79/80

Nowak M. 2006. Results of the 1999 archaeological excavations at Gnojno, site 4, district of Busko-Zdrój, Świętokrzyskie voivodeship. *Recherches Archeologiques de 1999–2003: 39–54*.

2009. *Drugi etap neolityzacji ziem polskich*. Instytut Archeologii Uniwersytetu Jagiellońskiego. Kraków.

2010. Późna faza cyklu lendzielsko-polgarskiego w zachodniej Małopolsce w świetle wyników badań wykopaliskowych w Podłężu, stanowisko 17 (powiat wielicki). *Śląskie Sprawozdania Archeologiczne 52: 49–90*.

2014. Późny etap rozwoju cyklu lendzielsko-polgarskiego w zachodniej Małopolsce. In K. Czarniak, J. Kolenda and M. Markiewicz (eds.), *Szkice neolityczne. Księga poświęcona pamięci prof. dr hab. Anny Kulczyckiej-Leciejewiczowej*. Instytut Archeologii i Etnologii Polskiej Akademii Nauk. Wrocław: 239–284.

Nowak M., Dziegielewski K. and Szczerba R. 2007. Late Lengyel-Polgár in Western Little Poland reflected by excavations in Podłęże near Kraków. In J. K. Kozłowski, P. Raczky (eds.), *The Lengyel, Polgár and Related Cultures in the Middle/Late Neolithic in Central Europe*. Polish Academy of Sciences and Arts. Kraków: 449–470.

Przybyła M. M., Szczepanek A. and Włodarczak P. (eds.) 2013. *Koszyce, stanowisko 3: Przemoc i rytuał u schyłku neolitu / Koszyce, site 3: Violence and Ritual at the End of the Neolithic*. "Stater" Association of Field Archaeologists & Profil-Archeo Publishing House and Archaeological Studio. Kraków-Pękowice.

Przybyła M. M., Tunia K. 2013. Investigations in 2012 of the southern part of the Funnel Beaker culture temenos at Słonowice near the Małoszówka river. Fourth report. In S. Kadrow, P. Włodarczak (eds.), *Environment and Subsistence – Forty Years After Janusz Kruk's "Settlement studies..."*. Studien zur Archäologie in Ostmitteleuropa / Studia nad Pradziejami Europy środkowej 11. Institute of Archaeology Rzeszów University, Rudolf Habelt. Rzeszów, Bonn: 139–162.

Raczky P., Siklósi Zs. 2013. Reconsideration of the Copper Age chronology of the eastern Carpathian Basin: a Bayesian approach. *Antiquity 87: 555–573*.

Reimer P. J. and 25 co-authors. 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon 55: 1869–1887*. doi: org/10.2458/azu_js_rc.55.16947

Rodak T. 2011. Chronologia bezwzględna grobu kultury ceramiki sznurowej ze stanowiska 4 w Lelowicach, pow. proszowicki, woj. Małopolskie. In H. Kowalewska-Marszałek, P. Włodarczak (eds.), *Kurhany i obrządek pogrzebowy w IV-II tysiącleciu p.n.e.* Instytut Archeologii i Etnologii Polskiej Akademii Nauk. Kraków-Warszawa: 231–234.

Rook E., Nowak M. 1993. Sprawozdanie z badań wielokulturowego stanowiska w Krakowie-Prądniku Czerwonym, w latach 1990 i 1991. *Sprawozdania Archeologiczne 45: 35–72*.

Rybicka M. 2017. *Kultura trypolska – kultura pucharów lejkowatych. Natężenie kontaktów i ich chronologia*. in press.

Stadler P., Draxler S., Friesinger H., Kutschera W., Priller A., Rom W., Steirer P. and Wild E. M. 2001. Absolute chronology for early civilizations in Austria and Central Europe using ^{14}C dating with accelerator mass spectrometry with special results for the absolute chronology of the Baden Culture. In P. Roman, S. Diamandi (eds.), *Cernavodá III-Boleraz. Ein vorgeschichtliches Phänomen zwischen dem Oberrhein und der unteren Donau*. Symposium Mangalia/Neptun (18.–24. Oktober 1999). Bucureşti: 554–562.

Taylor R. E., Renfrew C. and Bar-Yosef O. 2014. *Radiocarbon Dating: An Archaeological Perspective*. 2nd edition. Routledge. Walnut Creek.

Tunia K., Włodarczak P. 2002. Radiocarbon results for the Corded Ware Culture from Southern Poland. *Przegląd Archeologiczny 50: 45–57*.

2011. Tumulus of the Funnel Beaker Culture in Małżyce, Kazimierza Wielka District. *Sprawozdania Archeologiczne 63: 203–220*.

Valde-Nowak P., Gil-Drozd A., Kraszewska A. and Paternoga M. 2015. The Proto-Boleraz grave in the Western Beskids. In M. Nowak, A. Zastawny (eds.), *The Baden Culture Around the Western Carpathians*. Krakowski Zespół do Badań Autostrad. Kraków: 191–219.

Walanus A., Goslar T. 2009. *Datowanie radiowęglowe*. Wydawnictwo Akademii Górniczo-Hutniczej. Kraków.

Wasylikowa K., Starkel L., Niedziałkowska E., Skiba S. and Stworzewicz E. 1985. Environmental changes in the Vistula valley at Pleszów caused by Neolithic man. *Przegląd Archeologiczny 33: 19–55*.

Wild E. M., Stadler P., Bondár M., Draxler S., Friesinger H., Kutschera W., Priller A., Rom W., Ruttkay E. and Steier P. 2001. New chronological frame for the Young Neolithic Baden Culture in Central Europe (4th millennium BC). *Radiocarbon 43: 1057–1064.*

Wilk S. 2014. An elite burial from the Copper Age: Grave 8 at the cemetery of the Lublin-Volhynian culture at Site 2 in Książnice, the Świętokrzyskie province. *Analecta Archaeologica Ressoviensia 9: 209–243.*

2016. New data about chronology of the impact of the Hunyadihalom-Lažňany horizon on Younger Danubian cultures north of the Carpathian Mountains. *Recherches Archéologiques NS 8: 7–28.*

Włodarczak P. 2004. Cemetery of the corded ware culture in Zielona, Koniusza commune, Małopolska. *Sprawozdania Archeologiczne 56: 307–360.*

2006a. *Kultura ceramiki sznurowej na Wyżynie Małopolskiej.* Instytut Archeologii i Etnologii Polskiej Akademii Nauk. Kraków.

2006b. Chronologia grupy południowo-wschodniej kultury pucharów lejkowatych w świetle dat radiowęglowych. In J. Libera, K. Tunia (eds.), *Idea megalityczna w obrządku pogrzebowym kultury pucharów lejkowatych.* Lublin-Kraków: Instytut Archeologii i Etnologii PAN, Oddział w Krakowie & Instytut Archeologii Uniwersytetu Marie Curie-Skłodowskiej. Lublin-Kraków: 27–66.

2008a. Absolute chronology of the barrow in Kolosy. *Sprawozdania Archeologiczne 60: 151–168.*

2008b. Corded Ware and Baden Cultures. Outline of chronological and genetic relations based on finds from western Little Poland. In M. Furholt, M. Szmyt and A. Zastawny (eds.), *The Baden Complex and the Outside World.* Proceedings of the 12th Annual Meeting of the EAA in Cracow 19–24th September 2006. Rudolf Habelt. Bonn: 247–262.

2008c. Archaeological interpretation of dendrochronological and radiocarbon dates. An example of Corded Ware Culture. Archaeological culture versus chronology. *Sprawozdania Archeologiczne 60: 103–128.*

2010. Uwagi o kontaktach transkarpackich w perspektywie genezy kultury ceramiki sznurowej. In J. Gancarski (ed.), *Transkarpackie kontakty kulturowe w epoce kamienia, brązu i wczesnej epoki żelaza.* Muzeum Regionalne w Krośnie. Krosno: 205–224.

2011. Kurhany i kultura ceramiki sznurowej nad dolną Nidą. In H. Kowalewska-Marszałek, P. Włodarczak (eds.), *Kurhany i obrządek pogrzebowy w IV-II tysiącleciu p.n.e.* Instytut Archeologii i Etnologii Polskiej Akademii Nauk. Kraków-Warszawa: 211–230.

2013. Projekt badań chronologii absolutnej eneolitu i początków epoki brązu w Małopolsce. In I. Cheben, M. Soják (eds.), *Otázky neolitu a eneolitu našich ktajín – 2010.* Zborník referátov z 29. Pracovného stretnutia bádateľov pre výskum neolitu a eneolitu Čiech, Moravy a Slovenska, Vršatské Podhradie, 27.–30.9.2010. Nitra: 373–387.

Włodarczak P. (ed.) 2017. *The Past Societies. Polish Lands from the First Evidence of Human Presence to the Early Middle Ages, vol. 2: 5500–2000 BC.* Institute of Archaeology and Ethnology Polish Academy of Science. Warszawa.

Zakościelna A. 2010. *Studium obrządku pogrzebowego kultury lubelsko-wołyńskiej.* Instytut Archeologii Uniwersytetu Marii Curie-Skłodowskiej. Lublin.

Zastawny A. 2001. Naczynia kultury ceramiki sznurowej typu Książnice Wielkie z Kryspinowa, stan. 2, pow. krakowski. *Sprawozdania Archeologiczne 53: 207–230.*

2008. The Baden and the Funnel Beaker-Baden settlement in Lesser Poland. In M. Furholt, M. Szmyt and A. Zastawny (eds.), *The Baden Complex and the Outside World.* Proceedings of the 12th Annual Meeting of the EAA in Cracow 19–24th September 2006. Rudolf Habelt. Bonn: 177–188.

2011. Chronologia i formy oddziaływań kompleksu badeńskiego w Małopolsce. In M. Popelka, R. Šmidtová (eds.), *Otázky neolitu a eneolitu našich zemí – 2009, Mělník 28.9.–1.10.2009.* Praha: 431–450.

2015a. The Baden complex in Lesser Poland – horizons of cultural influences. In M. Nowak, A. Zastawny (eds.), *The Baden Culture Around the Western Carpathians.* Krakowski Zespół do Badań Autostrad. Kraków: 119–150.

2015b. Absolute chronology of the Baden culture in Lesser Poland – new radiocarbon dates. In M. Nowak, A. Zastawny (eds.), *The Baden Culture Around the Western Carpathians.* Krakowski Zespół do Badań Autostrad. Kraków: 191–219.

back to contents