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IS IT A LONG OR SHORT-DURATION PHENOMENON? EXISTENCE OF FUNNEL BEAKER CULTURE SOCIETIES IN THE RZESZÓW FOOTHILLS IN THE CONTEXT OF THE CURRENT SET OF RADIOCARBON DATING MODELS

ABSTRACT

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In recent years, a considerable number of radiocarbon dates have been obtained from Funnel Beaker culture sites of various functions, located in the eastern part of the Rzeszów Foothills. In a group of a few dozen dates, there are some that suggest, on the basis of the probability distribution, that representatives of communities of this culture might have been present on the area ca. 3900-3800 BC. However, such dating may be disputable. Attempts in recent years to confront such early dates with contextual ceramic materials have not provided satisfactory answers to this question. This paper is focused on an assessment of the potential of absolute chronology determinations and their analytic values. After eliminating all questionable dates, statistic simulations of the chronology of the local Funnel Beaker culture have been made. The results obtained suggest that this phenomenon might have been more short-lived than so far believed.

Keywords: chronology, Funnel Beaker culture, radiocarbon dating, Bayesian method, kernel density estimation method
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INTRODUCTION

For many years, the question of the chronology of Funnel Beaker Culture (abbr. FBC) settlement in Subcarpathia has been discussed exclusively on the basis of the typology and style of local pottery, by referring it *per analogiam* to various phases of the southeastern group of this culture (Czopek and Kadrow 1987; Zych 2008; Nowak 2009; Dzierżanowska *et al.* 2010). The situation changed considerably with an inflow of new evidence – radiocarbon dates from FBC settlements and cemeteries obtained during rescue excavations prior to the construction of the A4 highway in the Rzeszów Foothills (Mazurek *et al.* 2013; Rybicka *et al.* 2014; Król *et al.* 2014; Dębiec *et al.* 2015; Sznajdrowska 2016; Rybicka 2016; Rybicka *et al.* 2017), as well as later investigations (Rogoziński 2014; Sieradzka and Głowacz 2017; Król 2018). As a result of an increasing empirical database of ^{14}C dates and typologically and stylistically diverse pottery groups, new proposals of the chronology of the FBC on loess areas of the Rzeszów Foothills have been put forward especially with regard to its earliest manifestations, including the concept of dating its first appearance to ca. 3800-3700 BC (Rybicka 2016; cf. Sznajdrowska 2016; Król 2018), and even to ca. 3900-3800 BC (Rogoziński 2014). As a result, the earliest development of the local FBC settlement network has been shifted back by around 100-250 years (cf. Nowak 2009).

According to observations presented above, local FBC groups appear in new chronological, spatial and cultural positions, different than those of groups of that culture in Lesser Poland, the Lublin region, and western Ukraine. Furthermore, the loess areas of the Rzeszów Foothills should be firmly encompassed by the discussion on the origin of the FBC phenomenon on the Polish-Ukrainian Carpathian foreland (cf. Rybicka 2017). The question, however, is whether proposals to move back the beginning of the FBC on our territories of interest based on absolute dates especially placing the initial stage prior to 3800 BC are really justifiable. Are the available ^{14}C dates reliable?

It is necessary to evaluate critically the true analytical potential of available radiocarbon dates. Such an approach entails selecting chronometric units obtained from organic substances. These substances, because of their unfavorable attributes, are prone to a high risk of laboratory errors, beginning with sample isolation and preparation. Therefore, in this research, several chronological models of the FBC phenomenon on loess areas of the Rzeszów Foothills will be created, with application of statistical methods: *The Bayesian Approach* (Buck *et al.* 1996; Buck 1999) and *Kernel Density Estimation* (abb. KDE; Bronk Ramsey 2017). To obtain this objective, tools of OxCal v4.3.2 (Bronk Ramsey 2017) with calibration curve: 5 IntCal 13 (Reimer *et al.* 2013) will be utilized.

THE DATA SET AND ITS QUALITY

Discussions on the use of radiocarbon dates for determining a more or less exact age of homogenous assemblages (pits, graves and their inventories) or – more generally – the construction of new or the detailing of old chronological schemes, appear constantly in Polish archaeological literature (Kadrow 1991; 1994; Czebreszuk and Szmyt 2001; Bronicki *et al.* 2003; 2004; Kośko and Szmyt 2006; 2007ab; Włodarczak 2006; 2013; Domańska and Rzepecki 2008; Nowak 2009; 2017; Kukawka 2010; Pelisiak and Rybicka 2013; Rzepecki 2014; Grygiel 2008; 2016; Kukawka *et al.* 2016; Kruk *et al.* 2018).

There exist several substantial problems in absolute dating. They are related to field exploration, laboratory and post-laboratory stages, and interpretation. The most important is pre-laboratory handling, because at this stage the substance to be dated is chosen (in the contextual and qualitative sense). Even if we assume an ideal selection of the organic substance, sample preparation and laboratory analysis, we still face one problem. No matter what chemical standards of sample preparation and which measurement techniques are adopted (LSC or AMS), the calendar ages (with application of the AMS technique, the minimum uncertainty range is ±20 or ±30 years) and the results after calibration are being framed into bigger or smaller probability ranges, or several such ranges (Goslar and Walanus 2009). In other words, even with the best possible set of absolute dates we obtain only a theoretical chronological outline of the examined prehistoric events.

In the case of the Rzeszów Foothills we have in hand 26 radiocarbon dates from 10 functionally diversified FBC sites. They are: Pawłosiów, site 52 (7 samples); Skołoszów, site 31 (4); Skołoszów, site 7 (3); Chłopice, site 11 (2); Mirocin, site 27 (2); Skołoszów, site 16 (2); Rozbórz, site 28 (2); Szczytna, site 6 (2); Szczytna, site 5 (1); and Jankowice (1; Table 1). Dates come from: charcoal (8 cases), carbon deposit (6), charcoal separated from potsherds (3), animal bones (3), wood (2), undetermined vegetal vestiges (2), human bone, and organic coating. Samples have been collected from various contexts: settlement features (23 cases), cultural accumulation layer (2), and burial (Table 1).

The quality of some samples and/or their contextual background may be disputable, although these doubts are not necessarily confirmed in laboratory assessments and post-laboratory simulations and interpretations. Notable, for example, is the poor state of preservation of collagen (2.3% and 3%) in animal bone samples from settlement pit 3/2015 in Chłopice, site 11, and the relatively high collagen level (6.4%) of human bones from grave 1227 from Skołoszów, site 7 (Table 1). However, this does not disqualify ^{14}C results from these samples (cf. Goslar and Walanus 2009). Additionally, their classic ceramic context is acceptable (Rybicka *et al.* 2017; Król 2018).

Besides dates from bone samples, which come from relatively short-living beings, the majority of absolute dates from the Rzeszów Foothills have been obtained from charcoal. Although charcoal samples do not create laboratory problems (Goslar and Walanus 2009), the obtained dates can be misleading due to the so-called old-wood effect and/or risks

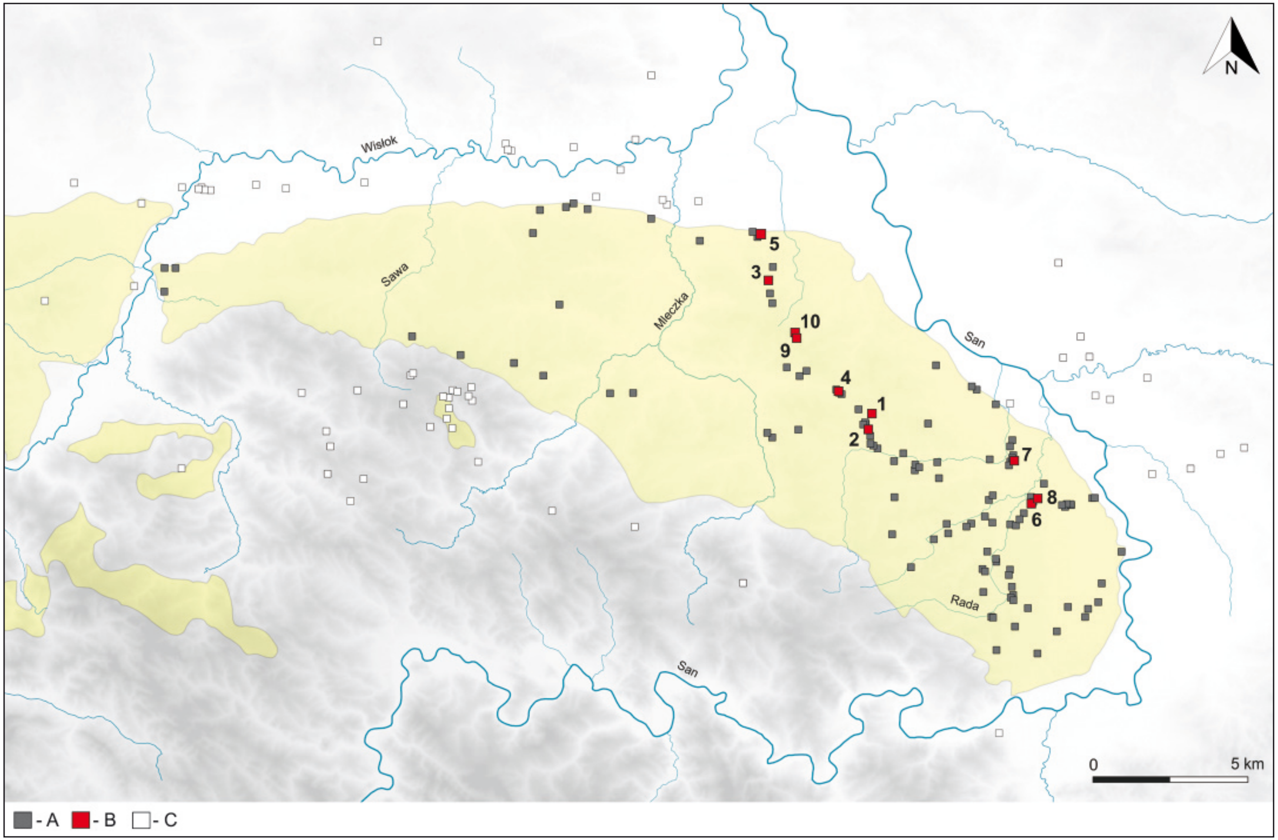

Fig. 1. FBC sites in the Rzeszów Foothills and neighboring zones.
A – sites on studied area, B – radiocarbon dated sites (numbers according to Table 1), C – other sites. Drawn by D. Król

Table 1. List of radiocarbon dates of FBC sites in the Rzeszów Foothills

No.	Site	Context	Sample details	Lab. code	BP	BC 95.4%	References
1	**Chłopice 11** settlement	pit 3/2015	animal bone/ 1% N, 4,2% C, 2,6% coll.	Poz-100648	4625±30	3513-3350	Król 2018
		pit 3/2015	animal bone/ 0,7%, N, 4% C, 3% coll.	Poz-100647	4600±40	3517-3118	Król 2018
2	**Jankowice 9** settlement	pit 202	animal bone	MKL-1617	4830±70	3770-3370	Dębiec *et al*. 2015
3	**Mirocin 27** settlement	pit 41	charcoal	Poz-54047	4955±35	3798-3653	Sznajdrowska 2016
		pit 41	vegetal vestige	Poz-82264	4920±40	3780-3641	
4	**Pawłosiów 52** settlement	pit 171	carbon deposit	Poz-42295	4810±40	3693-3518	Rybicka *et al.* 2014
		pit 1665	vegetal vestige in sherd/0.3 mg	Poz-42294	4780±60	3660-3375	
		pit 23	charcoal	Poz-42296	4765±35	3640-3382	
		pit 1140	carbon deposit	Poz-47396	4730±40	3636-3376	
		pit 2079	organic coating	Poz-42291	4655±35	3620-3361	
		pit 229	carbon deposit	Poz-42300	4650±35	3520-3360	
		pit 1568	carbon deposit	Poz-42301	4510±35	3356-3096	

Table 1 cont. List of radiocarbon dates of FBC sites in the Rzeszów Foothills

No.	Site	Context	Sample details	Lab. code	BP	BC 95.4%	References
5	**Rozbórz 28** bog deposit	pit 3834	wood	MKL-1770	4780±50	3654-3378	Mazurek *et al*. 2013
		pit 3834	wood	MKL-1769	4760±70	3656-3370	
6	**Skołoszów 7** non-megalithic cemetery	posthole 626	charcoal	Poz-45530	4800±35	3651-3521	Król *et al*. 2014
		ditch 644	charcoal	Poz-46077	4775±30	3642-3387	
		grave 1233	human bone/ 0,6% N, 5% C, 6,4% coll.	Poz-82441	4675±35	3625-3366	Rybicka *et al*. 2017
7	**Skołoszów 16** settlement	pit 5/2017	charcoal	Poz-100857	4765±35	3640-3382	Król 2018
		pit 6/2017	charcoal	Poz-100856	4680±35	3625-3366	Król 2018
8	**Skołoszów 31** settlement	cultural layer	carbon in sherd	Poz-64321	5240±40	4228-3968	Rogoziński 2014
		cultural layer	carbon in sherd	Poz-64320	5150±40	4043-3804	
		pit 3	charcoal	Poz-82330	4745±35	3636-3380	Sieradzka and Głowacz 2017
		pit 3	charcoal	Poz-82442	4720±40	3634-3374	
9	**Szczytna 5** settlement	pit 323	carbon deposit	Poz-57508	4700±35	3631-3371	Rybicka 2016
10	**Szczytna 6** settlement	pit 220	carbon in sherd	Poz-57507	5020±35	3943-3710	Rybicka 2016
		pit 306	carbon deposit	Poz-57506	4805±35	3654-3521	

involved in dating from tree cores (Warner 1990; cf. Palincaş 2017) or secondary depositions of charcoal (e.g. Pelisiak and Rybicka 2013). In the first case, this means that the radiocarbon age of charcoal deposited in indisputable homogenous ceramic contexts may be older than this context by a few hundred years (depending on the tree species). This is already a well-known fact in the literature (e.g. Nowak 2009).

If we take into account that the radiocarbon dates from loess areas of the Rzeszów Foothills lack information on the tree species of charcoal samples (Table 1), their real value may be disputable. This is especially true with regard to the above questions related to the chronology of the earliest manifestations of settlement activities of FBC people on the area in question. This is well illustrated by pit 41 in Mirocin, site 27, which received an early date: Poz-54047 4955±35 BP (Table 1). We know that the sample was collected from the bottom part of the pit, yet the tree species of the analyzed charcoal sample is unknown (Sznajdrowska 2016). This fact cannot be overlooked, as in the fill of the pit, there were remains of relatively short-lived birch, but also of oak (Lityńska-Zając 2016). The expected life-span of the latter is among the longest of European trees (e.g. Palincaş 2017). There is one more sample dated from the same pit (41): Poz-82264 4920±40 BP (Table 1), also without reference to tree species. Moreover, their context is less reliable (Sznajdrowska 2016). We cannot, on this ground, disqualify the dates mentioned above as useless, especially since the pottery assemblage from Mirocin contains, apart from the so-called classic elements, more archaic elements (Sznajdrowska 2016). If we do this based on the absence of species determination, we should do the same with all dates of that kind. Certainly, this would be hardly acceptable.

The case of dates obtained from charcoal extracted from pottery mass is different. In relation to loess areas of the Rzeszów Foothills it is especially significant, because such dates, together with other elements, constitute the basis of the concept of the early penetration of FBC groups into this region (Rogoziński 2014; cf. Rybicka 2016). A hypothetical chronological shift of this event to the first centuries of the 4th millennium BC is based mainly on two very early absolute dates from Skołoszów, site 31: Poz-64321 5240±40 BP and Poz-64320 5150±40 BP (Fig. 2; Table 1), and on a simplified pottery typology and style at this site (Rogoziński 2014; Rybicka 2016; 2017; cf. Sieradzka and Głowacz 2017). The above dates are not only the earliest in the area of interest and count among the earliest from all of southeastern Poland (Włodarczak 2006*;* Nowak 2009). Close to them is another "Subcarpathian" date from Szczytna, site 6: Poz-57507 5020±35 BP (Table 1; Fig. 2). The fact that three of four dates are older than 5000 years BP should not be overlooked.

The dating of organic substances identified in pottery contexts is not new in archaeology (Hedges *et al.* 1992). For example, it was applied during research on FBC settlement on the so-called Prokopiak Hill in Opatowice (Kovaljuch and Skripkin 2007; Kośko and Szmyt 2006; 2007a; 2007b). While radiocarbon chronometry based on such substances as carbonaceous residue or food vestiges tends to yield good results as a rule (e.g. Berstan *et al.* 2008), problems may appear with charcoal from pottery mass. There might have been

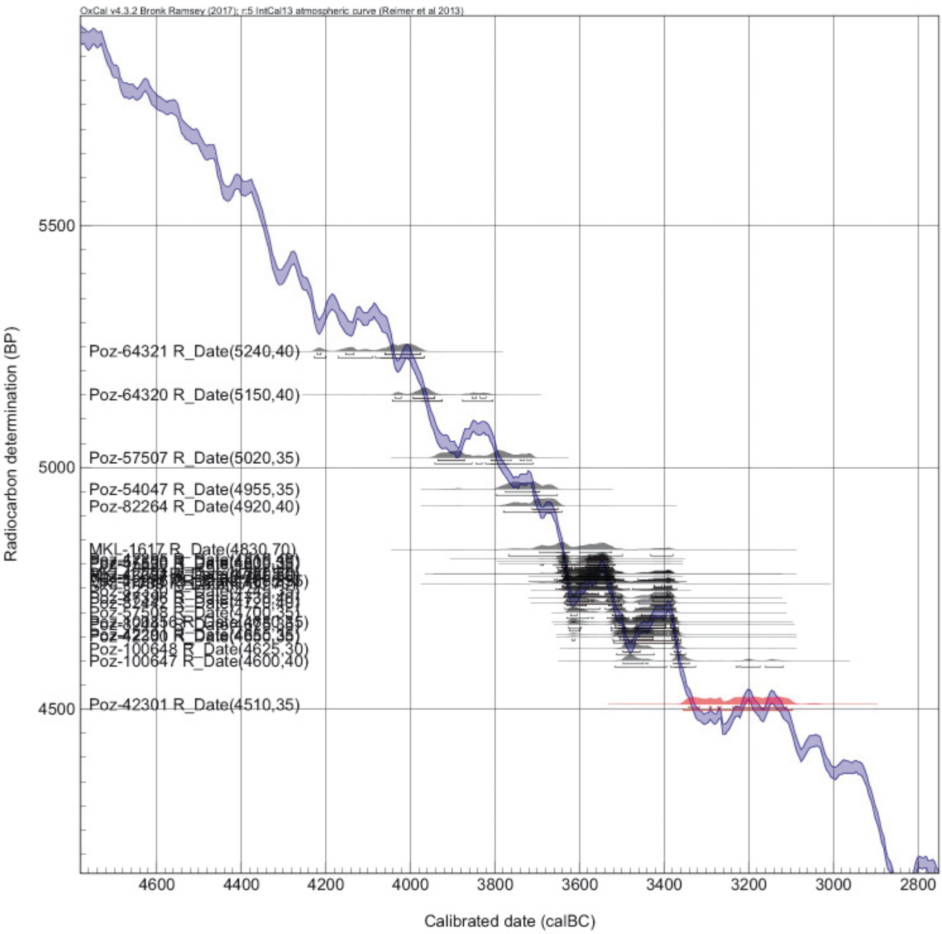

Fig. 2. Non-modelled ^{14}C designations on the calibration curve. Edited by D. Król

an intrusion in raw potter's paste of an element of humic acid, which also affects vessels or their fragments during their time in a humus layer (Hedges *et al.* 1992; cf. Kovaljuch and Skripkin 2007). Charcoal from paste used in pottery production may yield dates too old, while charcoal from humus – too young (Goslar *et al.* 2013).

According to Reports of the Poznań Radiocarbon Laboratory nos. 7654/13 and 8694/14 both ceramic samples from Skołoszów, site 31, and a sample from Szczytna, site 6, were prepared with hydrofluoric acid (HF). This acid is used for washing out the humic acid (Hedges *et al.* 1992; Goslar *et al.* 2013). Hydrofluoric acid was applied in an attempt to solve the dating problems of the FBC pottery from Opatowice in Kuyavia. Initial AMS ^{14}C

dates obtained without use of HF were younger than expected. As a result of testing various HF saturation levels (0.2%, 5%, and 70%), optimal results were obtained (Goslar *et al.* 2013). It was observed that the higher the HF saturation, the more effectively humic acid is removed; however, charcoal from raw paste is also being mobilized (Goslar *et al.* 2013). Obviously, this can result in obtaining dates older than the age of the pottery itself. If HF was used in the case of pottery from Skołoszów, site 31, and Szczytna, site 6, and the expected age was unknown, we should cautiously ask if the obtained results were not influenced by excessively high HF saturation and the charcoal mobilization mentioned above.

Let us look at the question from the point of view of *stricte* archaeological evidences. As discussed above, the early chronology for the settlement in Skołoszów, site 31, has so far been attributed to a simplified style of pottery from the vast cultural layer. It has been compared with the early lowland materials of Podgaj-Przybranówek in Kuyavia and those from quasi-lowlands of the Gnojno type in Lesser Poland (Rogoziński 2014; Rybicka 2016; Sieradzka and Głowacz 2017). Inferring *per analogiam*, it was to some degree explicable. Moreover, recently published research on the lowland settlement in Smólsk, site 2/10, near Brześć Kujawski, corroborated such reasoning. The pottery from Smólsk was similar to that from Skołoszów, site 31, while radiocarbon dates suggested that the settlement in question might have begun before 3800 BC (Grygiel 2016). Is it justified to assume a similar chronology for the settlement in Skołoszów, site 31? The presence of pottery typologically and stylistically spare relative to the classic phase of the southeastern group of the FBC is apparently not a sufficient reason to accept very controversial radiocarbon dates. Contradictory to it are two much younger dates from charcoal from pit 3 (Table 1). The style of pottery from that pit only slightly differs from the pottery in the cultural layer (Sieradzka and Głowacz 2017). Therefore, it cannot be excluded that the settlement in Skołoszów, site 31, should be perceived as an intermediate stage of retardation or a poly-linear development of the FBC, rather than as a model of the early settlement intrusion of that culture on the eastern loess areas of the Rzeszów Foothills, between 3900-3800 BC or 3800-3700 BC. Problems of this kind are nothing new in relation to the whole extent of the FBC. In the literature, there are reported difficulties in determining the chronology of specific pottery decoration (cf. Papiernik and Rybicka 2002; Kukawka *et al.* 2016), as well as a possible stylistic conservatism (Hawinskyj *et al.* 2013; Rybicka 2016).

The observations presented above controvert the use of both early indicators for determining the chronology of the settlement in Skołoszów, site 31, and as the basis for constructing chronological models of FBC development throughout the entire Rzeszów Foothills region. This is also true in relation to the early date from Szczytna, site 6. The consequences of this are much bigger than constraining the life-span of the discussed phenomenon. They beg the question of why, in Skołoszów, site 31, there appeared pottery of a reduced style, atypical for the developed stage of the southeastern group of the FBC (cf. Kadrow 2009). Is it really the result of the aforementioned retardation and/or poly-linear development of the FBC, or perhaps connected to a still unknown (alternative?) function of that site?

As a final consideration of the analytical value of ^{14}C evidence, we should mention a relatively young date: Poz-42301 4510±35 BP, obtained from carbonaceous residue on a vessel from pit 1568 in Pawłosiów, site 52 (Table 1). The location of this date on a vast *plateau* of the calibration curve during the period ca. 3350-3100/3000 BC (Fig. 2) creates difficulties in determining its probability level (Goslar and Walanus 2009). In this situation it is difficult to decide what stage it refers to. In this case, the dilemma cannot be resolved with reference to pottery from the pit. Its typological-stylistic characteristics cannot be clearly linked with either the (late?) classic or the youngest FBC stage, poorly recognized and insufficiently described from the area of our study (Rybicka *et al*. 2014; Rybicka 2016). However, from other areas of the settlement in Pawłosiów, site 52, there are known some infrequent materials featuring Baden and Late Tripolye elements (Rybicka 2016; 2017).

MODELS

Nowadays we cannot expect satisfactory answers to questions related to the possible multidirectional development of the FBC in the Rzeszów Foothills (cf. Rybicka 2016). This problem can be only acknowledged and underscored. In contrast to the better-recognized milieux of that culture, such as the eastern group (Kuyavia) and the southeastern group (generally Lesser Poland), research on local FBC communities on the Rzeszów-Przemyśl loess areas is much less advanced. There are still very few statistically valid assemblages to be compared among one another, and to be combined with numerous (and representative) absolute dates in order to construct vertical and horizontal development schemes of local FBC groups. But even the availability of such assemblages would not guarantee that our schemes would be adequately trustworthy. Examples from Kuyavia and Lesser Poland indicate that changes in typological-stylistic patterns within this cultural phenomenon are very complex, and development schemes presented so far are disputable (e.g. Kośko 1981; Kruk and Milisauskas 1983; Kukawka 1997; 2001; Papiernik and Rybicka 2002; Rzepecki 2004; 2014; Włodarczak 2006; Nowak 2009; Grygiel 2016). This problem has been also reported in relation to the Rzeszów Foothills (Rybicka 2016; 2017).

Due to the inadequate database from the Rzeszów Foothills, it is difficult to built more complex statistical models of chronological sequences, combining typological-stylistic elements of pottery, its stratigraphic context and radiocarbon dates (cf. Włodarczak 2006; Kukawka *et al*. 2016). It is possible, however, by critically reviewing (and eliminating) all doubtful absolute dates, to refine and narrow radiometric frames of the discussed phenomenon with the use of Bayes' theorem and KDE. By applying these methods we can construct models with higher precision than by summing up all probabilities ^{14}C designations, where the generated distribution is a simple superposition of calibrated distributions (cf. Bronk Ramsey 2017). It should be noted that the proposed models do not reflect "closed situations," such as those encountered on settlement and funerary sites, and tested as such (e.g. Rzepecki 2014; Grygiel 2016; Kruk *et al.* 2018). These models do not show the static, fixed chronological frames of completely explored materials, but rather the dynamically constructed (as opposed to constituted) chronological frames of the continuous, ongoing exploration of materials.

Non-Model (Sum)

The set of 26 absolute dates from the Rzeszów Foothills includes various values (Table 1). At least three dates should be excluded from the construction of chronological models of the local FBC. Taking them into account in a simple summation of probabilities would generate unacceptable time spans of 4221-3111 BC (68.2%) and 4229-3097 BC (95.4%), covering extreme periods of 1110 and 1132 years. With exclusion of these three controversial dates from pottery — those from Skołoszów, site 31, and Szczytna, site 6 — the time spans are restricted to 3775-3111 BC (68.2%) and 3798-3097 BC (95.4%), i.e. to 644 and 701 years. Although still quite broad, we can correct such results by appropriate statistical modeling. Below, there are six chronological simulations of the FBC settlement on loess areas of the Rzeszów Foothills (I, Ib, II, IIb, III, and IIIb).

Model I (Phase)

This is a constant, single-phase model, in which the set of radiocarbon dates is treated as coming from a single FBC Phase, extending between the Start FBC Boundary and the End FBC Boundary. The model is based on *Agreement Indices* of the entire set, as well as individual designations and Convergence, where *Individual Agreement Indices* A_{model} (*Model agreement index*) and $A_{overall}$ (*Individual agreement index*) should be at least 60%, and Indicator C (*Convergence integral*), useful in analyses of extreme values – 95% at least. This model, built on the basis of 23 converted ^{14}C designations, complies with statistical essentials. Values of agreement indicators for the whole formation are: A_{model} = 93.3% and $A_{overall}$ = 94.4% (Fig. 3). In individually assessed designations the unacceptable values (A ≥ 60%, C ≥ 95%) are absent. Remarkable are the relatively low values of coefficient A from dates from Mirocin, site 27, pit 41 (Poz-54047 4995±35 BP; A = 76.5%), and from Pawłosiów, site 52, pit 1568 (Poz-42301 4510±35 BP; A = 68.8%); coefficient C of the latter date: C = 95.0% (Fig. 2). The start boundary of the generated model I is: 3716-3666 BC (68.2%) and 3764-3654 BC (95.4%), mean 3701 BC and median 3696 BC. The end boundary is: 3356-3301 BC (62.8%) and 3479-3256 BC (95.4%) → 3479-3397 BC (11.2%) and 3373-3256 BC (84.2%), mean 3338 BC and median 3333 BC. The modelled duration of the formation (FBC Span) is 306-376 years (68.2%) and 185-424 years (95.4%) → 185-269 years (13.0%) and 288-424 years (82.4%), mean 332 years and median 337 years (Table 2). Such frames are considerably closer than those resulting from the summation of probabilities of absolute dates.

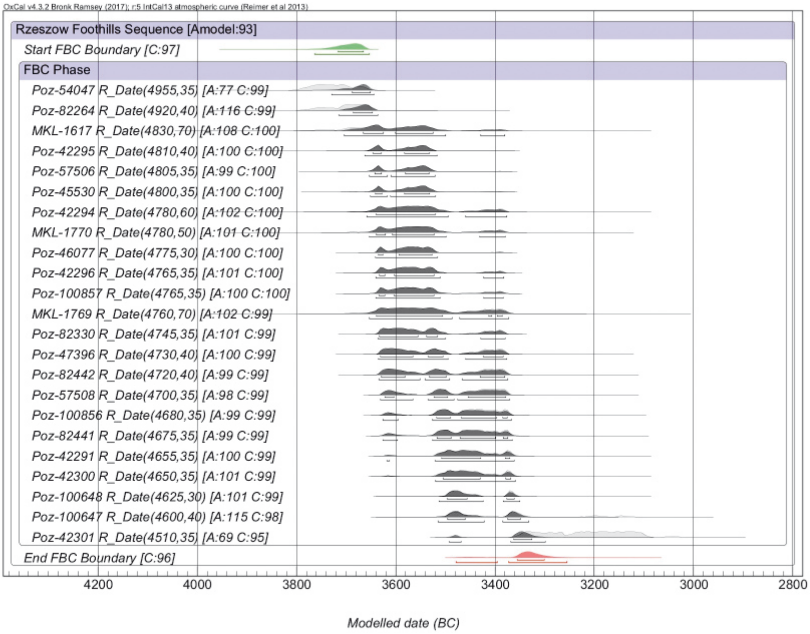

Fig. 3. Model I (Phase). Probability distribution. Edited by D. Król

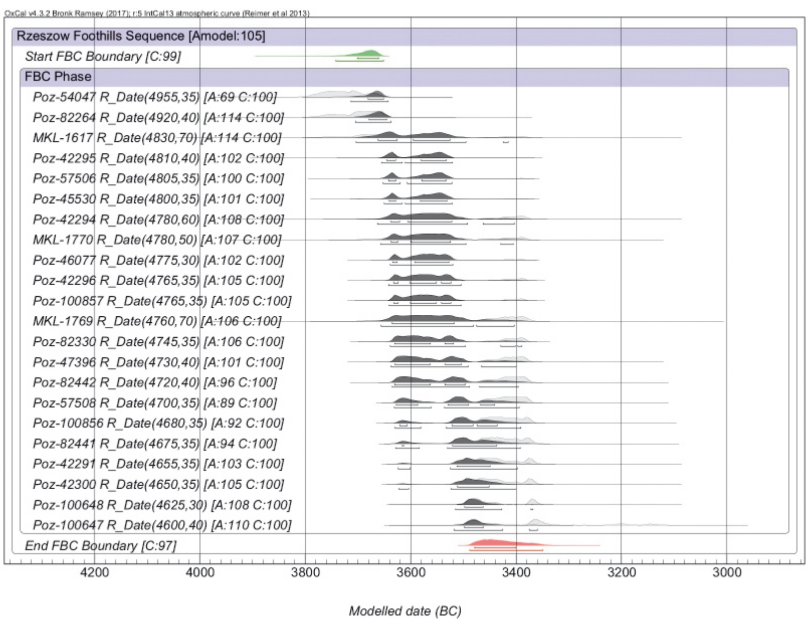

Fig. 4. Model Ib (Phase). Probability distribution. Edited by D. Król

Model Ib (Phase)

Due to the low indicator C from the date Poz-42301 4510±35 BP, another model (or rather sub-model of model I) has been generated. Considering the minimal value of this indicator—despite the absence of objective arguments for doubting the quality of the date in question—we can attempt to generate a simplified model (Ib) without this chronometric unit, which is statistically more consistent than model I: A_{model} = 105.4%, $A_{overall}$ = 105.3% (Fig. 4). Moreover, there are not any unacceptable individual dates. However, indicator A decreases considerably in comparison to the date from Mirocin, site 27, pit 41: Poz-54047 4995±35 BP (A = 68.8%). Indicator C values are fully acceptable – not lower than 98.8%. The start boundary of model Ib is located in a relatively narrow span: 3702-3661 BC (68.2%) and 3743-3652 BC (95.4%), mean 3689 BC and median 3684 BC. The end boundary is also narrow: 3479-3401 BC (62.8%) and 3489-3350 BC (95.4%), mean 3426 BC and median 3433 BC. The modelled duration of this formation is 183-270 years (68.2%) and 168-327 years (95.4%), mean 240 years and median 234 years. These spans are different from those already presented – they restrict the duration of the FBC population on loess areas of the Rzeszów Foothills to about 10-15 generations.

Model II (Tau_Boundary)

If models I and Ib have been generated on the basis of the presupposition of a uniform event distribution, model II has the character of an exponential distribution. Models of this kind have already been presented by M. Nowak (2009). Such a model assumes a constant increase of events (^{14}C dates) until the optimum is reached, i.e. maximal density of their summed probabilities (Nowak 2009). The mean of the summed probabilities of 23 radiocarbon dates from the Rzeszów Foothills is 3350 BC (R_Simulate: 4718±61 BP). To create such a model, five absolute designations with values below 4657 BP were omitted (see Table 1). As a result, a model of moderate statistical significance was obtained: A_{model} = 95.9%, $A_{overall}$ = 88.4 % (Fig. 5). Remarkable are the unacceptably low indicators A of individual dates from Skołoszów, site 16, pit 6/2017: Poz-100856 4680±35 (A = 54.0%), and from Skołoszów, site 7, grave 1233: Poz-82411 4675±35 (A = 49.3%). They do not disqualify the whole formation, but decrease its significance. The start boundary of the generated model is: 3621-3571 BC (68.2) and 3639-3547 BC (95.4%), mean 3595 BC and median 3596 BC. The end boundary is: 3579-3495 BC (68.2%) → 3579-3548 BC (28.6%) and 3525-3495 BC (39.6%) and 3597-3488 BC (95.4%), mean 3536 BC and median 3531 BC. The modelled duration of the event in question can be estimated as 112-221 years (68.2%) and 76-266 years (95.4%), with mean 172 years (Table 2).

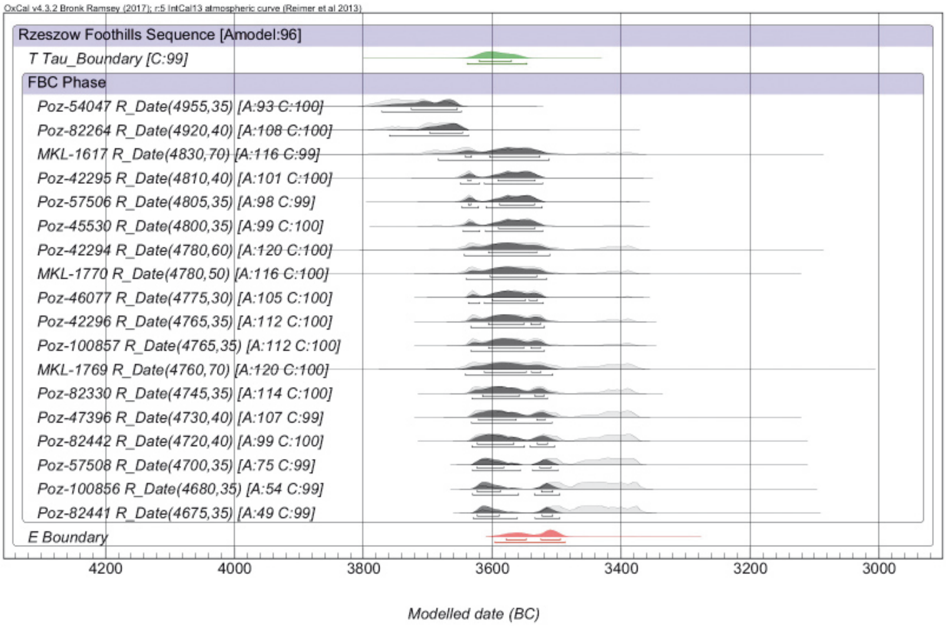

Fig. 5. Model II (Tau_Boundary). Probability distribution. Edited by D. Król

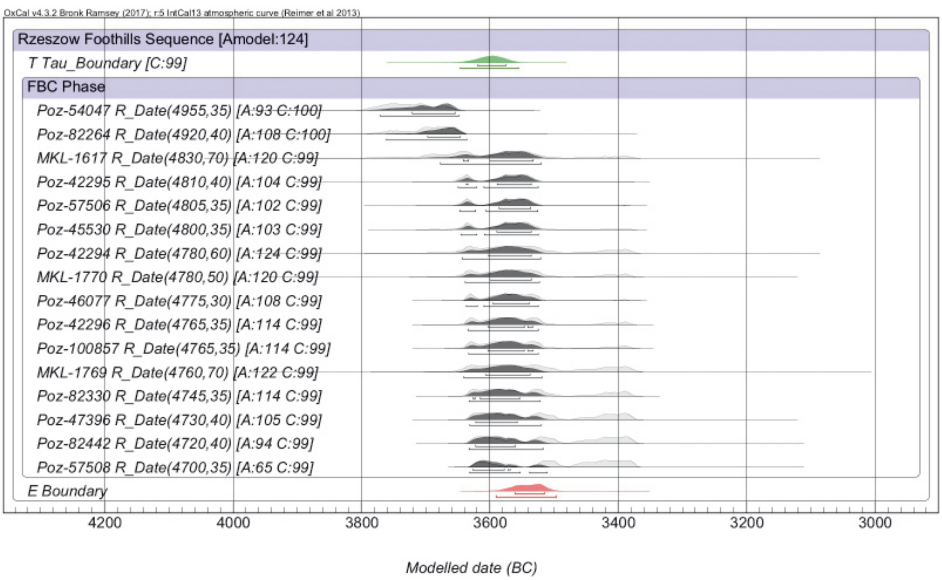

Fig. 6. Model IIb (Tau_Boundary). Probability distribution. Edited by D. Król

Model IIb (Tau_Boundary)

Values of indicators A below 60% of two radiocarbon dates in model II suggest constructing one more model (sub-model), even though the quality of these dates cannot be objectively denied. In the new model (IIb), significance indicators are very high: A_{model} = 124.3%, $A_{overall}$ = 124.0 % (Fig. 6). In such a construction there are no deviating indicators, although indicator A of the date from Szczytna, site 5, pit 323: Poz-57508 4700±35, is relatively low (A = 64.6%). The start boundary of the model is: 3620-3575 BC (68.2%) and 3646-3556 BC (95.4%), mean 3600 BC and median 3599 BC. Values of the end boundary are: 3562-3516 BC (68.2%) and 3591-3497 BC (95.4%), mean 3542 BC and median 3541 BC. The estimated durations of the model are 118-207 years and 83-254 years mean 165 years and median 164 years (Table 2).

Model III (KDE)

The reduction of chronological dispersion resulting from the summation of all probabilities of ^{14}C dates can also be achieved with the use of KDE tools. They not only allow for correction of the standard sums, but they also eliminate perturbations in Bayes models (Bronk Ramsey 2017). To generate model III, the parameters *kernel* and *factor* should be set (by default N[0.1] and U [0.1]). As a result, the obtained model has relatively high significance indicators: A_{model} = 102.9%, $A_{overall}$ = 102.8 % (Fig. 7, 8). There are no deviating indicators, although the younger date from Pawłosiów, site 52, pit 1568: Poz-42301 4510±35 BP, has a „traditionally" low value of indicator A (A = 72.5%). The sum of probabilities of the modelled absolute designations is located in spans: 3716-3319 BC (68.2%) and 3763-3266 BC (95.4%), mean 3546 BC and median 3547 BC. The estimated duration of probabilities of this model is: 317-414 years (68.2%) and 209-459 years (95.4%), mean 354 years and median 359 years (Table 2). In modeling with the KDE technique, start and end boundaries are not estimated. Attempts to combine Bayes and KDE models may falsify the results (Bronk Ramsey 2017).

Model IIIb (KDE)

As in the case of models I and II, we can omit the „weakest" individual value generated in model II – Poz-42301 4510±35 BP. The generated „sub-model" is interesting. It has high probability levels: A_{model} = 109.9%, $A_{overall}$ = 108.8 % (Fig. 9, 10) with an absence of low A and C values reflecting individual events. The boundaries are: 3713-3450 BC (68.2%) and 3761-3347 BC (95.4%), mean 3546 BC and median 3547 BC. The duration of the modelled formation is estimated to be 223-31 years (68.2%) and 182-381 years (95.4%), mean and median 279 years (Table 2).

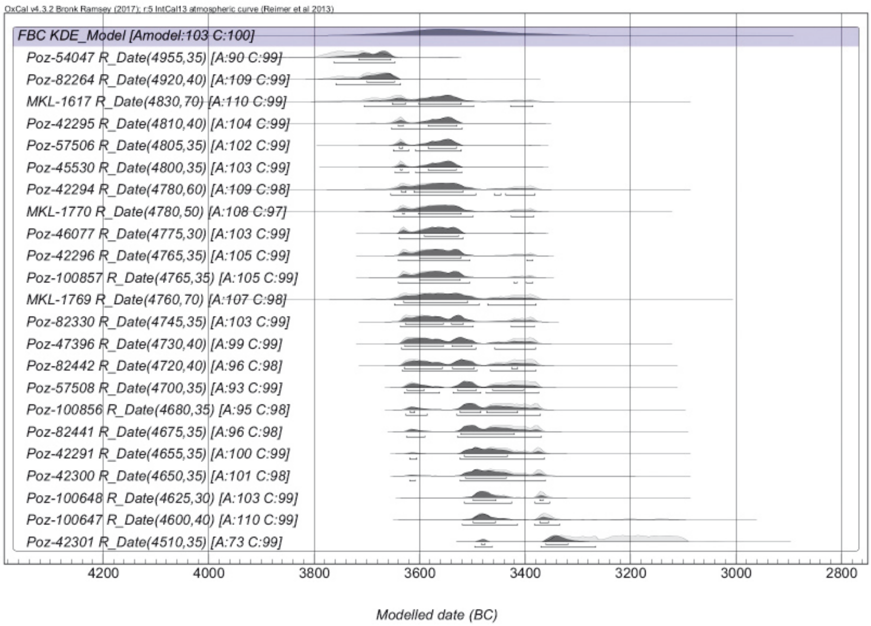

Fig. 7. Model III (KDE). Probability distribution. Edited by D. Król

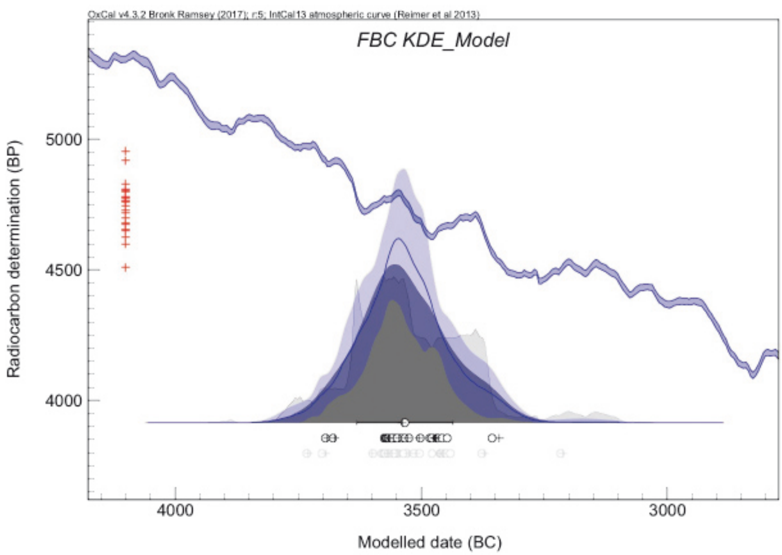

Fig. 8. Model III (KDE). Probability distribution. Dark grey – estimated KDE distribution; blue line and light blue band – mean ±1 sigma of snapshots of KDE distribution; light gray – basic summation on non-modelled ^{14}C dates. Edited by D. Król

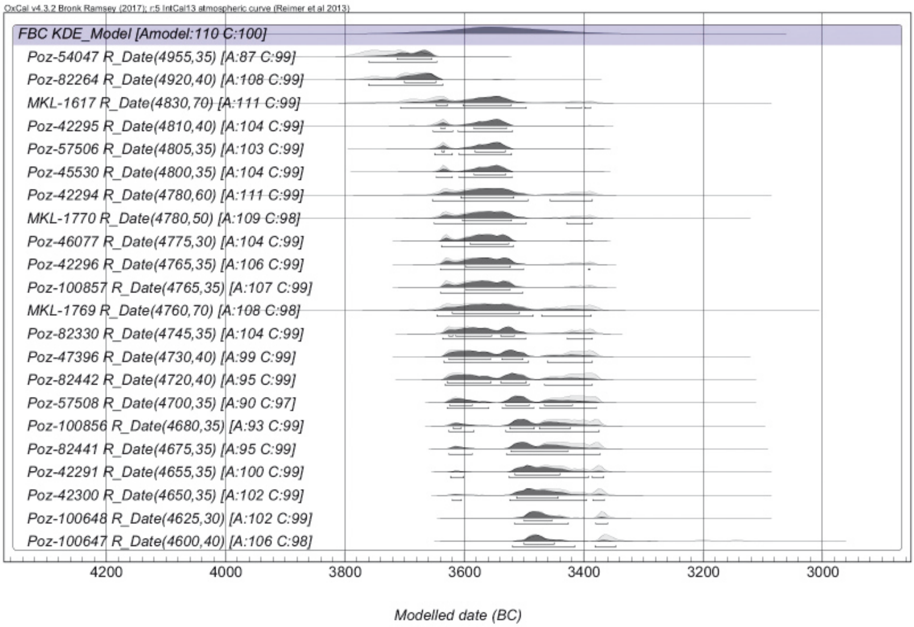

Fig. 9. Model IIIb (KDE). Probability distribution. Edited by D. Król

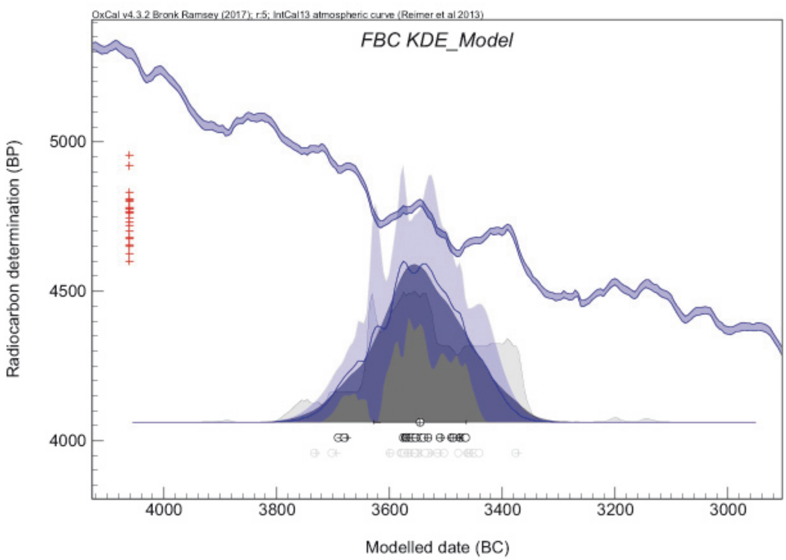

Fig. 10. Model IIIb (KDE). Probability distribution. Dark grey – estimated KDE distribution; blue line and light blue band – mean ±1 sigma snapshot of KDE distribution; light grey – basic summation of all probabilities of ^{14}C dates. Edited by D. Król

Table 2. Comparison of the values of FBC settlement models in the Rzeszów Foothills

	Non-model (SUM)	Model I (PHASE)	Model Ib (PHASE)	Model II (TB)	Model IIb (TB)	Model III (KDE)	Model IIIb (KDE)
Quantity	23	23	22	18	16	23	22
Spread 68.2%	3775-3111	3689-3327	3682-3463	3726-3507	3722-3569	3716-3319	3713-3450
Spread 95.4%	3798-3097	3730-3300	3714-3360	3772-3496	3772-3512	3763-3266	3761-3347
→ diff. 68.2%	664	362	219	219	153	397	263
→ diff. 95.4%	701	430	354	276	260	497	414
Start_B 68.2%	-	3716-3666	3702-3611	3621-3571	3620-3575	-	-
Start_B 95.4%	-	3764-3654	3743-3652	3639-3547	3646-3556	-	-
→ mean	-	3701	3689	3595	3600	-	-
→ median	-	3696	3684	3596	3599		
End_B 68.2%	-	3356-3301	3479-3401	3579-3495	3562-3516	-	-
End_B 95.4%	-	3479-3256	3489-3350	3597-3488	3591-3497	-	-
→ mean	-	3338	3426	3536	3542	-	-
→ median	-	3333	3433	3531	3541		
Span 68.2%	-	306-376	183-270	112-221	118-207	317-414	223-331
Span 95.4%	-	185-424	168-327	76-266	83-254	209-459	182-381
→ mean	-	332	240	172	165	354	279
→ median	-	337	234	172	164	359	279

SUMMARY AND CONCLUSIONS

Results of the Bayes and KDE simulations present a few different scenarios of the functioning of FBC communities on the loess areas of the Rzeszów Foothills (Table 2). No matter which method is adopted, the estimated values differ from the standard summation of probabilities of radiocarbon dates. Generally, the models indicate that the beginning of FBC settlement on the area in question cannot be placed before about 3740 BC, but probably in the period about 3730-3700 BC. It declined not later than about 3250 BC, probably close to 3430-3300 BC. Therefore, the duration of the entire settlement period was no longer than 400 years, possibly about 300-350 years. Models Ia and IIIa, which do not take into account the date from Pawłosiów, site 52: Poz-42401 4510±35 BP, delimit this period even more – to about 230-280 years.

For the purposes of the research objectives outlined at the beginning of the paper, the presented statistical facts seem to be significant. They indicate that FBC settlement on the Rzeszów Foothills was of a shorter duration than the superficial interpretation of absolute and relative chronological indicators may suggest (cf. the case of Skołoszów, site 31). Conclusions drawn from the presented analyses should be verified by thorough studying of FBC settlement-cultural development, including sites with ceramic assemblages of the most archaic and most recent styles.

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