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RESEARCH ARTICLE

The chronology of the Early Trypillian expansion

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Abstract
A new series of 22 radiocarbon dates provides new insights on the origin and distribution of the Early Trypillian archaeological culture in modern-day Moldova and Ukraine. The paper presents data from the sites of preceding groups (5 dates), highlighting gaps in the agricultural settlement of the region, dates related to the Early Trypillia directly (14 dates) and dates from the ceramic hunter-gatherers' sites that yielded some Early Trypillian pottery (3 dates). The results indicate that the expansion of Early Trypillia into Moldovan and Ukrainian forest-steppe took place during 47–45th centuries BCE and it was a relatively fast colonization likely spanning only 3–5 generations.

Introduction

The roots of the impressive Trypillian material culture (Chapman et al. 2019; Müller et al. 2018) are sought in the preceding chronological or cultural horizon: the Precucuteni or Early Trypillia groups (P-ET) (Dumitrescu 1963; Passek 1949; Videiko 2004). As established by Romanian scholars (Dumitrescu 1957, 1963; Marinescu-Bîlcu 1974), the latter appeared in the small region situated on both slopes of the Carpathian mountains (Precucuteni I) and spread towards north and east during the subsequent stages II (corresponding to Trypillia A 1-2, (Videiko 2004)) and III (corresponding to Trypillia A3; Videiko 2004). The stages were mostly defined by the typo-chronology of ceramic assemblages. There was a discussion on the groups ancestral to the P-ET: the list of potential sources includes Late Criş culture (Burdo 2011, 367), Linear Pottery Culture (Nestor 1951, 22–23), Dudeşti and other fluted pottery cultures, Boian-Giulesti (Vulpe 1957), Buh-Dniester, and Hamangia (Dumitrescu 1963) with a notable degree of disagreement between scholars (Burdo 2003; Comşa 1987; Garvăn et al. 2009; Ursu 2016; Zbenovich 1989, 1996).

The early Trypillians "domesticated" the landscapes of the Ukrainian and Moldovan forest-steppe, which later saw development of "mega-sites" (Gaydarska et al. 2020a, 2020b; Ţerna et al. 2019; Videiko et al. 2015). However, the absolute dating of this expansion demonstrated a poor correspondence to the existing periodization schemes, unable to differentiate the time-spans of the earlier and later sites according to the typo-chronology (Shatilo 2021). While an implicit wave-of-advance model under-laid many discussions of the Early Trypillian spread (Zbenovich 1989), the available radiocarbon datasets could not demonstrate a significant time lapse between the earliest and the easternmost sites of the Early Trypillia (Gaskevych 2014; Rassamakin 2012). So, in order to resolve this controversy, we aimed to obtain a series of radiocarbon dates covering both typo-chronological stages of Early Trypillian spread in the sites located at the eastern and western limits of its distribution.

Table 1. *Sampling and contexts*

Site	Context	Sample	Lab no.	Period/culture
Sacarovca	Feature 21	Fr-t of deer metacarpal	BE-16910	Cris III/IV
Sacarovca	Feature 44	Fr-t femur of deer or Bos sp.	BE-16911	Cris III/IV
Sacarovca	Feature 44	Fr-t of big ungulate's bone	BE-18271	Cris III/IV
Sacarovca	Feature 46	Fr-t of deer's metacarpal	BE-16912	Cris III/IV
Floreşti-1	Pit 18	Fr-t of long bone of big ungulate	BE-16907	LBK
Bern-1	Dw. 4	Fr-t of worked antler	BE-18274	PCII-TrA1-2
Bern-1	*Dw. 6*	*Fr-t of worked antler*	*BE-18275*	*PCII-TrA1-2*
Rogojeni-1	Pit 4	I phalanx of cattle	BE-16915	PCII-TrA1-2
Rogojeni-1	Pit 4	Fr-t tibia of deer	BE-16916	PCII-TrA1-2
Rogojeni-1	Pit 3	Small chip of animal's bone	BE-16917	PCII-TrA1-2
Mohylna-3	Soil section	Fr-t long bone of big ungulate	BE-16908	PCIII-TrA3
Mohylna-3	Soil section	Fr-t long bone of big ungulate	BE-16909	PCIII-TrA3
Cărbuna-2	Pit 9	Fr-t of big ungulate's bone	BE-18273	PCIII-TrA3
Cărbuna-2	Pit 9	Fr-t humerus of deer	BE-16918	PCIII-TrA3
Cărbuna-2	Pit 6	Fr-t of big ungulate's bone	BE-18272	PCIII-TrA3
Cărbuna-2	Pit 6	Fr-t humerus of large ungulate	BE-16919	PCIII-TrA3
CN	tt 1, sq. 1/B, str 8	Fr-t of humerus of Bos sp.	BE-16920	PCIII-TrA3
CN	tt 1, sq. 1/B, str 8	Fr-t bone of large ungulate	BE-16921	PCIII-TrA3
Sab-2	Dw. 1	Fr-t of worked bone	BE-18276	PCIII-TrA3
Puhach-2	–240–250 cm	A tooth of a deer	BE-18268	PN -TrA3
MB	*–280 cm*	*Unidentified animal bone*	*BE-18269*	*PN -TrA3*
MB	–268 cm	Unidentified animal bone	BE-18270	PN -TrA3

Bern – Bernashivka, CN – Cărbuna-Negrub, Sab-2 – Sabatynivka 2, MB – Mykolyna Broiaka. PCII-III – Precucuteni II-III, TrA1-3 – Trypillia A1-3, PN-TrA3 ceramic hunter-gatherers with some finds of Trypillia A3, *dates non-relevant for the discussion are in italics*. Tt – test-trench, dw – dwelling. Fr-t – fragment.

The dataset for radiocarbon chronology of P-ET horizon consists mostly of conventional dates (25 dates, Burdo 2003; Mantu 1998; Monah 1987; Patokova et al. 1989; Vogel and Waterbolk 1972; Vornicu 2017; Vornicu et al. 2018). They have large standard deviation, were often done on charcoal (thus, with a possibility of "old wood" effect or being a "bulk" charcoal date, which is not a date at all), and often bring inconsistent results. Of those, 16 dates were done in the Kyiv laboratory in several series, which are often incongruent with recent re-dating results (Gaskevych 2014; Kiosak and Lobanova 2021; Lobanova et al. 2021; Rassamakin 2012; Shatilo 2021). Before the present study, there were only 21 AMS dates for 8 sites (Garvăn et al. 2022; Tencariu et al. 2022; See Suppl. Table 1), so the 14 new AMS dates from 6 sites are an important addition to the dataset (Table 1).

Recently, a Bayesian analysis was performed on a set of ten radiocarbon dates available for the Precucuteni sites to the west of Prut river, in the modern-day Romania, as a part of a larger analysis covering all so far published Precucuteni-Cucuteni dates (Popovici and Draşovean 2020). Taking into account stratigraphic considerations, they concluded that structure L36 of Poduri-Dealul-Ghindaru site (Precucuteni II), dated by a single date on charcoal (Bln-2804, 5820±50 BP), most likely existed in a timeslot of 4720–4701 cal BCE ("median date"; Popovici and Draşovean 2020, 371). The following stage, Precucuteni III, was attested in the structures L31 and L8 of the same site already by 4626–4609 calBCE ("median date"; Popovici and Draşovean 2020, 371). While such an approach of median dates is obviously flawed (Stuiver and Polach 1977), these observations lay the foundation for further Bayesian modeling, which will be done in this study, using the enlarged dataset.

Material and methods

The samples were dated in the Laboratory for the Analysis of Radiocarbon with AMS (LARA) at the University of Bern employing the MICADAS equipment (Szidat et al. 2014). Collagen extraction was

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performed according to Szidat et al. (2017) with an additional ultrafiltration step. The results were calibrated with OxCal software (Bronk Ramsey and Lee 2013) Version 4.4.2 using the IntCal20 calibration curve (Reimer et al. 2020).

Here and thereafter we differentiate clearly between calibrated ^{14}C dates (cited calBCE) and estimates interpolated from ^{14}C dates, typological seriation and stratigraphies (cited BCE).

We use several techniques implemented in OxCal software (Bronk Ramsey and Lee 2013) to summarize large numbers of calibrated dates in an effective way. In particular, we use Kernel Density Estimate to estimate the dates available for each phase (ceramic style) of P-ET. The basic idea behind KDE is to place a kernel (a smooth, usually symmetric, probability distribution function) at each data point and then sum up these kernels to create a smooth estimate of the underlying probability density function. As KDE_Plot function of OxCal is based on the assumption that every dated event is independent, which is not the case here, we apply KDE_Model (Bronk Ramsey 2017) to construct our Model 1 (see Figure 3).

In order to solve the issue of the chronological relationship between phases (ceramic styles) of P-ET, we use a comparison of three types of models available in OxCal software: sequences with contiguous, sequential and overlapping phases (Models 2–4, Table 2, Suppl. mat. 2). In the case of overlapping phases, the different phases are treated entirely independently. Contiguous phases follow one after another with a transition event modeled as the same boundary used for the end of one phase and the start of the next. Sequential phases do not specify whether the next phase starts immediately after the preceding phase. So there are two boundaries used for the end of one phase and the start of the next (Bronk Ramsey 2009) Then, we tried to reverse the question and built a model of sequential phases (Model 5, Suppl. mat. 3) excluding "irrelevant" dates from consideration. While this model produces a reasonable solution for the problem of the chronology of P-ET phases, it is evidently a result of the pre-selection of dates for the analysis. To estimate the possible gaps between preceding cultural groups and P-ET, we used an Interval query of OxCal (Model 6-7, Suppl mat. 4 [dates for the models 6-7], Suppl. mat 5 [code] and Suppl. mat 6 [figure]).

Sites

Taking into account the aim of the study, a diversified set of Early Trypillian sites (Table 1) was selected for radiocarbon sampling together with some sites of preceding cultural groups. The antecedent stages of agricultural colonization are represented by sites of Sacarovca 1 (Late Criş, Figure 1: 1) and Floreşti 1 (Linearbandkeramik culture, LBK, Figure 1: 2).

The sites of the first phase of Early Trypillian expansion (Precucuteni II, II-III, Trypillia A1-2) include Rogojeni 1 and Bernashivka. **Rogojeni** 1 (Figure 1: 3) is situated in the basin of Raut river, and was investigated by Vs. Marchevici, and S. Bodean on many occasions (Bodean 2001; Bodean and Bicbaiev 2014; Covalenco et al. 2015). **Bernashivka** (Figure 1: 4) was discovered by confluence of the Dniester river and the river of Zhvan. It was extensively investigated by V. Zbenovich (Zbenovich 1996) and is under examination in an on-going project (interrupted by the war in 2022) led by D. Chernovol. It is one of the northernmost points of Trypillia A1-2 expansion.

The following phase of Early Trypillia was sampled at the sites coming from the microregions situated at the limits of the extent of the Early Trypillia. The settlements of **Cărbuna 2 and Cărbuna-Negrub** (Figure 1: 5) are located at the fringe of the last hilly area in front of the Pontic Steppe—the westernmost corner of the Great Eurasiatic Steppe (Bodean and Heghea 2018, 2019, 2021; Bodean and Noroc 2019), while the sites of **Mohylna 3** (Burdo 1997; Hasiuk 1954; Kiosak et al. 2021) and **Sabatynivka 2** (Burdo 2018) are located in the Middle Southern Buh catchment (Figure 1: 6–7).

Nearby, in the same basin of the Southern Buh river (Kotova 2015), there are sites of fishers, hunters, gatherers equipped with pottery (para-Neolithic; Kiosak et al. 2021) or sub-Neolithic (Haskevych 2021) groups). Some of these sites yielded notable assemblages of Early Trypillian ceramics and lithic tools alongside with inventory typical for ceramic hunter-gatherers (Tovkailo 2020). The sites of **Puhach 2**

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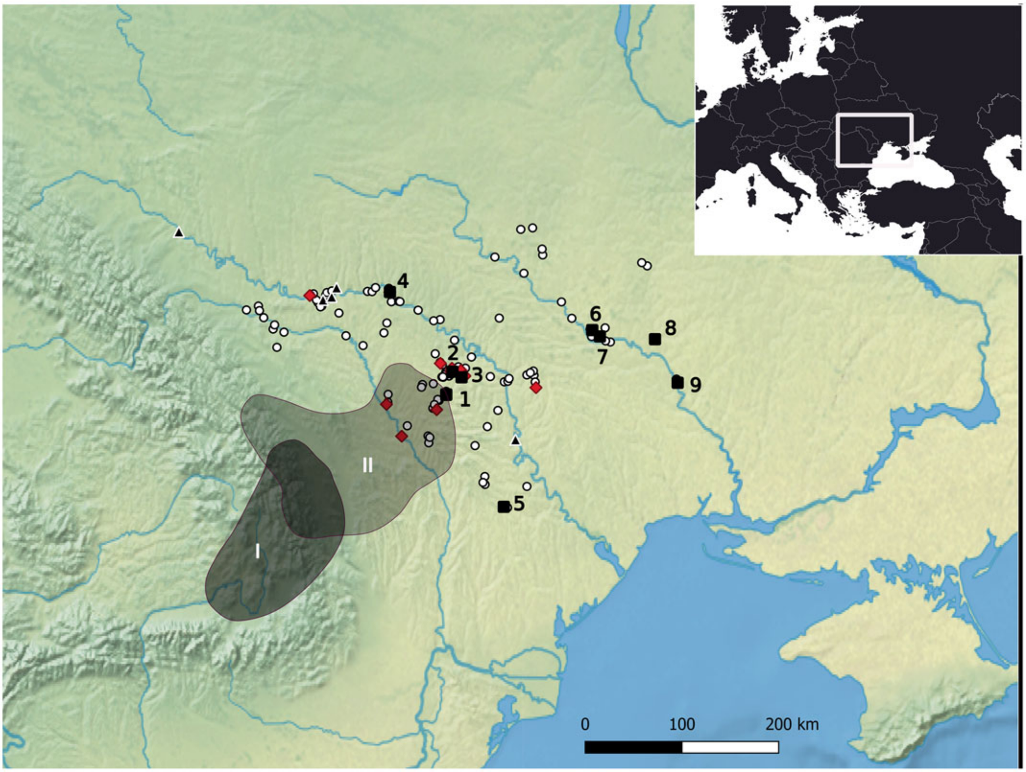

Figure 1. *Map of the sampled sites for the current project versus Early Trypillian sites distribution. I, II—distribution of Precucuteni I and II (Garvăn et al. 2009). Rhomboids—Precucuteni II - Trypillia A1-2 sites, circles—Precucuteni III - Trypillia A3 and undefined early Trypillian sites, triangles—Trypillia A4 sites. Black squares—dated sites: 1—Sacarovca 1 (Criş III-IV), 2—Floreşti 1 (LBK), 3, 4—Rogojeni and Bernashivka (3–4—Trypillia A1-2), 5—Cărbuna sites, 6—Mohylna 3, 7—Sabatynivka II (5–7—Trypillia A3), 8—Mykolyna Broiaka, 9—Puhach 2 (8–9—Trypillia A3 and ceramic hunter-gatherers).*

and **Mykolyna Broiaka** (Figure 1: 8–9) yielded the latest (from typo-chronological point of view) assemblages of these ceramic hunter-gatherers. Puhach 2 brought in 472 Early Trypillian potsherds (12% of total potsherds coming from its cultural layer). On the contrary, only a few Early Trypillia sherds were found in Mykolyna Broiaka among hundreds of ceramic fragments typical for ceramic hunter-gatherers (Kozubovsky 1933; Tovkailo 2005). Both sites were dated in order to compare the chronology of the complex rich in Early Trypillian artefacts with that of another complex, with few finds of this type and, thus, shed light on the chronological correspondence of encampments of ceramic hunter-gatherers and Early Trypillian habitations.

Sampling

Bones were collected from animals and identified to species where possible. When species identification was not feasible, bones massive enough to belong to large ungulates were sampled, thereby excluding dogs that might have had a fish diet. All samples from the Criş, LBK, and P-ET sites were taken from either pits or dwellings, ensuring their association with archaeological material. In some instances, the samples included fragments of worked antler. At the Mohylna 3 site, the soil section cut through the remains of a dwelling, associating the samples and archaeological material with this context (Kiosak and

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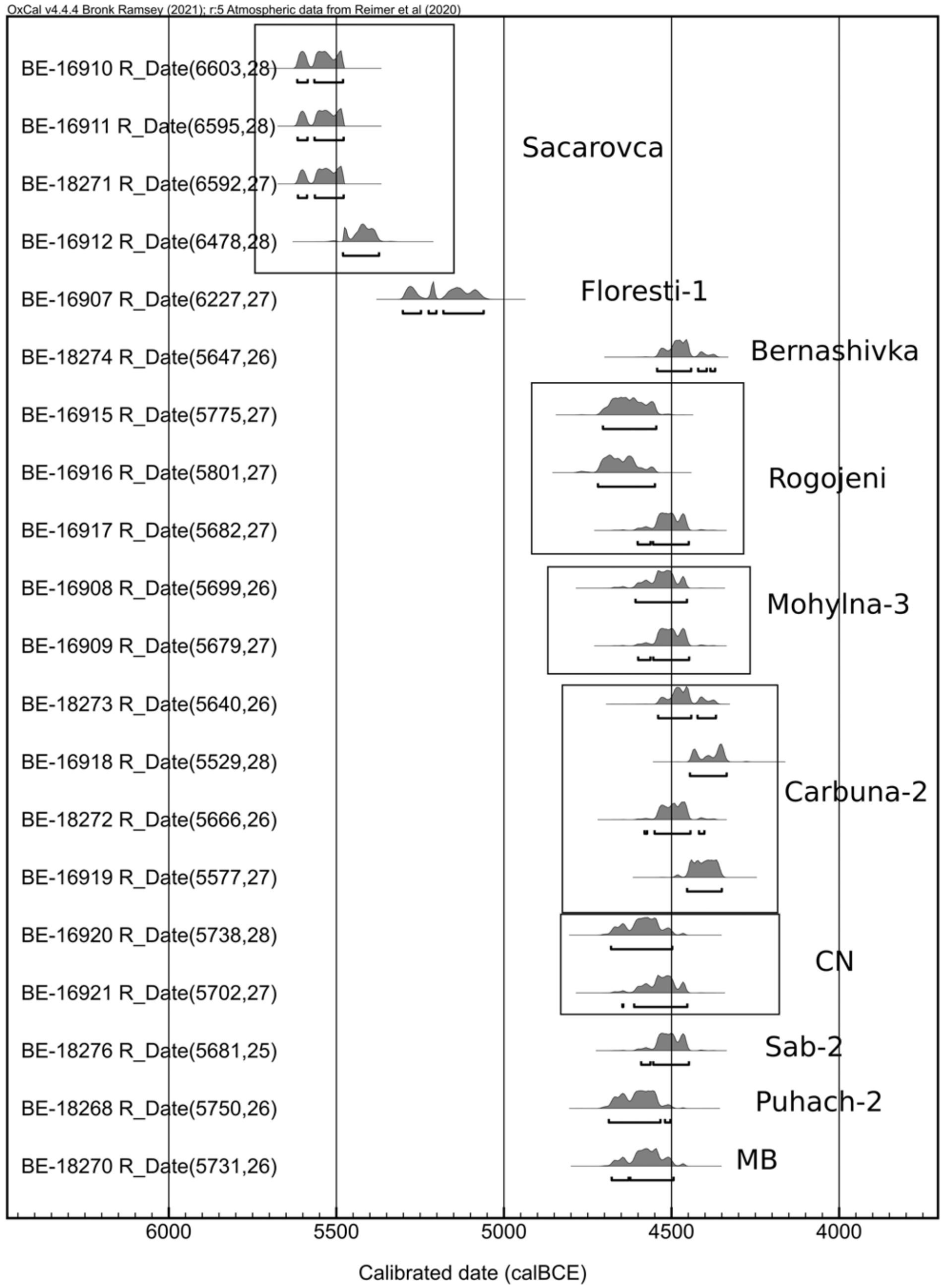

Figure 2. Calibration of the new dates. CN—Cărbuna-Negrub, Sab-2—Sabatynivka 2, MB—Mykolyna Broiaka.

Matviishyna 2023). For the sites of ceramic hunter-gatherers, samples were taken from cultural layers due to the lack of well-defined structures, which is a characteristic feature of these ephemeral encampments.

Table 2. *New radiocarbon dates*

Site	Lab no.	BP	±	$\delta^{13}C$ (AMS, ‰)	C content,% w/w	C:N	calBC (2 σ)
			Cris III/IV—LBK				
Sacarovca	BE-16910	6603	28	–20.5	46.8	3.2	5616–5479
Sacarovca	BE-16911	6595	28	–21.2	47	3.22	5615–5477
Sacarovca	BE-18271	6592	27	–20.4	44.7	3.25	5614–5477
Sacarovca	BE-16912	6478	28	–21	45.7	3.24	5479–5372
Floreşti-1	BE-16907	6227	27	–20.5	46.9	3.22	5301–5060
			PCII-TrA1-2				
Bern-1	BE-18274	5647	26	–21.6	43.7	3.22	4542–4369
Bern-1	*BE-18275*	*4656*	*24*	*–19.9*	43.6	3.23	*3515–3365*
Rogojeni-1	BE-16915	5775	27	–21	46.7	3.19	4704–4545
Rogojeni-1	BE-16916	5801	27	–22.1	46.6	3.19	4719–4549
Rogojeni-1	BE-16917	5682	27	–25	45.9	3.19	4600–4448
			PCIII-TrA3				
Mohylna-3	BE-16908	5699	26	–18.6	47.2	3.21	4607–4453
Mohylna-3	BE-16909	5679	27	–23.2	47.1	3.22	4599–4447
Cărbuna-2	BE-18273	5640	26	–18.4	44.6	3.19	4539–4367
Cărbuna-2	BE-16918	5529	28	–26.1	42.3	3.24	4444–4335
Cărbuna-2	BE-18272	5666	26	–20.3	40.6	3.19	4580–4401
Cărbuna-2	BE-16919	5577	27	–22.7	44.1	3.25	4453–4349
CN	BE-16920	5738	28	–23.9	44.7	3.22	4680–4497
CN	BE-16921	5702	27	–23.9	45.2	3.22	4646–4452
Sab-2	BE-18276	5681	25	–20.1	44.4	3.22	4590–4447
			Ceramic hunter-gatherers with TrA3 finds				
Puhach-2	BE-18268	5750	26	–21.1	44.8	3.24	4686–4503
MB	*BE-18269*	*6762*	*27*	*–19.9*	45.4	3.2	*5719–5625*
MB	BE-18270	5731	26	–21.3	44.4	3.22	4678–4493

Captions: see Table 1.

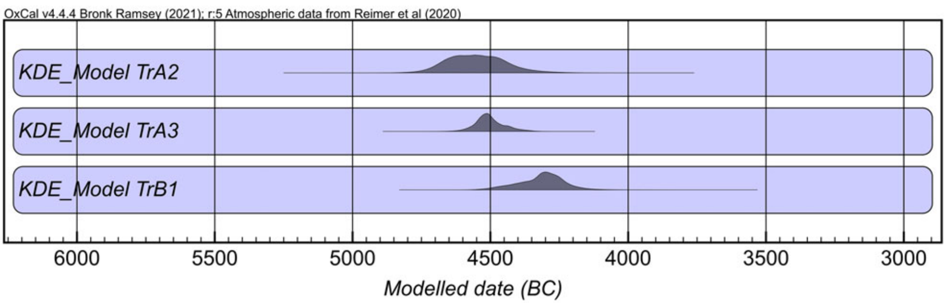

Figure 3. *Modeling of the dates, including legacy dates: KDE (kernel density estimates; Bronk Ramsey 2017) model plots according to OxCal. TrA1-A2—Precucteni II, Trypillia A1-A2 (9 dates); TrA3—Precucteni III, Trypillia A3 (27 dates); TrB1—Cucuteni A—Trypillia B1 (42 dates).*

Results

Four radiocarbon dates were obtained for the youngest Criş culture site in the region: Sacarovca I (Figure 2). Three dates (BE-16910, BE-16911, BE-18271; Tables 1–2) can be calibrated into the range starting at 5616 and lasting till 5477 calBCE at 2σ, while the fourth date, BE-16912, is slightly later:

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5479–5372 calBCE (2σ). A single radiocarbon date, BE-16907, for the LBK site of Floreşti I is calibrated to 5301–5060 calBCE (2σ), adding up to the picture of Neolithic chronology of the region prior to the Early Trypillian expansion (Figure 2).

The sites of the first phase of the early Trypillian expansion yielded somewhat contradictory results. Pit 4 from the site of Rogojeni was dated to the time-slot of 4719–4545 calBCE (2σ), or to 4711–4551 calBCE (2σ), when two dates for this pit are combined, assuming a quick filling of the pit 4 (Function R_Combine of OxCal), while pit 3 with a similar ceramic assemblage was placed into 4600–4448 calBCE (2σ) by a single date, BE-16917 (Figure 2). For the site of Bernashivka, the date BE-18275 is probably related to the Late Trypillian horizon of the site and is irrelevant for our discussion. It calls into question the homogeneity of the contexts of the early horizon of this site. The date BE-18274 can be calibrated to 4542–4369 calBCE (2σ) and evidently is not the earliest date in our dataset

The dates for the settlements of the Cărbuna microregion may indicate their diachronic chronological position. The site of Cărbuna-Negrub existed during 4680–4452 calBCE (2σ), while the site of Cărbuna 2 was settled in 4580–4335 calBCE (2σ). Two dated pits of Cărbuna 2 (N 6 and N9) existed roughly contemporaneously but rather for a prolonged period of time.

The settlements from the Southern Buh river valley were founded by 4607–4447 calBCE, 2σ (Mohylna-3, BE-16908, BE-16909) or 4590–4447 calBCE, 2σ (Sabatynivka-2, BE-18276, Figure 2).

A slightly earlier set of dates was obtained for the encampments of ceramic hunter-gatherersyielding Early Trypillian potsherds. Puhach II site was dated to 4686–4503 calBCE, 2σ. Mykolyna Broiaka obtained two inconsistent dates. An earlier date (BE-18269) comes from a scatter of finds designated as "dwelling 1" by the excavator (Danilenko 1969) and the depth –280 cm, while above a later stratigraphic unit dated to 4678–4493 calBCE, 2σ (BE-18270, Figure 2) followed.

Discussion

The radiocarbon dates do often disagree with the existing ideas on the sequence of defined typological groups in Neolithic and Eneolithic: in the Balkans (Biagi et al. 2005), in the Carpathian Basin (Oross and Siklósi 2012), in central Germany (Müller 2004), as well as for later phases of Trypillia in Ukraine (Shatilo 2021; Videiko 2016, 64–67). The typo-chronology of Early Trypillia includes several stages defined mostly by ceramic decoration styles (Videiko 2004; Zbenovich 1989). It mirrors the scheme developed by Hortensia and Vladimir Dumitrescu for its Romanian Precucuteni counterpart (Dumitrescu 1957, 1963).

The dated sites can be subdivided into the supposed earlier group (Rogojeni and Bernashivka) and the supposed later group (Cărbuna II, Cărbuna-Negrub, Mohylna-3, Sabatynivka-2). The supposed sequence is based mostly on ceramic ornamentation. The earlier sites have not yielded only the earliest dates, but also dates synchronous with the later stages In Rogojeni, the pit 3 yielded a date slightly later than a pair of dates for pit 4, despite the fact that both pits had a similar ceramic assemblage. Surprisingly late dates were obtained for the site of Bernashivka labeled "the earliest Trypillian site in Ukraine" (Zbenovich 1989) on typo-chronological grounds. The same can be said about the sites of the later group. According to the pair of new dates, Cărbuna-Negrub was settled in 47–45th centuries BCE, while both pits of Cărbuna 2 were filled slowly somewhere in the range of 46–44th centuries BCE, because pairs of dates for each pit are difficult to combine.

Therefore, the novel dates for these two groups of sites are evidently overlapping. The same observation is true if legacy dates are included (Popovici and Draşovean 2020; Rassamakin 2012) as well as if we add to the sequence the third latest phase, including the dates of the following typo-chronological stage, Trypillia B1/Cucuteni A3 (Kiosak and Lobanova 2021; Mantu 2000). The Kernel Density Estimate (KDE) plots (Bronk Ramsey 2017) for each supposedly consecutive phase start in an expected order, however, they overlap to a large extent. The wiggles of the radiocarbon calibration curve between 4500 and 4300 calBCE increase the uncertainty in the chronological sequence.

When modeling with OxCal Bayesian Sequence models, if all available dates are taken into account, it is impossible to arrive at a consistent picture of the development of the P-ET group. First of all, the

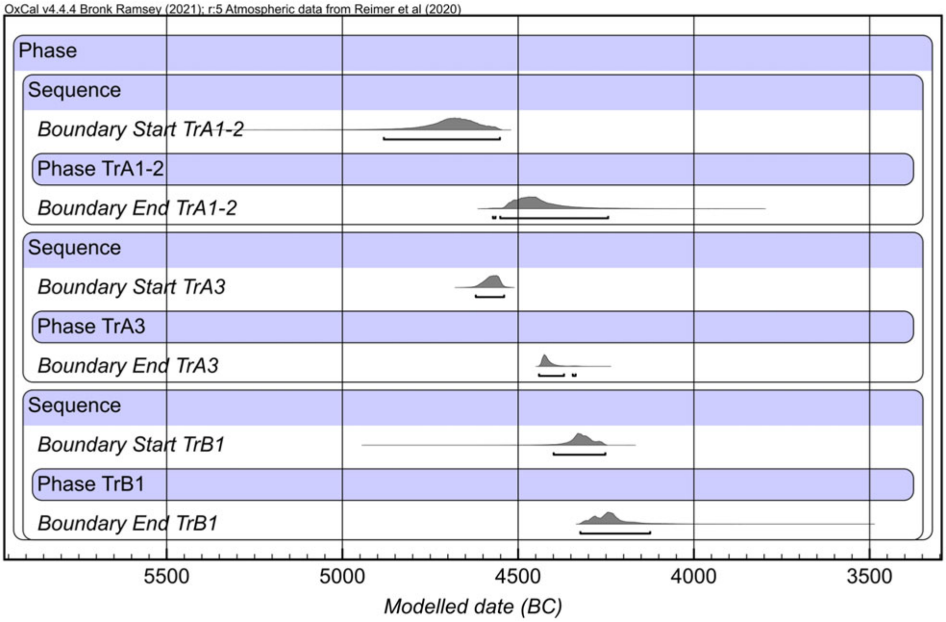

Figure 4. *Model 2 (with overlapping phases). TrA1-2—the early groups of P-ET sites; TrA3—the late groups of P-ET sites; TrB1—the reference group of Cucuteni A–Trypillia B1 sites (Suppl. mat. 2).*

dates of the Kyiv laboratory obtained in several series between 1998 and 2008 should be discarded. They are 400–600 years earlier than the other dates (Kiosak et al. 2023). Furthermore, many of the conventional dates have large standard deviations and turn into huge time intervals when calibrated. Moreover, many of the legacy dates come from unclear archaeological contexts or are outright inconsistent with the context from which the sample was taken, suggesting disturbances of cultural layers not noticed during excavations.

The simplest strategy is to consider only AMS dates, which was done in models 2–4 (Suppl. mat. 2, Figure 4). The dates for each chronological group defined on the basis of typo-chronology were united in a respective phase. The AMS dates for the latter and relatively well-dated Cucuteni A–Trypillia B1 (Popovici and Draşovean 2020; Kiosak et al. 2021) were used to limit the end of the latest group of P-ET. The delimiters (boundaries) between phases were organised to reflect the supposed ordering of them. The models reflect the different ways of organizing the chronological phases proposed for Oxcal: overlapping, when phases do not constraint each other (model 2 in Suppl. mat 2, Figure 4), contiguous, when phases are in chronological order and share a single boundary (transition) in-between (model 3 in Suppl. mat 2), earlier phases limit the later phases, and sequential, when earlier phases constraint the later but there is a possibility of a gap between phases (model 4 in Suppl. mat 2). The agreement indices are acceptable only for model 2 (overlapping phases), while models of sequential and contiguous phases fail at the validation by agreement indices (Table 3). Thus, this type of modeling largely supports the assumption that the P-ET phases developed partially simultaneously rather than sequentially.

However, there can be another strategy. Accepting that the phases are sequential, we can discard some (not all) legacy dates and also some AMS dates badly fitting into the hypothesis of the sequential phases. When we discard the dates done on charcoal (due to probable "old-wood" effect) as well as the dates for dubious stratigraphic contexts (as it is the case for Bernashivka dates), there is some space for the chronological separation of the phases (OxCal Sequential Phases Model 5, Suppl. Mat 3: Trypillia A1-2—4753–45451 calBCE, 2σ; Trypillia A3—4592–43819 calBCE, 2σ; Trypillia B1—4389–4218 calBCE, 2σ, see Suppl. Materials 3, Figure 5). However, these Bayesian estimates are largely an artefact of the preliminary selection of dates and the chronological intervals stated above need to be treated with

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Table 3. *Results of modeling of AMS dates for Precucuteni–Trypillia A (28) and selected reference dates for CuA–Trypillia B1 (5) in OxCal (Suppl. Mat. 2)*

	Sequential-model 3		Overlapping-model 2		Contiguous-model 4
Phase	Start	End	Start	End	Start
PCII—TrA1-2	4686–4547	4603–4522	4882–4553	4565–4240	4706–4552
PCIII—TrA3	4586–4511	4439–4330	4624–4542	4441–4369	4604–4531
CuA—TrB1	4372–4257	4325–4195	4394–4253	4323–4139	4439–4317
Agreement	Poor agreement, A = 23.8%		Amodel = 72.8		Poor agreement, A = 31%

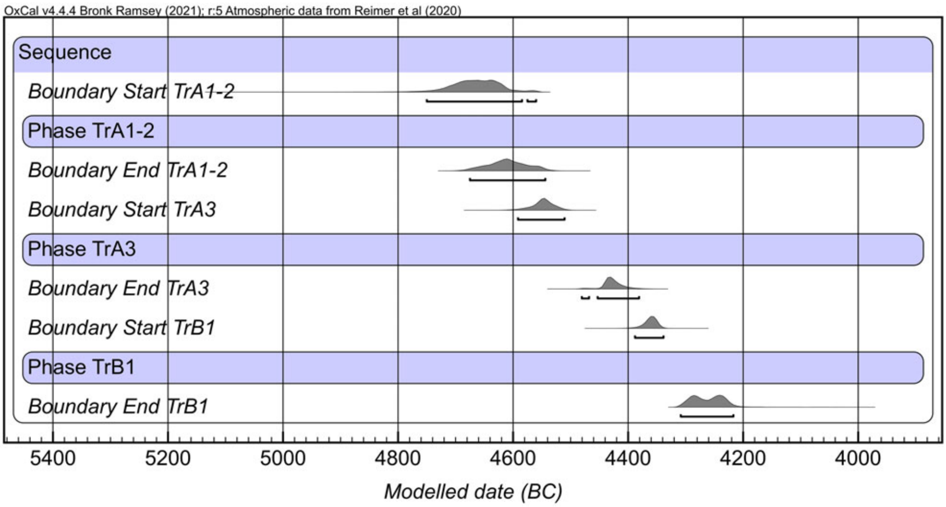

Figure 5. *The model (Model 5, Suppl. Mat 3.) with "irrelevant" dates excluded (dates which showed poor agreement with the model as defined by OxCal). Captions: see Figure 4.*

caution and be verified by the enhanced stratigraphic controls as well as by additional radiocarbon dating. Rather, it is likely that ceramic styles defining supposed phases of Early Trypillian typo-chronology appeared in chronological order as suggested by archaeological seriation, but, then, coexisted over a long period of time.

The results indicate that stylistic groups of pottery decoration are not necessarily defined by the chronological position of respective sites. They could reflect other complex social processes and coexist for quite long intervals of time.

Early Trypillians have reached into the North Pontic Steppe as evidenced by finds of their pottery on the riverside sites of the Southern Buh river (Tovkailo 2005). The new date for Puhach 2 site corresponds well to the previous dating efforts (Tovkailo 2004, 2014) and could be related to the Early Trypillian habitation as well as to the stratigraphic unit left by ceramic hunter-gatherers. It is synchronous with the beginning of life on the Early Trypillian settlements of Mohylna-3 and -5 and slightly pre-date the Early Trypillian sites of Hrebeniukiv Iar and Sabatynivka II. The Mykolyna Broiaka site of ceramic hunter-gatherers (which, contrary to Puhach 2, has not yielded Early Trypillian pottery but a few shards) yielded a date related to the same timeslot, thus we cannot exclude a chronological "window of possibilities" (Haskevych 2021) for the contact between indigenous hunter-gatherers equipped with pottery and early farmers of Trypillia A, however, additional data are evidently required to state it with certainty.

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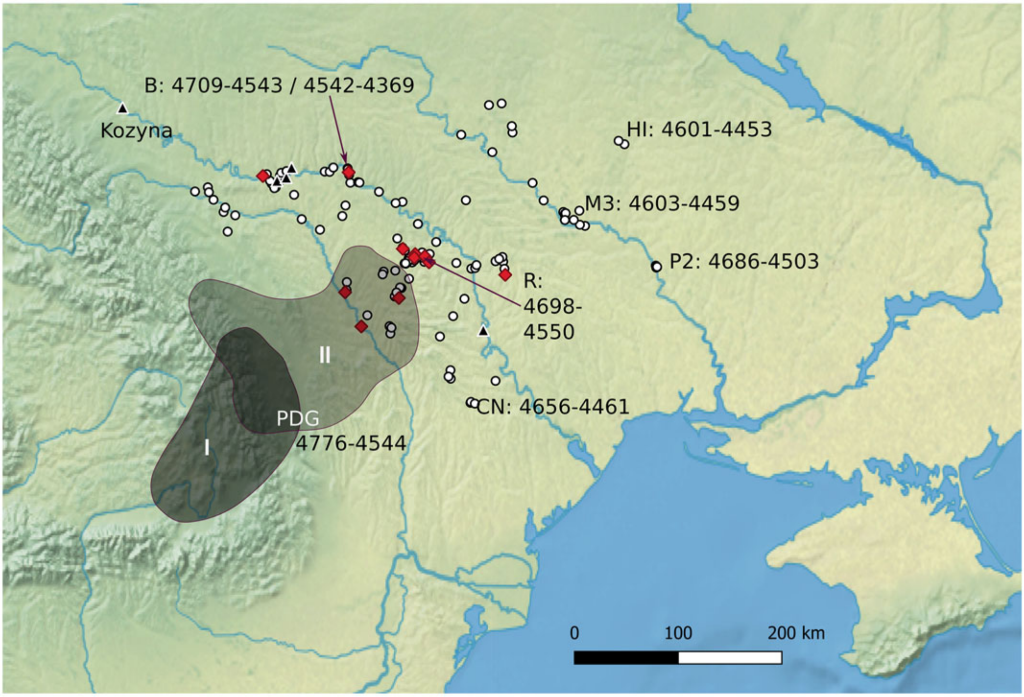

Figure 6. *Map of Early Trypillia distribution indicating the calibrated relevant dates available to this moment (in years, BCE, 2σ). I, II—distribution of Precucuteni I and II (Garvăn et al. 2009). Rhomboids: Precucuteni II - Trypillia A1-2 sites, circles—Precucuteni III - Trypillia A3 and undefined early Trypillia sites, triangles—Trypillia A4 sites. PDG—Poduri-Dealul-Ghîndaru, M3—Mohylna-3, B—Bernashivka, R—Rogojeni, CN—Cărbuna-Negrub, Hrebenniukiv Iar—HI, Puhach-2—P2.*

Some Neolithic cultural groups have been pointed out as sources of the P-ET ceramic complex, but the available radiocarbon dating database contradicted these typological assumptions, as there was a significant time gap between their end and the expected beginning of the P-ET. The new results of Sacarovca 1 dating are consistent with an observation made on the chronology of the Starčevo-Criş-Körös complex in general: namely, that it is highly unlikely that it survived after 5400 BCE (Meadows 2019, 39). Thus, a chronological gap of ca. 500–800 years (estimated by Interval query of OxCal, see Suppl. Materials 5) between the latest local Criş communities and the arrival of the Early Trypillians (P-ET) is quite long. It is highly unlikely that the late Criş contributed to the formation of P-ET directly.

The same hypothesis could be put forward regarding the role of LBK in the origin of P-ET. The single new date for Floreşti 1 adds up to the existing database of 25 relevant AMS-dates for LBK in its eastern range (Kiosak et al. 2021; Moskal-del-Hoyo et al. 2024; Saile 2020; Salavert et al. 2020; Suppl. Table 4). It is in reasonable correspondence to the chronology of the *Notenkopf* phase of LBK in Central Europe (Oross and Banffy 2009). Floreşti I was attributed to the later phase of LBK in the Eastern Europe (Larina 1999). Thus, there is insufficient evidence to support the longer persistence of LBK in the south of Eastern Europe than elsewhere and, probably, there is a gap of 150-250 years between the latest LBK and the P-ET (TrA1-3, spread; see Suppl. Table 4 and suppl. Mat. 5; or otherwise ca. 4950–4850 BCE [Stadler and Kotova 2021, 236] and 4750–4700 BCE, this work). Thus, the new dates highlight the existing gaps between these cultural groups and the time of the spread of P-ET.

The Early Trypillian expansion happened in the 47–45th centuries BCE and was not a slow and gradual diffusion. Instead, the banks of the Dniester and Southern Buh were reached relatively fast in the course of the propagation of early farming groups (Figure 6). In fact, it may have taken at most 3–4 generations of Trypillians to cover the distances of several hundred kilometres. For example, the

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interval of dates between the earliest dates for the site of Poduri-Dealul-Ghindaru in Carpathians and the set of dates for the easternmost dated sites of Hrebeniukiv Iar and Mohylna 3 is 0–170 and 0–140 years, 2σ, respectively (modeled in OxCal with Interval query), while the distances between them are 340 and 380 km. Taking into account the possible "old-wood" effect for the charcoal Berlin laboratory dates of Poduri-Dealul-Ghindaru, the actual chronological interval for diffusion may be even narrower. We thus assume that Early Trypillia did spread in a "leapfrog" mode (Forenbaher and Miracle 2005), "jumping" great distances and bypassing large, unsettled areas.

Conclusion

The novel series of AMS dates almost doubled the existing database for P-ET horizon. They indicate that some cultural groups supposedly taking part in the formation of Precucuteni-Early Trypillia disappeared several centuries prior to the appearance of the earliest sites in question. This observation favors models that give a major role in the origin of Precucuteni to somewhat younger cultural groups, namely Boian (like Comşa 1987; cf. Garvăn et al. 2009). Furthermore, the expansion of Early Trypillia into Moldovan and Ukrainian forest-steppe took place during the 47th–45th centuries BCE. It was a relatively fast dispersal. According to the radiocarbon chronology, the stylistic groups of Early Trypillian pottery appeared in sequence expected on the basis of typo-chronological analyses and, then, coexisted to a large extent. The earlier dates for Poduri-Dealul Ghindaru, Rogojeni and Bernashivka could point to the appearance of Precucuteni II–Trypillia A1-2 stylistic group by 47th century BCE. However, already in 46–45th century BCE, a complex system of Precucuteni III–Trypillia A3 settlements was founded reaching the farthest corners of Early Trypillian distribution (Figure 6): in the steppe (Cărbuna-Negrub and Puhach-2), in the north-east direction (Mohylna-3, and slightly later: Sabatynivka-2, Hrebeniukiv Iar), and in the north, towards the Dniester river (novel date for Bernashivka). The northwest limit of distribution (the site of Kozyna, Figure 6) was reached during another typo-chronological phase, Trypillia A4 (Tkachuk et al. 2010), already contemporaneous with the sites with painted pottery of Cucuteni A and Trypillia B1.

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Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/RDC.2024.88

References

Biagi P, Shennan S and Spataro MP (2005) Rapid rivers and slow seas? New data for the radiocarbon chronology of the Balkan peninsula. In Nikolova L and Higgins J (eds), *Prehistoric Archaeology and Anthropological Theory and Education*. Salt Lake City and Karlovo: Reports of Prehistoric Research Projects, 41–52.

Bodean S (2001) *Aşezarile Culturii Precucuteni-Tripolie A Din Republica Moldova (Repertoriu)*. Chişinău: Pontos.

Bodean S and Bicbaiev V (2014) Cercetări arheologice preventive în staţiunea eneolitică Rogojeni I (com. Rogojeni, r-nul Şoldăneşti). *Arheologia preventivă în Republica Moldova* **I**(1–2), 9–22.

Bodean S and Heghea S (2018) Investigaţii arheologice în siturile eneolitice de la Cărbuna (campania 2018). *Akademos. Revistă de ştiinţă, inovare, cultură şi artă* **50**(3), 91–94.

Bodean S and Heghea S (2019) Cercetări arheologice în siturile eneolitice de la Cărbuna. Campania 2018. In Vornic V (ed), *Cercetări Arheologice În Republica Moldova: Campania 2018: Sesiunea Naţională de Rapoarte, 18 Aprilie 2019: Program: Rezumatele Comunicărilor*. Chişinău: Comisia Naţională Arheologică, 19–21.

Bodean S and Heghea S (2021) Cercetări arheologice în aşezarea eneolitică Cărbuna II. Campania 2020. In Vornic V (ed), *Cercetări Arheologice În Republica Moldova: Campania 2020: Sesiunea Naţională de Rapoarte, 16 Aprilie 2021: Program: Rezumatele Comunicărilor*. Chişinău: Comisia Naţională Arheologică, \7–9.

Bodean S and Noroc I (2019) Aşezarea Precucuteni-Tripolie A de la Cărbuna-Negrub. Consideraţii preliminare. In Ghilaş V and Dolghi A (eds), *Patrimoniul Cultural: Cercetare, Valorificare, Promovare. Vol. I. Materialele Conferinţei «Patrimoniul Cultural: Cercetare, Valorificare, Promovare», Ediţia a 11-a, Chişinău, 29-30 Oct. 2019*. Chişinău: Institutul Patrimoniului Cultural, 29–30.

Bronk Ramsey C (2009) Bayesian analysis of radiocarbon dates. *Radiocarbon* **51**(1), 337–360. https://doi.org/10.1017/S0033822200033865.

Bronk Ramsey C (2017) Methods for summarizing radiocarbon datasets. *Radiocarbon* **59**(6), 1809–1833. doi: 10.1017/RDC.2017.108.

Bronk Ramsey C and Lee S (2013) Recent and planned development of the program OxCal. *Radiocarbon* **55**(2–3), 720–730. https://doi.org/10.1017/S0033822200057878.

Burdo N (1997) Ranniotrypils'ki pamiatky mizh selamy Mohylna ta Zhakchyk na Kirovogradschyni [Early Trypillieаn sites between villages Mohyl'na and Zhakchik in the Kirovograd region]. *Archaeometria ta ohorona istoryko-kul'turnoji spadschyny* **1**, 67–71.

Burdo N (2003) Novye dannye dlia absolutnoj datirovki neolita i rannego eneolita na territorii Ukrainy [New data for absolute chronology of Neolithic and Early Aeneolithic in the territory of Ukraine] (In Russian). *Stratum Plus*, 431–446.

Burdo N (2011) Late Neolithic cultural elements from the Danube and Carpathian regions of Precucuteni—Trypillia A culture. *Documenta Praehistorica* **38**: 367. https://doi.org/10.4312/dp.38.28

Burdo N (2018) Early Trypillian sanctuary at Sabatynivka II. Problem of interpretation of Trypillian building remains. *Archaeology and Early History of Ukraine* **28**(3), 39–45. http://dspace.nbuv.gov.ua/handle/123456789/162316

Chapman J, Gaydarska B and Nebbia M (2019) The origins of Trypillia megasites. *Frontiers in Digital Humanities* **6**(10). https://doi.org/10.3389/fdigh.2019.00010

Comşa E (1987) *Neolitcul Pe Teritoriul României – Consideraţii*. Bucureşti: Editura Academii Republicii Socialiste România.

Covalenco S, Bodean S and Bicbaiev V (2015) Flint artefacts from excavations of Early Trypillian settlement of Rogojeni I in 2013 [Kremnevye izdeliia iz raskopok rannetripolskogo poselenia Rogojeni v 2013 g.]. *Revista Arheologică, seria nouă* **11**(1–2), 143–153.

Danilenko VN (1969) *Neolit Ukrainy: Glavy Drevnejshej Istorii Jugo-Vostochnoj Evropy [Neolithic Ukraine: Issues of Ancient History of South-East Europe]*. Kyiv: Naukova dumka.

Dumitrescu H (1957) Contributii la problema originii culturii Precucuteni. *Studii şi cercetari de Istorie Veche* **VIII**(1–4), 53–72.

Dumitrescu V (1963) Originea şi evolutia culturii Cucuteni-Tripolie I. *Studii şi cercetari de Istorie Veche* **XIV**(1), 51–74.

Forenbaher S and Miracle P (2005) The spread of farming in the Eastern Adriatic. *Antiquity* **79**, 211–222.

Garvăn D, Buzea D, Frînculeasa A and Dumitroaia G (2009) Precucuteni : Originea Unei Mari Civilizaţii ; Catalog de Expoziţie/ Centrul Internaţional de Cercetare a Culturii Cucuteni ... Daniel Garvăn ; Dan Buzea ; Alin Frînculeasa. Ed.: Georghe Dumitroaia. Muzeul de Istorie Şi Archeologie Piatra-Neamţ. *Bibliotheca Memoriae Antiquitatis* **23**. Piatra-Neamt: Ed. Constantin Matasă.

Garvăn D, Munteanu R, Dinu C and Frinculeasa A (2022) Datarea nivelului Precucuteni de la Lipia—Movila Drumul Oilor (jud. Buzău). In Diaconu V (ed), *Ab lapide admetallum: Studia in honorem Professoris Marin Cârciumaru,* 219–232.

Gaskevych DL (2014) Problemy radiovugletsevogo datuvannia bugo-dnistrovskoji neolitychnoji kul'tury [Issues of the radiocarbon dating of Bug-Dniester Neolithic culture] (In Ukrainian). *Arheologija [Археологія]* **4**, 3–17.

Gaydarska B, Nebbia M and Chapman J (2020a) Trypillia megasites in context: Independent urban development in Chalcolithic Eastern Europe. *Cambridge Archaeological Journal* **30**(1), 97–121. https://doi.org/10.1017/S0959774319000301.

Gaydarska B, Nebbia M, Chapman J, Caswell E, Arbeiter S, Ovchinnikov E, Gaskevych D, Lazăr C, Ignat T, Boyce A, Dolan A, Newton J, Kiosak D, Belenko M, Craig OE, Robson HK, von Tersch M, Lucquin A, Tóth Z, Choyke A, Orton D, Nottingham J, Rainsford-Betts G, Hosking K, Millard A and Pashkevych G (2020b) The finds. In Gaydarska B (ed), *Early Urbanism in Europe: The Trypillia Megasites of the Ukrainian Forest-Steppe*, 265–414.

Hasiuk MS (1954) Razvedky rannetripolskih poselenij u s. Mohilna [Surveys of Early Trypillian sites by vill. Mohyl'na]. *Kratkie soobschenia Instituta istorii material'noi kul'tury* **54**, 173–75.

Haskevych D (2021) Beside or by turn? The Buh-Dnister foragers and the Linear Band Pottery farmers on the Southern Buh River (Ukraine). *Sprawozdania Archeologiczne* **73**(1), 216–245. https://doi.org/10.23858/SA/73.2021.1.2480.

Kiosak D, Kotova N, Tinner W, Szidat S, Nielsen E, Brugger S, de Capitani A, Gobet E and Makhortykh S (2021) The last hunter-gatherers and early farmers of the middle Southern Buh river valley (Central Ukraine) in VIII–V mill. BC. *Radiocarbon* **63**(1), 121–137. https://doi.org/10.1017/RDC.2020.120.

Kiosak D and Lobanova M (2021) On the chronology of the Sabatynivka group of the Cucuteni-Trypillia cultural complex (Central Ukraine). *Sprawozdania Archeologiczne* **73**(2), 25–46. https://doi.org/10.23858/SA/73.2021.2.2405.

Kiosak D and Matviishyna Z (2023) The soils of early farmers and their neighbors in the southern Buh Catchment (Ukraine): Micromorphology and archaeological context. *Land* **12**(2). https://doi.org/10.3390/land12020388.

Kotova NS (2015) *Drevnejshaja Keramika Ukrainy [The Most Ancient Pottery in Ukraine]*. Kyiv - Kharkiv: Maidan.

Kozubovsky FA (1933) *Arheologichni Doslidzhennia Na Terytorii BOHESu 1930–1932 Rr. Pidsumky Arheologichnyh Robit v Raioni Maibutniogo Pidtoplennia Boz'koji Hidroelectrocentrali Archaeological Investigation on the Territory of BOHES in 1930–1932. Results of Archaeological Wor*. Kyiv: VUAN.

Larina OV (1999) Kul'tura linejno-lentochnoj keramiky Pruto-Dnestrovskogo regiona [Linearbandkeramik culture in Prut-Dniester region]. *STRATUM Plus* **2**, 10–140.

Lobanova MA, Matviishyna ZhM and Kiosak D (2021) The issue of the stratigraphy of the site Sabatinovka i and the enviromental settings of the Southern Bug Region in the Eneolithic–Late Bronze Age. *Stratum Plus* **2021**(2), 31–52. https://doi.org/10.55086/sp2123152.

Mantu C-M (1998) *Cultura Cucuteni. Evoluţie, cronologie, legături*. Piatra-Neamţ: Muzeul de istorie Piatra Neamţ.

Mantu CM (2000) Relative and absolute chronology of the Romanian Neolithic. *Analele Banatului, S.N.* **VII–VIII**, 75–106.

Monah D (1987) La datation par C-14 du complexe culture Cucuteni-Tripolie. In Petrescu-Dimbovita M (ed), *La civilisation de Cucuteni en contexte Européen*. Iasi: Université "Al. I. Cuza", 67–79.

Marinescu-Bîlcu S (1974) *Cultura Precucuteni Pe Teritoriul României*. Bucureşti: Editura Academii Republicii Socialiste România.

Meadows J (2019) Radiocarbon dating and Bayesian chronological modeling. In Spataro M (ed), *Starčevo Ceramic Technology: The First Potters of the Middle Danube Basin*. Bonn: Verlag Dr. Rudolf Habelt GmbH, 34–45.

Moskal-del Hoyo M, Kapcia M, Salavert A, Alexandrowicz WP, Saile T, Kiosak D and Dębiec M (2024) Archaeobotanical and palaeoenvironmental analyses from the easternmost Early Neolithic sites at Kamyane-Zavallia (Ukraine) and Nicolaevca V (Moldova). *Vegetation History and Archaeobotany* **33**, 49–61 https://doi.org/10.1007/s00334-023-00944-y.

Müller J (2004) Typologieunabhängige Datierung und die Rekonstruktion prähistorischer Gesellschaften. *Archäologie in Sachsen-Anhalt* **2**, 21–29.

Müller J, Hofmann R, Ohlrau R and Shatilo M (2018) The social constitution and political organisation of Triolye mega-sites: hierarchy and balance. In Meller H, Gronenborn D and Risch R (eds), *Überschuss Ohne Staat - Politische Formen in Der Vorgeschichte, 10. Mitteldeutscher Archäologentag, 19-21 Oktober 2017 Halle (Saale)/Surplus without the State – Political Forms in Prehistory, 10th Archaeological Conference of Central Germany, 19–21 Octob.* Halle: Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, 247–262.

Nestor I (1951) Ceramica liniara in Moldova. *Studii şi cercetari de Istorie Veche* **II**(2), 17–26.

Oross K and Banffy E (2009) Three successive waves of Neolithisation: LBK development in Transdanubia. *Documenta Praehistorica* **XXXVI**, 175–189. https://doi.org/10.4312/dp.36.11.

Oross K, Siklósi Z (2012) Relative and absolute chronology of the Early Neolithic in the Great Hungarian Plain. In Anders A and Siklósi Z (eds), *The First Neolithic Sites in Central/South-East European Transect. Volume III. The Körös Culture in Eastern Hungary. BAR International Series 2334*. Oxford: Archaeopress Publishing Ltd, 129–160.

Passek TS (1949) *Periodizatsiia Tripol'skih Poselenii (III–II Mill. BC)*. Moscow-Leningrad: MIA.

Patokova EF, Petrenko VG, Burdo NB and Polischuk LY (1989) *Pamiatniki tripol'skoi kul'tury v Severo-Zapadnom Prichenomorie [The sites of Trypillian culture in North-western Black Sea region]*. Kyiv: Naukova dumka.

Popovici D and Draşovean F (2020) Despre evoluţia culturilor Precucuteni şi Cucuteni. Analiza bayesiană a datelor ^{14}C vs. Crono-tipologie. *Cercetări Arheologice* **27**: 331–86. https://doi.org/10.46535/ca.27.15.

Rassamakin Y (2012) Absolute chronology of Ukrainian Tripolian settlements. In Menotti F and Korvin-Piotrovsky A (eds), *The Tripolie Culture Giant-Settlements in Ukraine. Formation, Development and Decline*. Oxford and Oakville: Oxbow Books, 19–69.

Reimer PJ, Austin WEN, Bard E, Bayliss A, Blackwell PG, Bronk Ramsey C, Butzin M, Cheng H, Edwards RL, Friedrich M, Grootes PM, Guilderson TP, Hajdas I, Heaton TJ, Hogg AG, Hughen KA, Kromer B, Manning SW, Muscheler R, Palmer JG, Pearson C, van der Plicht J, Reimer RW, Richards DA, Scott EM, Southon JR, Turney CSM, Wacker L, Adolphi F, Büntgen U, Capano M, Fahrni SM, Fogtmann,Schulz A, Friedrich R, Köhler P, Kudsk S, Miyake F, Olsen J, Reinig F, Sakamoto M, Sookdeo A and Talamo S (2020) The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* **62**, 725–757. https://doi.org/10.1017/rdc.2020.41.

Saile T (2020) On the Bandkeramik to the east of the Vistula River: At the limits of the possible, *Quaternary International* **560–561**, 208–227. https://doi.org/10.1016/j.quaint.2020.04.036.

Salavert A, Gouriveau E, Messager E, Lebreton V and Kiosak D (2020) Multi-proxy archaeobotanical analysis from Mesolithic and Early Neolithic sites in south-west Ukraine. *Environmental Archaeology* **26**(3), 349–362. https://doi.org/10.1080/14614103.2020.1746879.

Shatilo L (2021) *Tripolye Typo-Chronology. Mega and Smaller Sites in the Sinyukha River Basin*. Leiden: Sidestone Press.

Stadler P and Kotova N (2021) Chronology of the Brunn sites in the context of the Linear Pottery Culture. In Stadler P and Kotova N (eds), *Early Neolithic Settlement Brunn Am Gebirge, Wolfholz, Site 3 in Lower Austria and the Milanovce Phase of the Linear Pottery Culture (LPC)*. Langenweißbach and Wien: Beier and Beran, 235–238.

Stuiver M and Polach HA (1977) Discussion: Reporting of radiocarbon dates. *Radiocarbon* **19**, 355–363.

Szidat S, Salazar GA, Vogel E, Battaglia M, Wacker L, Synal H-A and Türler A (2014) ^{14}C analysis and sample preparation at the new Bern Laboratory for the Analysis of Radiocarbon with AMS (LARA). *Radiocarbon* **56**, 561–566. https://doi.org/10.2458/56.17457.

Szidat S, Vogel E, Gubler R and Lösch S (2017) Radiocarbon dating of bones at the LARA Laboratory in Bern, Switzerland. *Radiocarbon* **59**, 831–842. https://doi.org/10.1017/RDC.2016.90.

Tencariu FA, Delhon C, Vornicu DM, Asăndulesei A, Braşoveanu C and Danu M (2022) Science revealing ancient magic: Phytolith evidence from the Early Chalcolithic site of Isaiia (eastern Romania). *Biology* **11**(8). https://doi.org/10.3390/biology11081102.

Ţerna S, Vornicu A, Hofmann R, Dal Corso M, Shatilo L, Vasilache-Curoşu M, Rud V, Knapp H, Kirleis W, Rassmann K and Müller J (2019) Stolniceni—Excavation results from the 2017 campaign. *Journal of Neolithic Archaeology* **21**, 209–282. https://doi.org/10.12766/jna.2019.9.

https://doi.org/10.1017/RDC.2024.88 Published online by Cambridge University Press

Tkachuk T, Kukula R, Krekhovetskyi I, Melnychuk O and Figol A (2010) The Early Trypillian settlement Kozyna (urochysche Solovche) in the Upper Dniester region [Poselennia ranniogo Trypillia Kozyna (urochysche Solovche) na verkhniomu Podnisteriji]. *Arheologichni doslidzhenia Lvivskogo universytetu* **13**, 219–238.
Tovkailo M (2004) Do problemy datuvannia bugo-dnistrovs'kogo neolitu [On the issue of dating of Bug-Dniester Neolithic] (In Ukrainian). *Kamyana doba Ukrainy* **5**, 236–246.
Tovkailo M (2005) *Neolithic of Steppe Buh Region [Neolit Stepovogo Pobuzhzhia]*. Kyiv: Shliakh.
Tovkailo M (2014) Neolitizatsija Jugo-Zapadnoj Ukrainy v svete novyh issledovanij poselenija Gard [Neolithization of southwestern Ukraine in the light of new investigations of Gard settlement] (In Russian). *Stratum Plus* **2**, 183–245.
Tovkailo M (2020) The Neolithic period in Ukraine. In Lillie M and Potekhina ID (eds), *Prehistoric Ukraine (From the First Hunters to the First Farmers)*. Oxbow Books, 111–154.
Ursu C-E (2016) Precucuteni—a culture or a chronological horizon? In Govedarica B and Ţerna S, editors. *Interactions, Changes and Meanings. Essays in Honour of Igor Manzura on the Occasion of His 60th Birthday*. Chisinau, 73–79.
Videiko M (2004) Periodyzatija trypil's'koji kul'tury [Periodization of Trypillian culture]. In Videiko my and Burdo N (eds), *Encyclopedia Trypils'koji Cyvilizatii. T. 1*. Kyiv, 77–84.
Videiko M (2016) Dniester-Dnieper interfluvial region at the turn of V–IV millennia BC. *Stratum Plus* **2**, 63–79. https://journals.indexcopernicus.com/search/article?articleId=1449530.
Videiko MYu, Chapman J, Burdo N, Gaydarska B, Terna S, Rud VS and Kiosak D (2015) Kompleksnye issledovania oboronitelnyh sooruzhenij, proizvodstvennyh kompleksov i ostatkov postroek na tripol'skom poselenii u sela Nebelevka [Complex investigations of defensive systems, production complexes and remains of constructions on the Tripolye settlement by the Nebelivka village]. *Stratum Plus* **2**, 147–70.
Vogel JC and Waterbolk HT (1972) Groningen Radiocarbon Dates X. *Radiocarbon* **14**(1), 6–110. doi: 10.1017/s0033822200001016.
Vornicu DM (2017) The chipped stone assemblage from the Early Chalcolithic settlement at Isaiia—Balta Popii. *Materiale şi cercetări arheologice* **XIII**, 191–212.
Vornicu D-M, Asăndulesei A, Boghian D and Tencariu F-A (2018) Recent investigations in the Early Chalcolithic settlement of Balş-La Brigadă (Romania). *Arheologia Moldovei* **XLI**,161–178.
Vulpe R (1957) *Izvoare. Bucuresti. Sapaturile Din 1936–1948*. Bucureşti: Editura Academiei Republicii Populare Romîne.
Zbenovich VG (1989) *Ranny Etap Trypol'skoi Kul'tury Na Territorii Ukrainy [Early Stage of Trypillian Culture in Ukraine]*. Kyiv: Naukova dumka.
Zbenovich VG (1996) *Siedlungen Den Frühen Tripol'e-Kultur Zwischen Dnestr Und Südlichem Bug*. Espelkamp: Verlag Marie Leidorf GmbH.

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