Edited by:

ROBERT HOFMANN, WIEBKE KIRLEIS, JOHANNES MÜLLER, VITALII RUD, STANISLAV ŢERNA†, MYKHAILO VIDEIKO

From Ros to Prut:

TRANSFORMATIONS OF TRYPILLIA SETTLEMENTS

VOLUME II

SCALES OF TRANSFORMATION IN PREHISTORIC AND ARCHAIC SOCIETIES | **19.2**

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TRYPILLIA MACROSCALE

19. Radiocarbon dating: Trypillia detailed chronology, house duration estimates and the contemporaneity of earliest European mega-sites

Johannes Müller, Robert Hofmann, Wiebke Kirleis, Liudmyla Shatilo, Frank Schlütz, Mykhailo Videiko, Vitalii Rud, Stanislav Ţerna†, Andreea Ţerna

Abstract

In Europe, early giant settlements with a settled area of more than 100 ha are known from the Central Ukrainian Chalcolithic ca. 4100–3600 BCE. Recent environmental, geophysical and archaeological investigations confirmed the immense size of these 'mega-sites'. Nevertheless, answers to raised questions regarding population densities, carrying capacities and social developments depend on a secure chronological phasing of the phenomenon. In three test areas, the dating program for mega- and other sites was conducted. In addition to already existing data, context analyses of the sampled features allowed a secure reconstruction of the chronology including Bayesian calibration at many localities. The discovery of a clear spatial concept of settlement occupation, the contemporaneity of different investigated mega-sites, and the reconstruction of household durations and of overall site developments within local roots changed the view on Trypillia. In consequence, triggers of mega-site foundation and abandonment have been identified. The chronological models verify a high population density (not less than 37.5 p/km² in the Central Sinyukha Basin, Central Ukraine, representing the Trypillia mega-site core area during Middle Trypillia).

Introduction

The discovery of giant settlements in European prehistory is one of the most striking results of technical improvement of field survey methods within the last 20 years (cf. Gaydarska and Chapman 2022). From Andalusia to Southeast Europe and the Central

Ukraine, sites with approximately more than 100 ha have been discovered. For the interpretation of these phenomena, not only the temporal development of each site but also the temporal relation to nearby sites is of importance for answering certain questions: How big was the population in these mega-sites? How big was the population in the core areas of mega-sites? Was the carrying capacity of the environment reached at a certain stage of the development? Which environmental or social triggers are important for the foundation, development and end of these sites?

The appearance of giant settlements in different European regions is a phenomenon which is not interlinked but seems to be the result of perhaps similar structural developments in certain Chalcolithic societies. While the West Iberian giant settlements date to about 2800–2300 BCE, the Central Balkan Vinča candidates for giant settlements date to ca. 4800–4300 BCE and the Ukrainian Trypillia mega-sites to ca. 4100–3600 BCE. For Vinča, new research shows that at least contemporaneous parts of the sites were much smaller than originally thought (Raczky *et al.* 2022; Rassmann *et al.* 2021). In consequence, the Trypillia development indicates one of the most ancient appearances of mega-sites, roughly contemporaneous with early Near Eastern urbanisation processes.

The immense size of the domestic occupation area of Central Ukrainian mega-sites has not been reached in any other European region. As huge population agglomerations were postulated for the Middle Trypillia sites, both questions of early urbanisation and of the start of epidemic plagues within these demographic agglomerations have been discussed (Müller *et al.* 2016b; Gaydarska 2020; Rascovan *et al.* 2019). Furthermore, the concentric planning of huge house rings around an inner empty space as well as the discovery of special buildings motivated ideas about social planning and political organisation (Hofmann *et al.* 2019). In consequence, an environmental-archaeological research project was started, of which the evaluation of chronological information serves as the backbone for the interpretation of the Trypillia mega-phenomenon.

Archaeological samples and evaluation method

Within our still ongoing research project on Middle Trypillia mega-sites, three test regions, which represent three areas of dense Trypillia activity, are the focus of archaeological activities (Fig. 1; cf. Chapter 1: Fig. 2, this volume). The largest mega-sites are known from the Central Sinyukha Basin near Uman (Central Ukraine), where in an area of 9600 km², 12 sites measuring more than 100 ha in size cluster. In addition to geophysical surveys of many sites, larger excavations took place in Talianki, Maidanetske and Nebelivka, where different teams tried to reconstruct the activity patterns from household to site level. Detailed excavations were also carried out in Dobrovody, while in other sites with geophysical documentation, mainly small test trenches were conducted to gain dating samples (Müller *et al.* 2016b; Ohlrau *et al.* 2016; Shatilo 2021; Ohlrau 2020; Gaydarska 2020; Hofmann *et al.* 2019).

Trypillia sites range from small-scale sites to huge mega-sites. In the Central Sinyukha Basin, Maidanetske (2.00 km²) is one of the largest sites with 9 concentric house rings, two enclosures, a house-free ring corridor, an empty central space, different radial tracks that lead into the centre of the site, and public plazas (Müller *et al.* 2017; Ohlrau 2020). While most of the houses are oriented to the centre on their longitudinal axes, houses in between tracks and aside plazas could also be vertically oriented. Within the settlement, so-called mega-structures exist, which are placed at certain places which are empty of houses, at the trackways or within the open ring corridor. Altogether, 2,300 houses have been reported by their significant rectangular burnt daub remains ('ploshchadki') and house-associated pits, while about 300 further unburnt houses are recognised by their pits. Meanwhile,

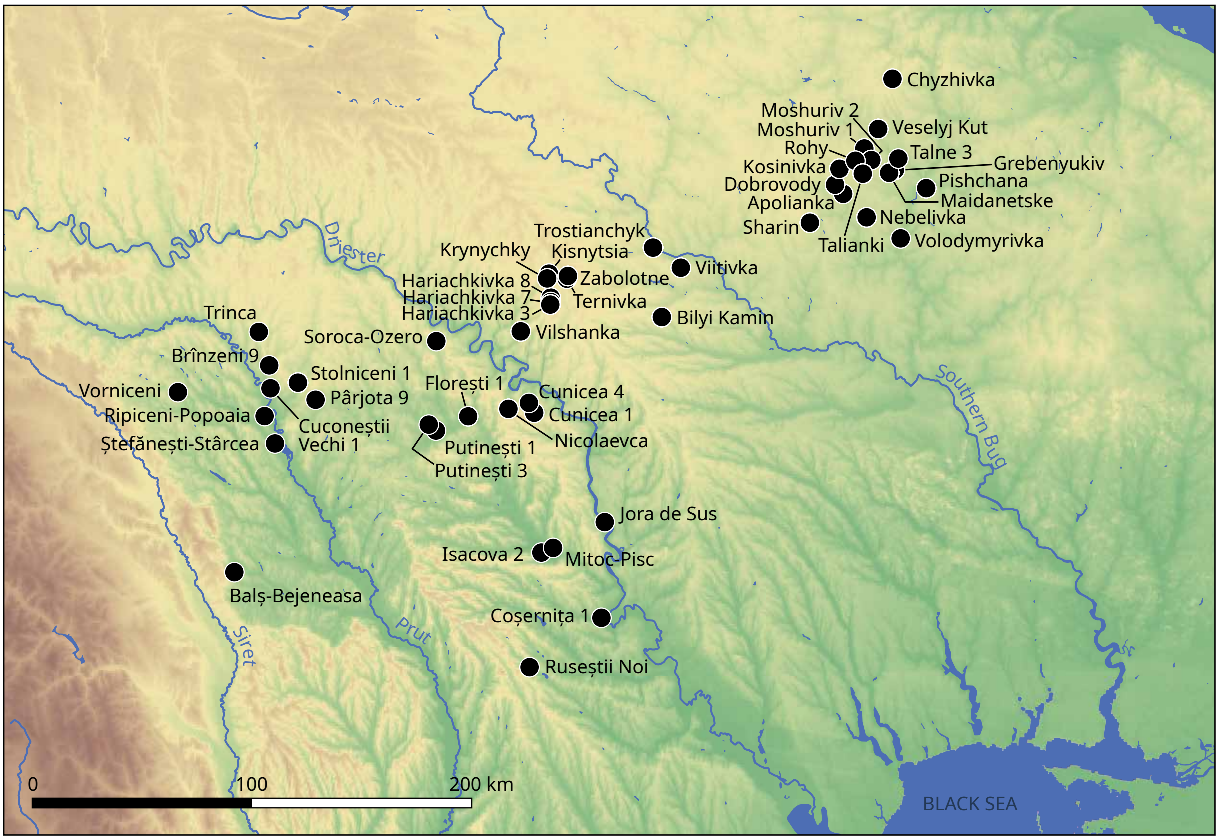


Figure 1. The distribution of sites with radiometric dates.

54 houses were excavated from 1973–2017, of which 19 had been excavated with high standards during the last 5 years.

At a distance of 15 km west of Maidanetske, Talianki (3.20 km²) is a site with a similar layout, but without special mega-structures (cf. Shatilo 2021). Geophysical features of 2,200 houses are known, 50 houses were excavated from 1989–2018. As the entire area was not surveyed, an interpolation results in ca. 1,800 houses that probably existed at Talianki. 15 km to the west, the mega-site Dobrovody (2.10 km²) has been partly surveyed and a mega-structure was excavated (Rassmann *et al.* 2014).

At further distance, the mega-site of Nebelivka (2.35 km²) has been fully surveyed, resulting in 1,445 houses that originally existed, of which 5 were excavated, including one mega-structure (Gaydarska 2020). The settlement layout is similar to the other sites.

While the mentioned sites exceed 100 ha in size, others are smaller. Within the Central Sinyukha Basin, these range from 5–100 ha, but in principle in a general division of the landscape, small and large sites are observed at a distance of about 15 km from each other.

Within the two other areas of interest, the layout of the sites is slightly different. From west to east, the size of the sites increases in general (Hofmann and Shatilo 2022). Thus, in Moldova the largest sites do not reach the large sizes of the Central Sinyukha Basin, but they are still much larger than contemporaneous smaller sites. Furthermore, the biggest sites have a circular layout, again with concentric house rings, ring corridors and an empty inner space. Mega-structures are known (Țerna *et al.* 2019; Rassmann *et al.* 2016; Uhl *et al.* 2014).

342 radiocarbon samples were taken from different contexts (Suppl. 1). These include Maidanetske with more than 90 radiocarbon datings, other sites with 20–50 dates each and such sites, where mainly a test trench was used for gaining ^{14}C dates (0–10 dates). Further published information that was used derives from sites such as Nebelivka (94 dates), Talianki (54 dates) and Petreni (9 dates). While many samples originate

from archaeological contexts, but without being further bound to stratigraphy, others are in stratigraphic order both in houses as well as in pits. Furthermore, a link to typological assemblages allows a conclusion about typochronological models that had been produced during the last 100 years of Trypillia history. In general, we concentrated our sampling strategy on Middle Trypillia mega-sites, but ^{14}C dates are also included from pre- and post-mega-site periods (Tab. 1).

The samples were calibrated individually, Bayesian models were calculated for individual contexts and sites, if possible, and the results were placed and discussed in relation to the wiggle phases of the calibration curve. The analyses were performed with the program Oxcal Version 4.4 and the Intcal 20 calibration curve (Reimer *et al.* 2020; Bronk Ramsey 2017; Bronk Ramsey 2009a; Bronk Ramsey 2009b; Bronk Ramsey 1994).

Results

Local and regional studies

The three selected test regions are localised in the western, the middle and the eastern areas of Trypillia large settlements (Fig. 1; cf. Chapter 1: Fig. 2, this volume). Depending on the scale of former or recent excavations, the documentation techniques, and the availability of datable material, the number of radiocarbon dates per site varies immensely. In consequence, the scope of possible analysis and interpretations differ from place to place. While there are four sites where the sampling strategy and the number of ^{14}C dates allowed a reconstruction of settlement processes, in others only single features, such as houses or even pits, could be dated. In general, the data can be used to reconstruct the overall dating of

Site	Number of samples	Dating (BCE)
Grebenyukiv	6	4550–4400
Chyzhivka	3	4120–3990
Dobrovody	6	3950–3700
Maidanetske	91	3970–3630
Nebelivka	96	3950–3700
Nicolaevca V	5	4530–4450
Talianki	43	3800–3600
Ternivka	2	4230–3970
Trostianchyk	15	4000–3800
Veselyj Kut	8	4070–4000
Vitivka	6	3850–3700
Vilshanka	6	4190–4080
Volodymyrivka	2	3920–3800
Zabolotone	7	4240–4080
Krynychky-Ferma	5	3620–3550
Kosinivka	12	3700–3600
Cunicea	2	3400–3200
Stonicieni	53	3980-3720
Petreni	9	3950–3800

Table 1. Number and chronological distribution of ^{14}C dates per site, from selected sites.

Trypillia phases as well as site formation processes, especially of larger sites. The results are listed according to the three test regions and within them according to the dating sequence from old to young.

Middle-Dniester region (Moldova and East Romania)

The western distribution area of Trypillia is composed of loess plateaus and larger river systems in present day Rumanian Moldova and Moldova. From west to east, the Suceava and Moldovan plateaus and the Upper Siret, Upper Prut and Middle Dniester main rivers are involved within the forest steppe environment.

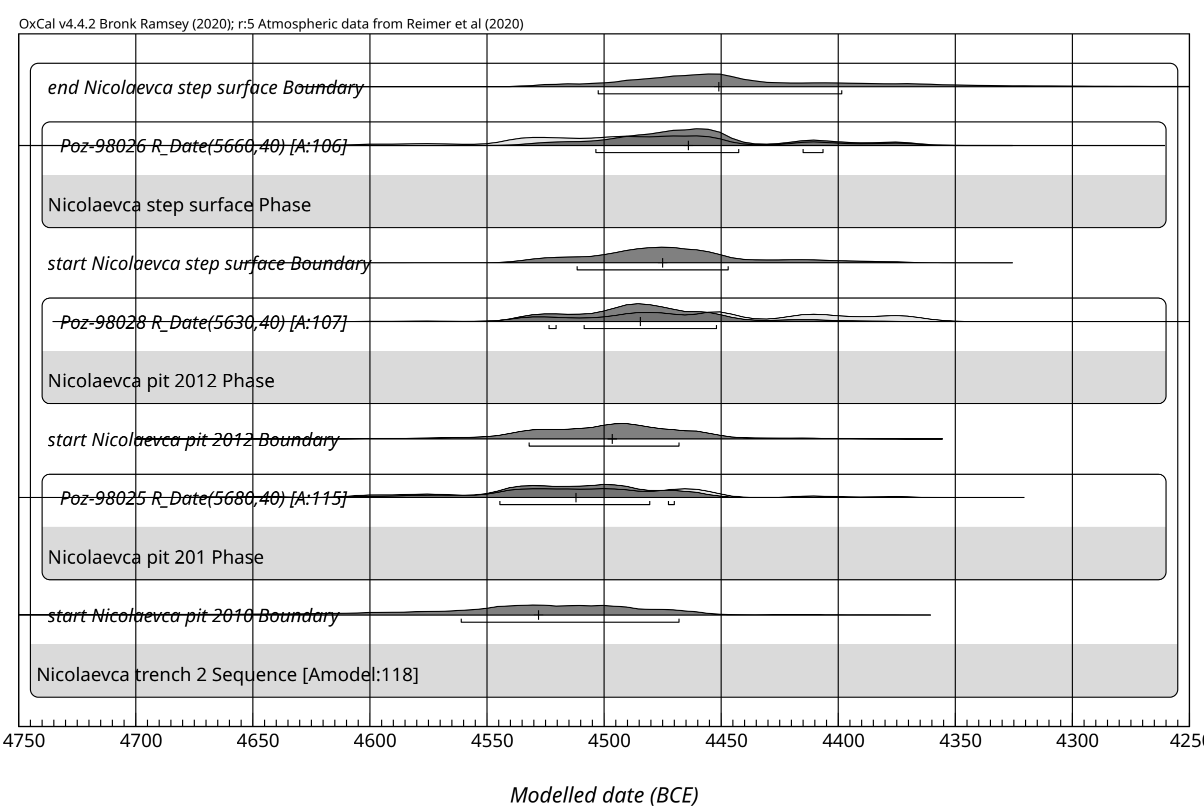
Precucuteni and Cucuteni

From **Nicolaevca V**, 4 samples from a 'pit-house', pits and a step surface belonging to (early) Precucuteni 3 (PCC 3) could be dated (Fig. 2). Stratigraphic information is gained from two pits, which are located under a burnt house, and the step surface near the house. The sum calibration resulted in a possible duration of the site ranging from ca. **4550–4450 BCE**. In detail, the Bayesian calibration of the three samples in stratigraphic position (a pit cut by a younger pit and both beneath the step surface) resulted in a very good fit of the model (A_{model}=117.9; $A_{overall}$=116.1) and a duration ranging from **4530–4450 BCE** (medians).

Beside the statistical observation, the position on the calibration curve describes the main part of the probabilities on the steeper part of the curve, while a smaller proportion also might belong to the flat part until **4375 BCE**. Two samples from Nicolaevca V belong to an LBK long pit of a longhouse and date from ca. 5200–5000 BCE.

Other new samples from Precucuteni 2 (PCC 2) sites (Suppl. 1), such as Balș-Bejeneasa (4690–4560 BCE, 1σ), Floresti I (4580–4470 BCE) or Floresti III (4690–4560 BCE), and Precucuteni 3 sites, such as Isacova II (PCC 2–3, 4690–4560 BCE), Coșernița I (PCC 3, early, 4610–4460 BCE), and Putinești I (PCC 3, 4680–4535 BCE), do not differ statistically from the PCC 2 datings. Only Rusestii Noi I (PCC 3-CC A1, 4490–4370 BCE) dates later and signifies the change to Cucuteni A1 (CC A1), probably around 4450 BCE.

Figure 2. The Bayesian calibrations of Nicolaevca V stratigraphy (cf. Suppl. 1–2).



In comparison with the general ideas on Precucuteni and Cucuteni dating (Mischka *et al.* 2019, 116, Fig. 2) the results are slightly younger[1]: PCC 3 is not securely dated to 4775–4650 BCE as expected, but to Nicolaevca V from ca. 4550–4450 BCE. The other dated PCC 3 site might imply the possibility of a start of PCC 3 around 4600 BCE. In principle, all newly dated PCC 3 sites cover dating intervals on the calibration curve from 4690–4600 BCE (flat) and the steep ones until 4550 BCE. Similar parts of the calibration curve are covered by PCC 2 sites such as Balș-Bejeneasa (4690–4560 BCE, 1- σ), Floresti I (4580–4470 BCE) or Floresti III (4690–4560 BCE). They are also much later than expected (4900–4775 BCE) and overlap completely with PCC 3.

CC A1 (expected 4600–4500 BCE) dates later at Rusestii Noi I (PCC 3-CC A1, 4490–4370 BCE), but together with other CC A sites, CC A includes the dating intervals at least until 4150 BCE. The described differences might be due to the use of samples with old wood effects within the older samples.

Trypillia

For Trypillia, the dates from **Cucuteni A/Trypillia B1** sites also indicate the dating of CC A until probably 4300/4250 BCE: Jora de Sus (CC A/B1), 4350–4260 BCE; Putinești III (CC A/B1), 4330–4180 BCE and Cuconeștii Vechi I (CC A/B1), 4340–4250 BCE. In consequence, **Trypillia B1** is dated on the two calibration intervals between ca. 4330 BCE and 4180 BCE.

Trypillia B1/B2 sites are slightly later: Vorniceni (B1–B2), 4320–4070 BCE; Ripiceni-Popoaia (B2 or B2/C1), 4040–3975 BCE; Mitoc-Pisc (B2 or B2/C1), 3950–3800 BCE. The date for Brînzeni IX (B2), 3970–3810 BCE, seems to be quite late.[2]

Trypillia B2 is dated to Brînzeni VIII (B2), 3970–3810 BCE, as expected. The same applies to Ripiceni-Popoaia (B2 or B2/C1), 4040–3975 BCE and Mitoc-Pisc (B2 or B2/C1), 3950–3800 BCE, so that we expect a range from **4040–3800 BCE.** Trypillia B2/C1 is dated in Petreni with 9 radiometric datings from **3890–3820 BCE** (medians; A_{model}=94.2; $A_{overall}$=96.7; Fig. 3).

Trypillia C1 dates between **3950 BCE and 3710 BCE, perhaps 3660 BCE**, about 150 years earlier than expected. The dating of C1-sites is congruent with the results from Stolniceni (3950–3700 BCE), where the bulk of dates can be used for detailed studies on the settlement (see below): Soroca-Ozero (C1), 3960–3810 BCE; Trinca (C1), 3890–3710 BCE; Pârjota IX (C1 late) 3760–3660 BCE and Ștefănești-Stârcea (C1–C2), 3940–3780 BCE[3].

For **C2**, the site of Cunicea 4 (C2) yielded two ^{14}C dates from a house and a pit, dating between 3490 BCE and 3040 BCE.

Summing up, in the western Trypillia area we would estimate the following phases: PCC 3/2 4690–4500 BCE and CC A1 4450–4300 BCE; Trypillia B1 4300–4150 BCE; Trypillia B1/2 4300–4000 BCE; B2 4050–3950 BCE; C1 3950–3700 BCE and C2 3490–3040 BCE (Fig. 4).

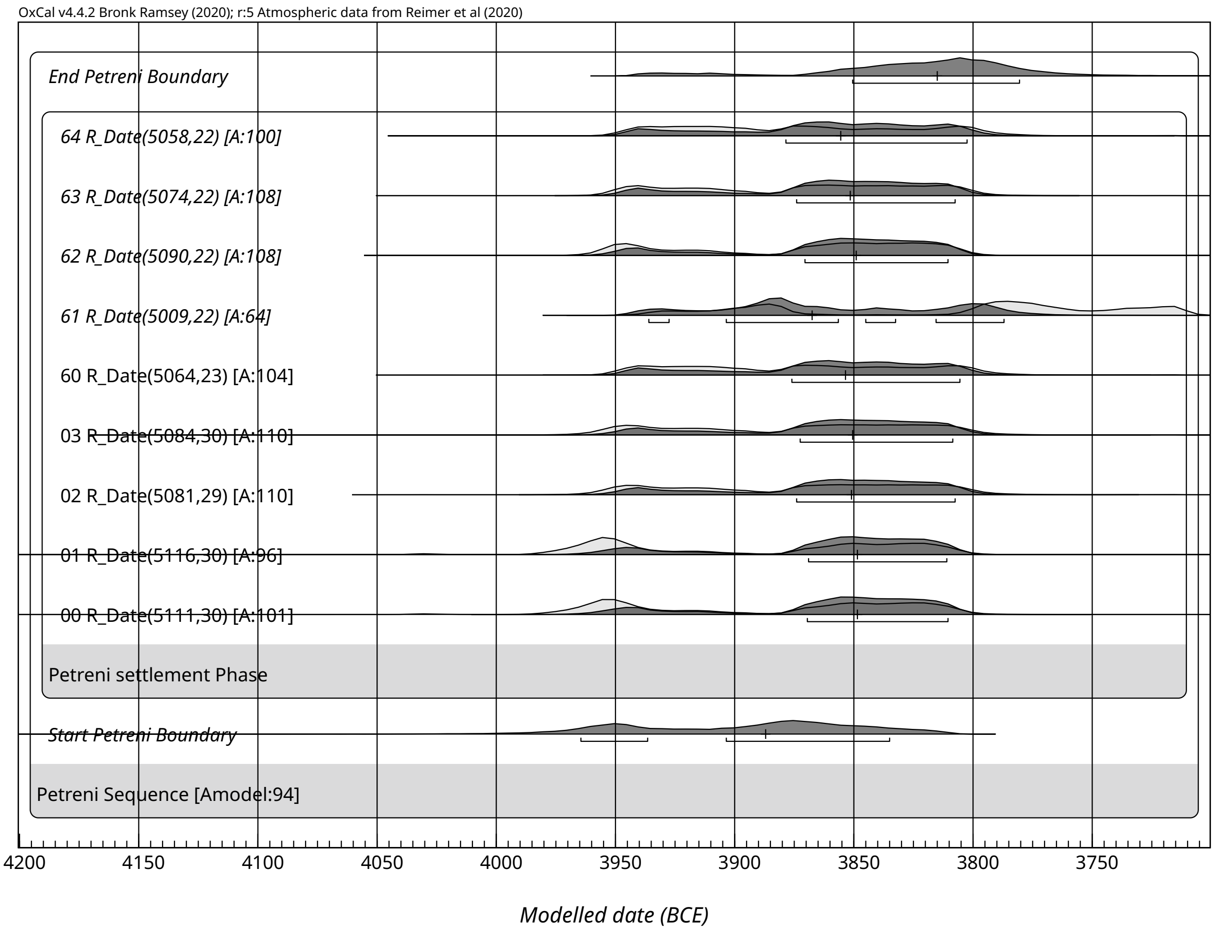
Figure 3 (opposite page, above). The Bayesian calibrations of Petreni (cf. Suppl. 1–2).

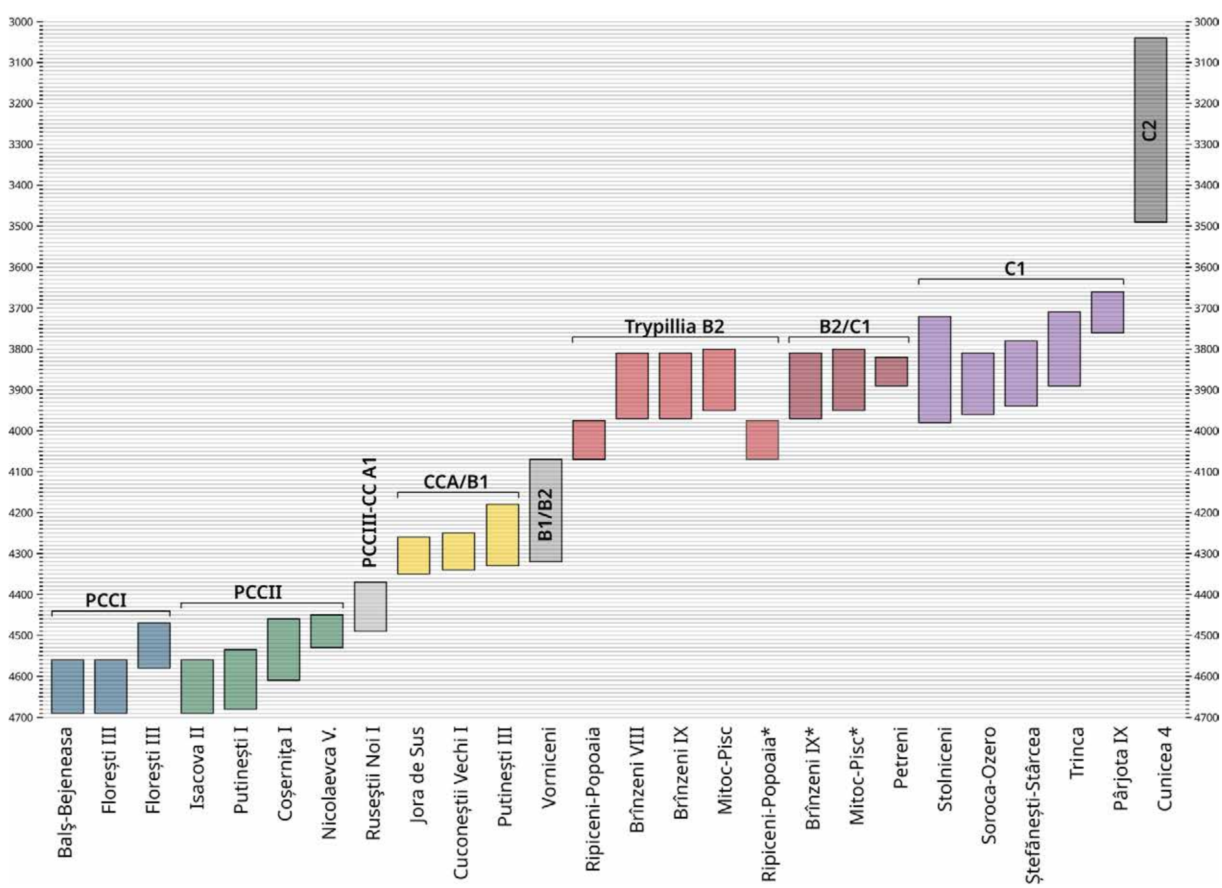
Figure 4 (opposite page, below). The comparison of Bayesian dates of individual sites from Middle-Dniester region.

1 PCC 5000–4600 (PCC 1 5000–4950, PCC 2 4900–4775, PCC 3 4775–4650), Cucuteni 4600–3550: Cucuteni A 4600–4050 (A1 4600–4500, A2 4500–4150, A3 4150–4050), CC A–B 4050–3800 (alpha, beta 4050–3900; gamma, delta 3950–3800), CC B 3800–3500 (CC B1 (epsilon) 3800–3650, CC B2 (3650–3500)).

2 In Brînzeni IX (C2), a date has been obtained from an antler tool, which may have been collected in prehistory from the settlement Brînzeni IV (B2/C1) located very close just on the other bank of a small stream. If so, the ^{14}C date would perfectly fit the expectations for this Trypillia B2/C1 site.

3 In this case, the date seems too old, but there is the possibility that it comes from a Trypillia C1 site (Ștefănești-Stânca). The materials have been subsequently mixed in the museum collections. If so, the ^{14}C date would perfectly fit the expectations for this Trypillia C1 site.


OxCal v4.4.2 Bronk Ramsey (2020); r:5 Atmospheric data from Reimer et al (2020)
End Petreni Boundary
64 R_Date(5058,22) [A:100]
63 R_Date(5074,22) [A:108]
62 R_Date(5090,22) [A:108]
61 R_Date(5009,22) [A:64]
60 R_Date(5064,23) [A:104]
03 R_Date(5084,30) [A:110]
02 R_Date(5081,29) [A:110]
01 R_Date(5116,30) [A:96]
00 R_Date(5111,30) [A:101]
Petreni settlement Phase
Start Petreni Boundary
Petreni Sequence [Amodel:94]
4200 4150 4100 4050 4000 3950 3900 3850 3800 3750
Modelled date (BCE)


3000 3100 3200 3300 3400 3500 3600 3700 3800 3900 4000 4100 4200 4300 4400 4500 4600 4700
PCCI
PCCII
PCCIII-CC A1
CCA/B1
B1/B2
Trypillia B2
B2/C1
C1
C2
Balş-Bejeneasa
Floreşti III
Floreşti III
Isacova II
Putineşti I
Coşerniţa I
Nicolaevca V.
Ruseştii Noi I
Jora de Sus
Cuconeştii Vechi I
Putineşti III
Vorniceni
Ripiceni-Popoaia
Brînzeni VIII
Brînzeni IX
Mitoc-Pisc
Ripiceni-Popoaia*
Brînzeni IX*
Mitoc-Pisc*
Petreni
Stolniceni
Soroca-Ozero
Ştefăneşti-Stârcea
Trinca
Pârjota IX
Cunicea 4

Stolniceni (C1)

Stolniceni is one of the few Moldovan Trypillia sites, where after geophysical surveys, a concept of test trenches and main trenches was applied during field surveys and excavations (Țerna *et al.* 2019). In consequence, the site enables information on its internal chronological development (Figs. 5–10).

In detail, the following information can be noted for Stolniceni (cf. Suppl. 1-2):

- There are four dates from kilns (Suppl. 2: Fig. S13): They are set at ca. **3930–3810 BCE** (median of boundaries of kiln from Trench 5) and ca. **3945–3870 BCE** (median **3870 BCE** for the kiln in Trench 3), but are positioned within a flat part of the calibration curve. From the kiln in Trench 3, Poz-87976 belongs to the fill of the firing chamber or one of the channels. From the kiln in Trench 5, Poz-97940 and KIA-52653 belong to the fill of the firing chamber, additionally also the human bone of Poz-128150. Therefore, they probably indicate an infilling event just before or after the final use of the kiln, for which the highest probability is around **3870/3860 BCE** (median and mean).
- Several dates on the 3-ditch and palisade system of the site are available (Suppl. 2: Fig. S12). If we follow the statistical probabilities, activities took place from ca. **3900–3790 BCE** (median boundaries). Two samples belong to the inner palisade that dates very close between **3885 BCE and 3856 BCE** (medians). The outer ditch is also roughly dated by two samples from different parts of the lower infill, around **3885–3850 BCE.** The lower level of the original about one-metre deep ditch was interpreted as a sediment with continuous infilling (Țerna *et al.* 2019b). Two radiocarbon dates from the middle and inner ditch indicate a similar time scale (medians: **3875 BCE**). In summary, the ditch and the palisade system were probably filled in during the first half of the 39th century BCE[4].
- Two samples come from a settlement pit from the vicinity of the palisade-ditch system (Țerna *et al.* 2019b). Both date the major deposition event identified in the middle part of the pit's infill. They show a long duration between **3950 BCE and 3600 BCE** (median of boundaries), which – if not distorted by the calibration curve – might indicate the use of the pit during two phases. The infill might have started during the earliest activities at the site (indicated by the dates of the palisade and kilns), then the pit was left open and refilled towards the end of the site occupation.
- Pit 5 also dates within the 39th century BCE (**3920–3870 BCE**, means), more or less contemporary with the adjacent kiln. Pit 6 has a mean around 3870 BCE, dating from **3950–3800 BCE,** an age which is overruled by the one sample from the step-surface with a mean around **3920 BCE,** dating from **3980–3820 BCE**.
- Seven samples were taken from different filling events of Pit 20 (Fig. 6). These samples include two from the bottommost layers, one from the first major deposition event, two from the second deposition event, one from an intermediate layer between the two events, and the last one from the uppermost layer, marking the end of the pit use. The stratigraphical modelling of the dates indicates a duration of the feature from **3920–3840 BCE** (median of boundaries).
- 4 dates belong to the circular structure, dating with the early structure pit within the 39th century (**3900–3830 BCE**, means) and the use of the circular surrounding until **3770 BCE** (mean). Moreover, the mean of the boundaries of all dates together indicate a duration from **3890–3750 BCE** (Fig. 7).
- For Trench 19, three dates are available for the large pit associated with House 19 ('alpha house') and one date for a smaller pit located northeast of the main one (Fig. 8a; cf. Suppl. 2: Fig. 16). Two samples from the main pit date two of the

4 The real date might be hampered by the wiggle of the calibration curve, which also might imply an earlier construction.

Figure 5. Stolniceni: Radiometric dates and the settlement model. The occupation of the inner areas seems to develop later.

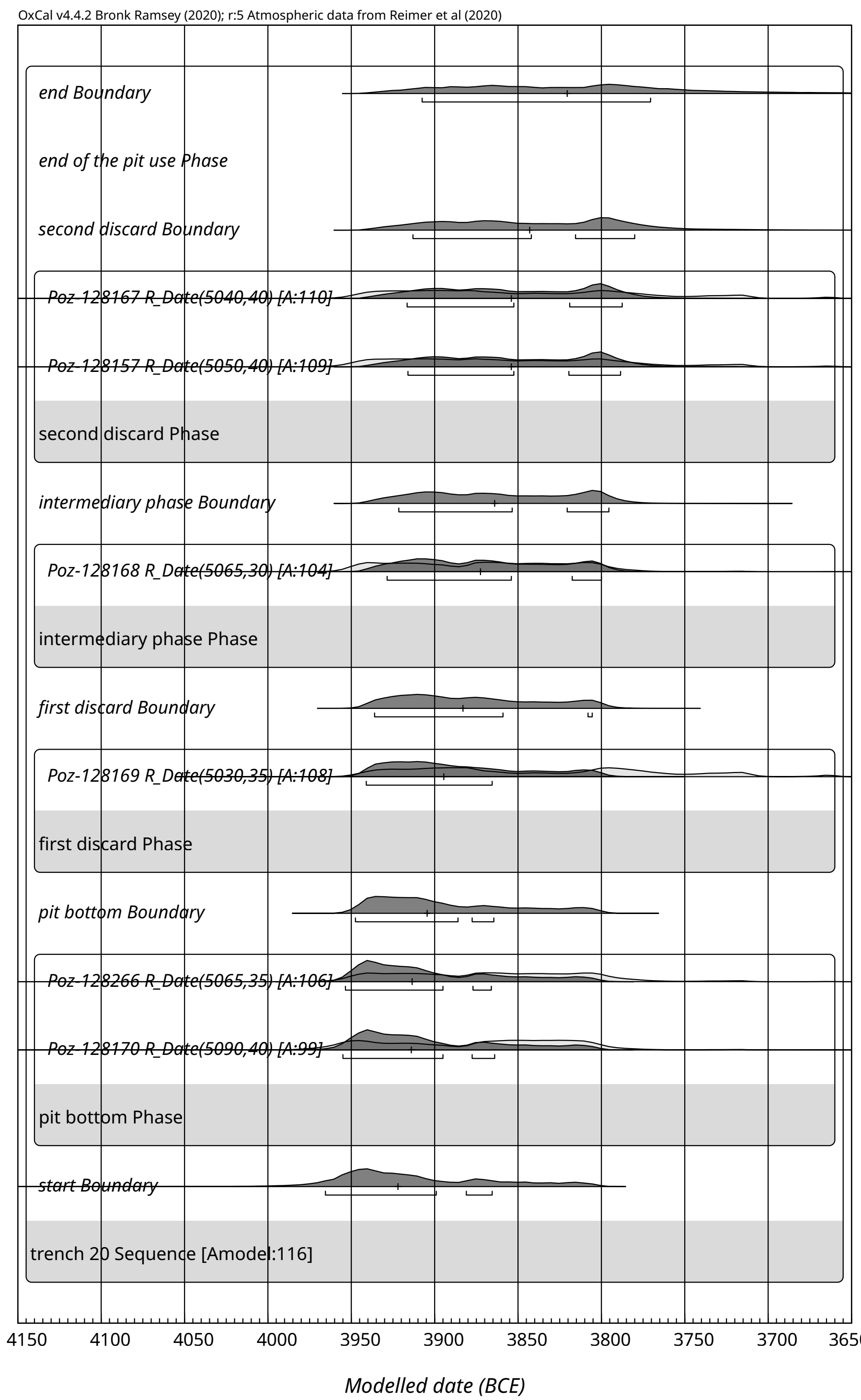


Figure 6. The Bayesian calibrations of usable samples from Stolniceni Pit 20 (cf. Suppl. 1–2).

lower layers, which correspond to the first massive deposition event (but not the first intentional infill), potentially linked to the early activity of the nearby house. The third sample was taken from the uppermost layer of the pit, which contains sediments naturally deposited after the nearby house's lifecycle had ended. Based on the dates obtained, the first major deposition event took place between **3920 BCE and 3800 BCE** (medians of boundaries), while the filling of the pit ended before **3670 BCE** (median).

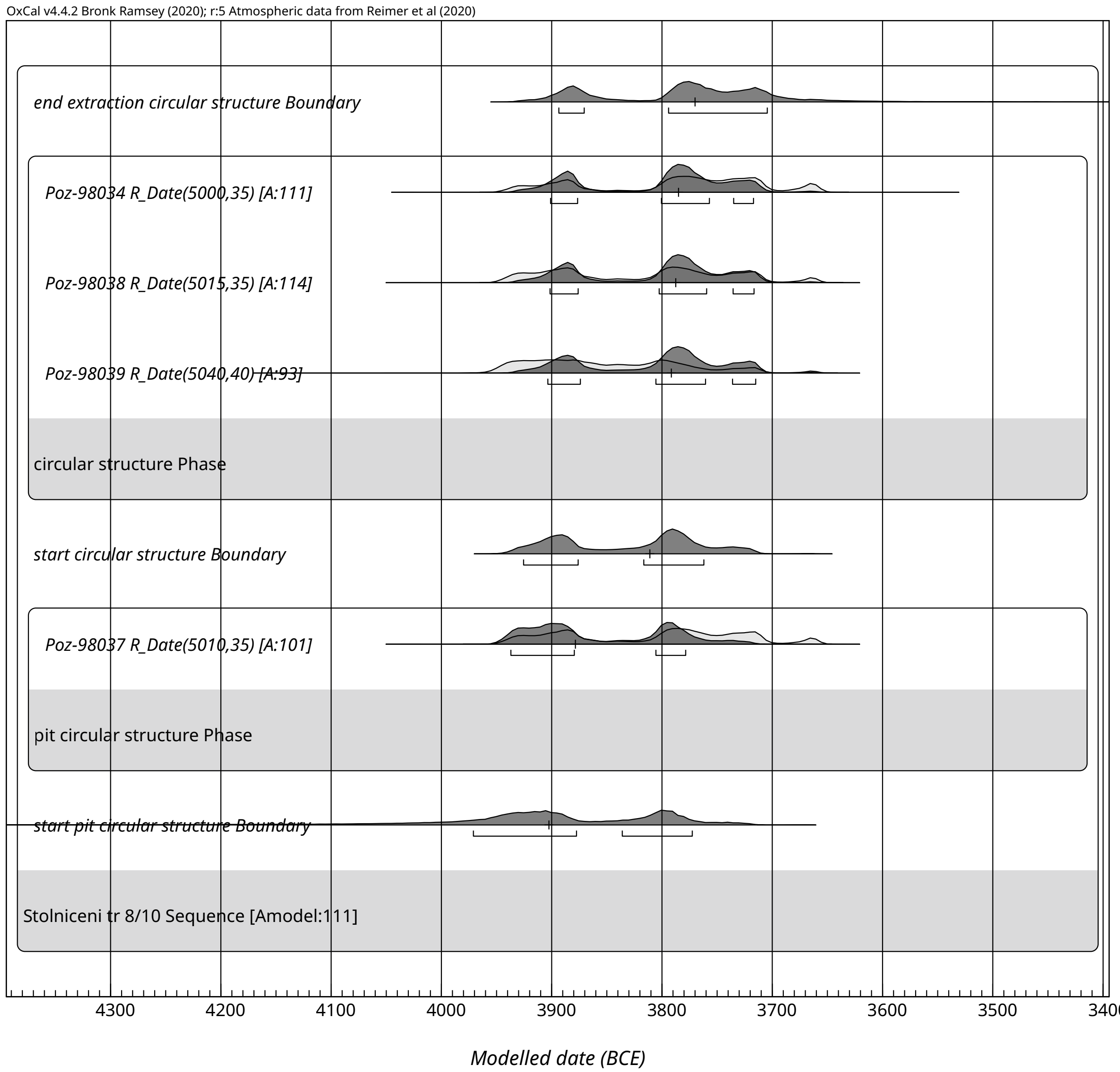


Figure 7. The Bayesian calibrations of Stolniceni circular structure (cf. Suppl. 1–2).

- Regarding the small pit situated north of the main one, the sample Poz-12815 was obtained from the bottommost layer, representing the very first infill, and it dates to **3942–3765 BCE** (median 3815 BCE). This indicates that the small pit was operational during the same period as the main pit.
- Four samples belong to House 7, which date within a sequential occupation with one sample for the original surface (**3930 BCE**), and the extraction pit from **3870–3830 BCE** to **3830–3780 BCE** (mean of boundaries). The duration of the house is calculated to a mean of **50 years**. Three other houses are dated with one ^{14}C date each, but they fall into a similar range (means: **3875 BCE** (House Trench 13 west), **3870 BCE** (House Trench 12), **3690 BCE** (House Trench 11)). If modelled together without the house from Trench 11, the duration of the house occupation is between **3920 BCE and 3820 BCE**.
- Four samples were used to determine the age of the pit associated with the mega-structure excavated in Trench 21 (Fig. 8b). Additionally, there is another date, Poz_128216, collected from a later pit that intersects the main feature at its western edge. The main pit itself contains several re-cuts, which are not clearly reflected by the ^{14}C sampling strategy. Thus, in the sequential calibration we con-

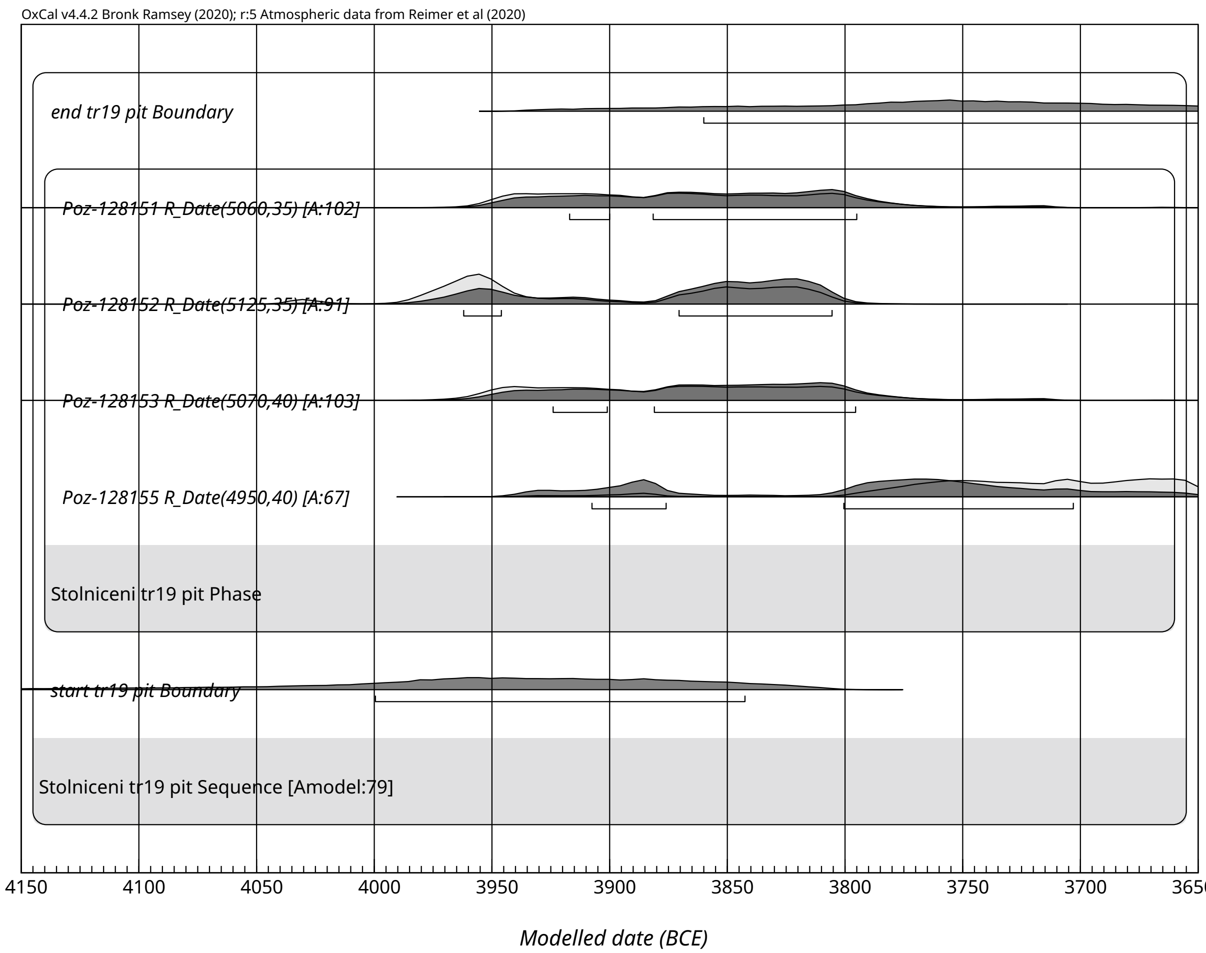


Figure 8a. The Bayesian calibrations of Stolniceni alpha pit (cf. Suppl. 1–2).

sidered only the depth of the samples. The dates show that the pit's duration spans between **3930 BCE and 3790 BCE** (median of boundaries). As for the second pit, it is dated to **3940–3770 BCE (3885 BCE**, median), which means that the filling of the second pit started after the one of the main features.

- One sample from the layer at one of the trackways displays a date around **3800 BCE** (mean, with 60.9% 3800–3710 BCE).
- Dealing even only with 56 samples and only a few stratigraphical orders, some tendencies are obvious. While we have to consider the data by themselves, on the one hand, and the depositional processes, on the other hand, the structure of the calibration curve also influences our probabilities and limits the value of our estimations. With respect to the datings from Stolniceni, three dating intervals of the calibration curve are of interest: A 4020–3950 – the calibration slope; B 3950–3790 – the main wiggle plateau; C 3790–3690 – a plain calibration curve part below the values from A and B.

Some surface activities, the kilns, some pits and the palisade around the settlement might have started around 3950 BCE, at the latest at 3900 BCE. But even if the statistical values might indicate such an early start, because of the calibration curve we cannot exclude the possibility of a much later dating that still lies before 3800 BCE.

Other dates – namely for the inner and middle ditches, the road and some houses – are later than 3800 BCE, but before 3700 BCE. Both for the houses and the circular structure, an existence through the early 39th century BCE and the late 38th century BCE at Stolniceni is probable.

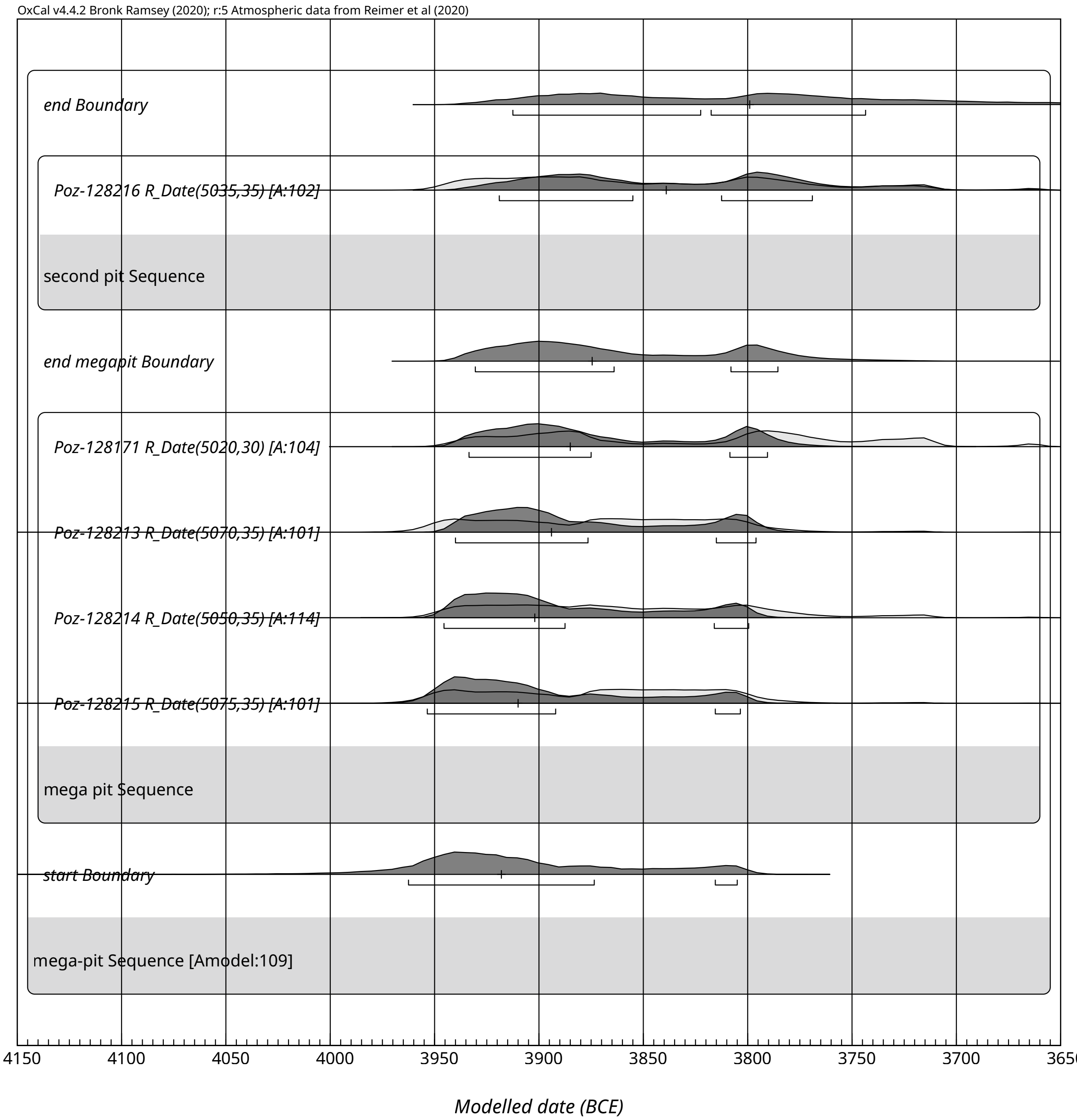


Figure 8b. The Bayesian calibrations of Stolniceni mega-structure pit (cf. Suppl. 1–2).

In consequence, Stolniceni is dated to the 39th and 38th centuries BCE. As no samples exist directly from houses, which are dated before 3950 BCE, a dating before 3950 is difficult to securely argument for (despite other single dates). Furthermore, because of the wiggle-structure, the tendencies for differences in the dating of specific contexts are similarly difficult to explain, even if the sum calibration curves support such a view.

Nevertheless, the palisade, the kilns and the pits clearly indicate an early demarcation of the place by an enclosure, an early installation of infrastructural elements and early domestic activities. In principle, these datings might be also associated with first house constructions. During the course of time, the 'filling' of the enclosed space, the enlargement of the enclosure with a ditch system and the installation of the circular structures took place. In this respect, the tendencies within the ^{14}C dates indicate a realistic scenario for the development of the site (Fig. 5 and 9).

Figure 9. The Bayesian calibrations of Stolniceni, all features (cf. Suppl. 1: Fig. S15). ***Due to the length of this figure, for ease of viewing it is only available online (https://doi.org/10.57892/100-55).***

For the reconstruction of demographic developments, the data was mapped along the main three wiggle-phases (Fig. 10). Only two dates from two locations (not deriving from a house) are known before 3950 BCE, 42 from 13 locations (of these

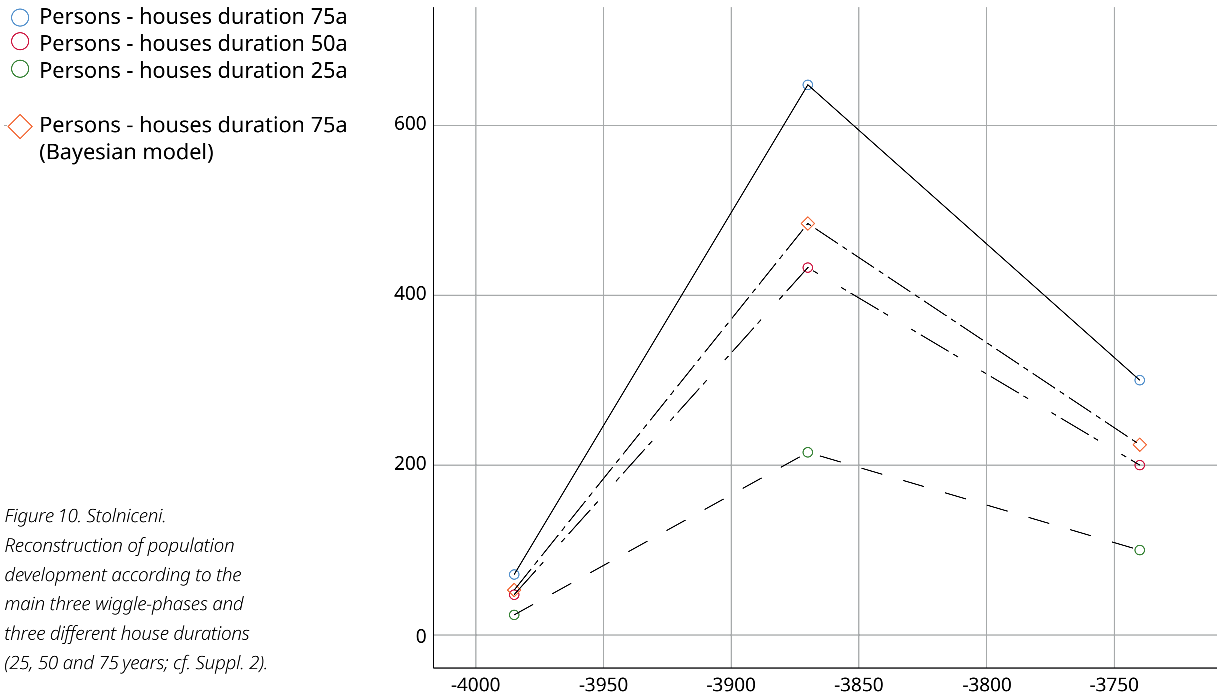


Figure 10. Stolniceni. Reconstruction of population development according to the main three wiggle-phases and three different house durations (25, 50 and 75 years; cf. Suppl. 2).

five houses) from the phase 3950–3790 BCE and 12 from 9 locations (of these three houses) are known from ca. 3790–3690 BCE. This distribution is based on a mapping of single dates, the Bayesian sequences do not change the distribution pattern.

The overall Bayesian model for Stolniceni also describes a duration of the site between **3980 BCE and 3720 BCE** (median boundaries; A_{model}=76.7; $A_{overall}$=72.2). Until around 3900 BCE, the spatial distribution displays all activities concentrated between the ring corridor and the outer enclosure, while later the activities also include the inner sector between the ring corridor and the free central place. Additionally, the circular structures outside of the fortification were also used.

With the data at hand, we are also able to reconstruct the demographic development of Stolniceni. We have to take the uneven duration of each of the three Stolniceni phases (absolute years: Phase 1: 70; Phase 2: 160; Phase 3: 100) as well as the differences in the distribution of the ^{14}C dates (Phase 1: 2; Phase 2: 42; Phase 3: 12) into account. Furthermore, the lifespan of a house might be estimated to 25, 50 or 75 years, what also influences the contemporaneity of houses. The basic values are represented by the 370 houses that were detected by geophysical investigations and were partly excavated. In consequence, three steps are necessary for the calculation:

1. (Σ^{14}C phase * Σhouses site) / Σ^{14}C site = a
2. phase duration (a) / lifespan house (a) = b
3. a/b = c (number of contemporaneous houses)

With this formula, the probability is high that during Stolniceni Phase 1 about 9.5, during Phase 2 ca. 86.5 and in Phase 3 ca. 40 houses existed contemporaneously, if the lifespan of a house is set to 50 years. If we calculate with a lifespan of 25 or 75 years for each house, the figures shift adequately (Fig. 10). If we assume that there were 5–10 residents per house, the population size of Stolniceni varies from ca. 47.5–95 inhabitants (Phase 1) to 432.5–865 inhabitants (Phase 2) and to 200–400 inhabitants (Phase 3) for a house lifespan of 50 years.

These calculations are based on the critical examination of all ^{14}C dates and their mapping according to the wiggle-phases (Phase 1: 4020–3950; Phase 2: 3950–3790; Phase 3: 3790–3690 BCE), which ends up with a duration of 330 years for the whole site. Taking the Bayesian calibration model for all dates from Stolniceni into account, the site duration is modelled to have been 40 years shorter (3980–3720 BCE: 290 years). In consequence, the actual population size might have been about 12% higher than calculated here, as the Bayesian time span of the site is about 12% shorter than the single ^{14}C calculation[5]. Thus, we would estimate 53–106 inhabitants (Phase 1) to 484.4–986.8 inhabitants (Phase 2) and to 224–448 inhabitants (Phase 3) for a house lifespan of 50 years.

Southern Bug-Dniester interfluve (Western Ukraine)

In today's Western Ukraine, the forest steppe areas between the Middle Dniester and the Middle Southern Bug, mainly composed of the Podolien Uplands, display a distinctive cluster of Trypillia sites.

Zabolotne and Ternivka (B1–B2)

At Zabolotne, test trenches within the 40-ha concentric site with 2 central mega-structures provided 7 dated samples, of which one came from an area outside of a house and 6 from a pit with stratigraphic order (Fig. 11). The data from the pit could be used for a Bayesian model because of the stratigraphy. While 2 data samples from the Kiel lab did not fit the model, the others fitted roughly. The range **4250–4080 BCE** (A_{model}=86.5; $A_{overall}$=88.7) does mainly fall within the dating interval 4220–4050 BCE. The single date from the vicinity of another house (Poz-97918, Context 3002) dates younger into a time interval 3650–3530 BCE, which might indicate a later activity.

From the 7-ha site Ternivka with a concentric plan and one large mega-structure, two samples are available from a house layer (1003) that was partly recovered in a test trench (Suppl. 2: Fig. 1). The two dates fall within the boundaries from **4210–3970 BCE** (medians), respectively **4080** and **4050 BCE.** The dates fall within the dating intervals 4220–4050 and 4050–3970 BCE, making a more secure dating difficult.

Ternivka and Zabolotne are topographically directly opposite from each other on different sides of the small Berezhanska canyon. A third site (Soniachne) was discovered between both sites. Interestingly, according to radiometric dating, they existed contemporaneously. In Ternivka, the dating is from the inner circle, in Zabolotne from an interior house of the second ring, which borders the ring corridor.

Vilshanka (B1–B2)

From the 25-ha site with a concentric plan and 1 mega-structure, 6 dated samples from the profiles of two pits are available (Fig. 12). The pits belong to houses in the southwest associated with the outer area of the settlement. They fall within a range from **4190–4080 BCE** (median; A_{model}=104.9; $A_{overall}$=105.3), with single ranges around **4130 BCE**. All dates belong to the dating interval **4220–4050 BCE**.

Hariachkivka 3, 7, 8 (B1–B2)

According to the geophysically surveyed area, the main structure at the settlement Hariachkivka 7 is the arc-like row of the buildings. The south end of the arc is located on the edge of the slope to the river valley, which lies between settlements Hariachkivka 7 and 8 (Chapter 14, this work, Vol. II). The site measures 5.5 ha. Hariachkivka 3 is a site of approximately 7 ha size. House rings, a ring corridor, a mega-structure and a free inner space have been detected. Hariachkivka 8 is a site measuring 7.5 ha and displays the concentric planning principle.

From Hariachkivka 8 (Fig. 15), two dates from a house (median of boundaries: **4380–4170 BCE**, but median of dates 4268 and 4287 BCE) and four and three dates

5 330 a - 290 a = 40 a - (40*100)/ 330 = 12.12%

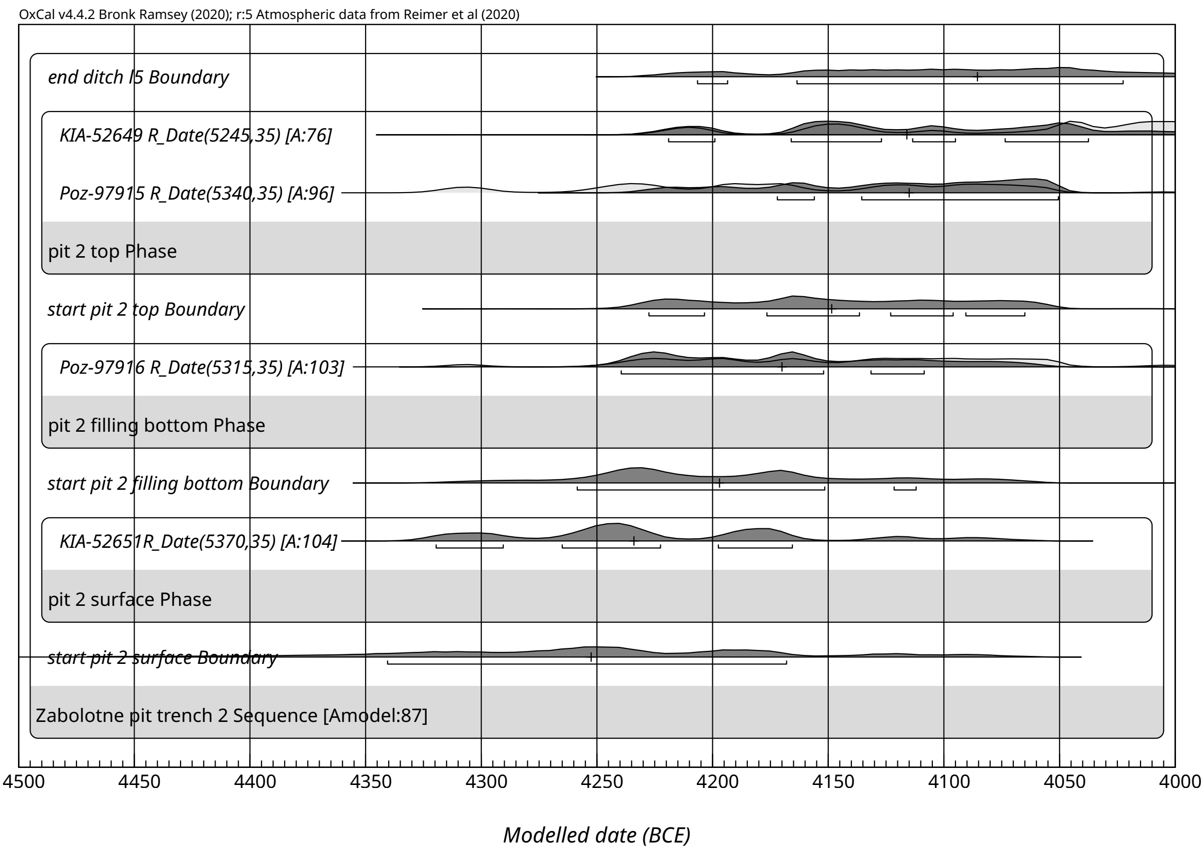
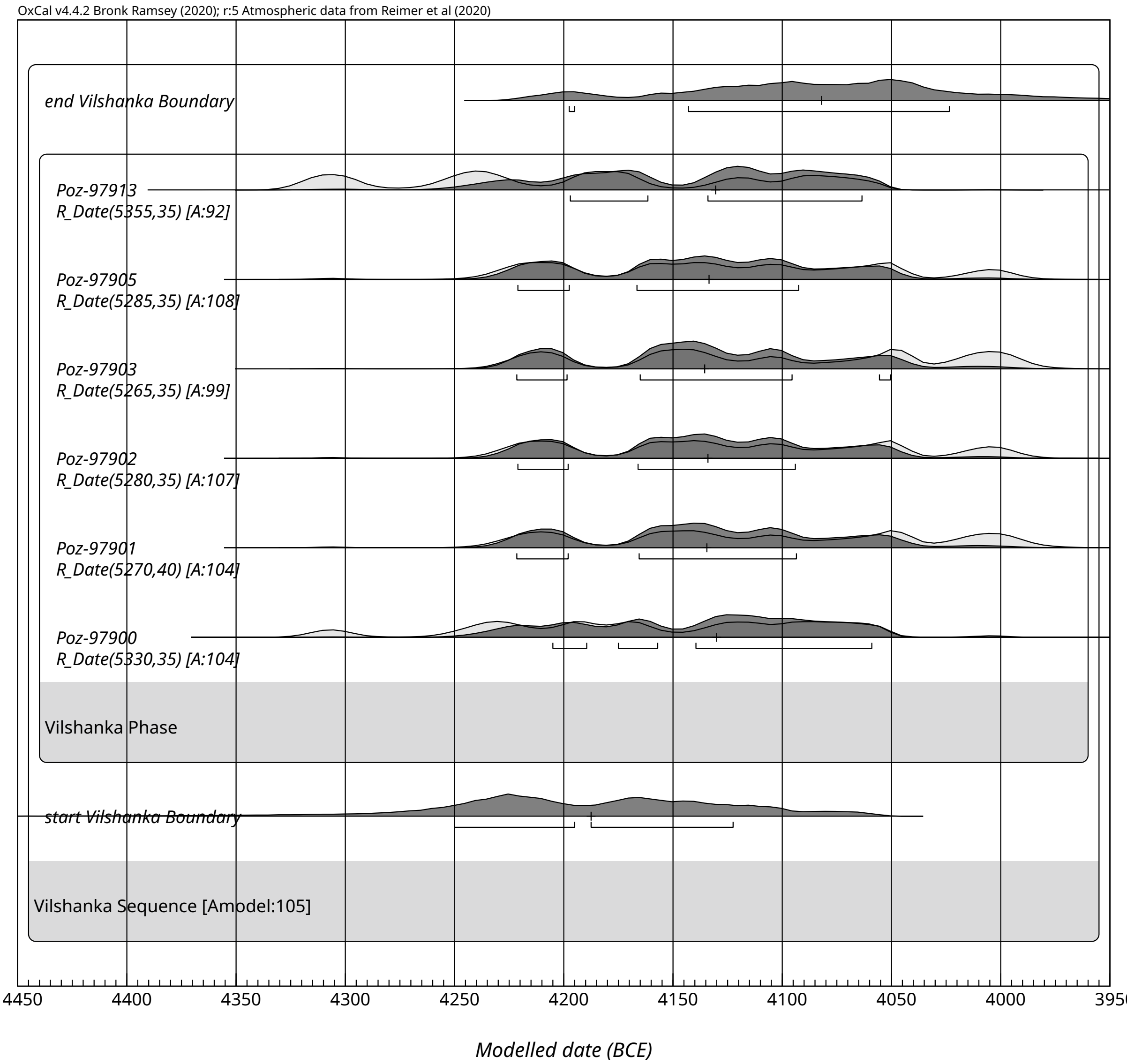


Figure 11. The Bayesian calibrations of Zabolotne (cf. Suppl. 1–2).

from two pits, respectively (median of boundaries: **4210–4070 BCE**; **4210–4060 BCE**) describe a dating mainly between **4270 BCE and 4060 BCE**. At Hariachkivka 3, four dates from a pit date to ca. **4045–3955 BCE** (median of boundaries; A_{model}=112.8; $A_{overall}$=113.4; Fig. 13), at Hariachkivka 7, three dates from a bottom of a pit date to **4230–4065 BCE** (A_{model}=101.3; $A_{overall}$=101.9; Fig. 14).

Trostianchyk (B2)

The 3-ha site of Trostianchyk is located on a promontory with one mega-structure. 15 dated samples are available from four pits and one oven. Within each of these features, the stratigraphic order of different contexts was documented, so that Bayesian statistics integrated this information into the dating model (Fig. 16). The site features are dated from **3975–3955 BCE** (medians). The oven and the pits (each **3970–3960 BCE**) all fall within a steep range of the calibration curve. The sharp



dating is due to the secure dating interval 3990–3950 BCE (steep calibration curve) and the ^{14}C dates are additionally modelled based on their stratigraphic position.[6]

Figure 12. The Bayesian calibrations of Vilshanka (cf. Suppl. 1–2).

6 'Three successive stages of the pit 1 filling were dated, although the lowest infilling layer was excluded from this due to a lack of datable sample material. Sample Poz-87490 was associated with the massive clay objects in the middle-lower part of the pit at the border between layers 3 and 2B. The sample Poz-87488 is related to an event of pottery infilling in layer 2A. The sample Poz-87489 dates the upper part of layer 2A. The modelling of these dates resulted in a very robust model with the high overall probability of 153.2. According to this model, the backfilling of the pit took place over a relatively short period between 4017–3959 BCE and 3974–3900 BCE (68.2%), or between 4172–3947 BCE and 3983–3721 BCE (95.4%). The highest dating probability falls in the narrow range of only 20 years between 3970 BCE and 3950 BCE (Fig. 8). Summarizing the results obtained from trench 1, the backfilling of pit 1 from Trostianchyk took place, with the 'highest' dating probability, during the first half of the 40th century BCE. Considering a more reliable dating range of 68.2% probability, a longer, 200-year use of the site from the middle of the 41st until the end of the 40th century is possible. Other dated contexts from Trostianchyk show, in the case of pit 2 and trench 4, similar narrow dating results falling in the first half of the 40th century […]. In contrast, the highest dating probability of pit 3 and trench 6 might indicate a significantly longer dating range of the settlement between the last decades of the 41st century and about 3800 BCE. However, in the case of the latter two contexts, the quality of the models might be influenced by the fact that in each case only two 14C-dates are available' (Rud *et al.* 2019b, 26–27).

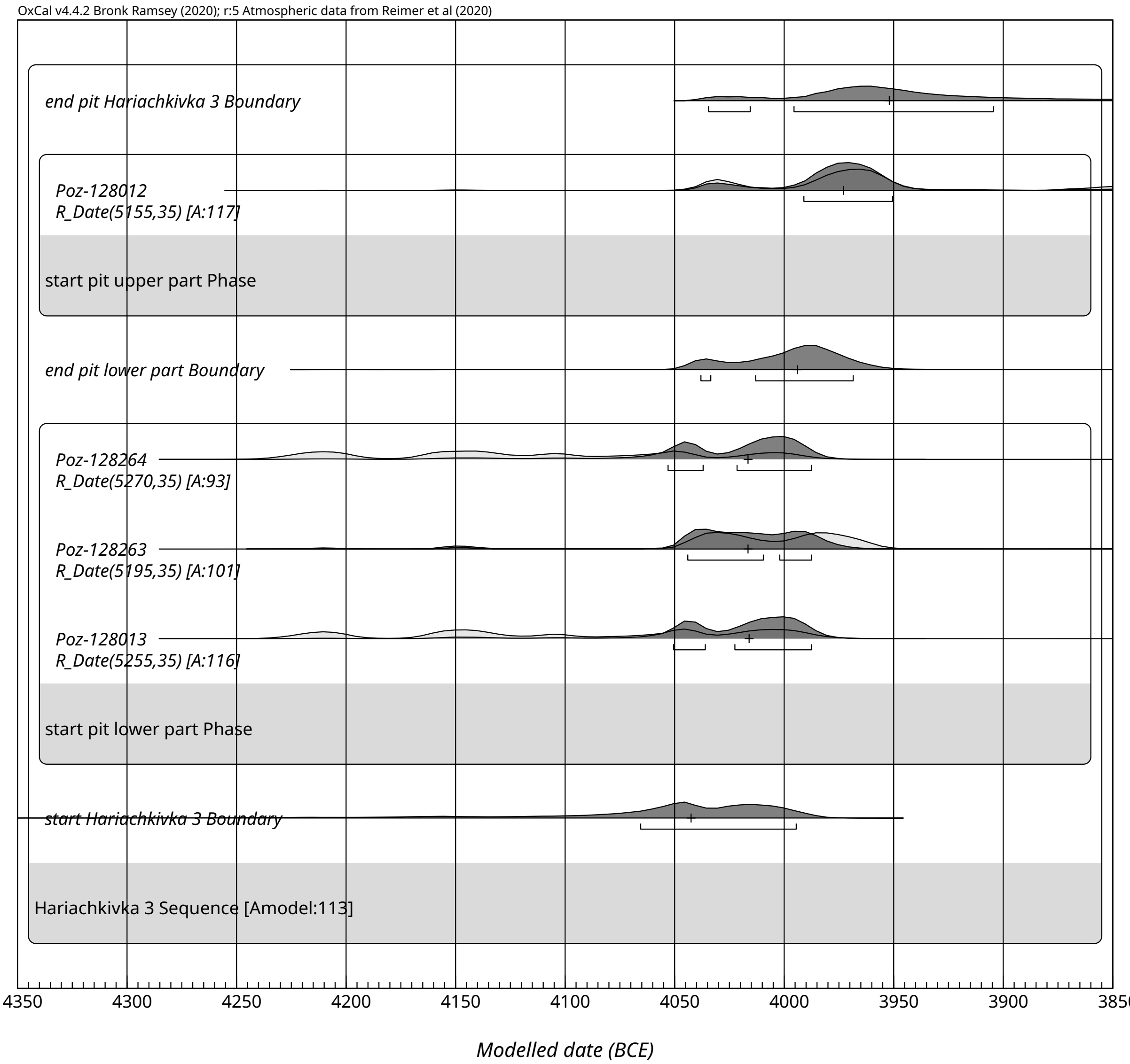


Figure 13. The Bayesian calibrations of Hariachkivka 3 (cf. Suppl. 1–2).

Bilyi Kamin (C1)

The 97-ha site has a trapezoidal layout with a radial orientation of the house rows including huge mega-structures in an open plaza. From Bilyi Kamin, nine bone samples were successfully radiometrically dated in the Poznan and Beta Radiocarbon Laboratories (Suppl. 1–2). The boundaries of the radiometric dating from a stratified pit, one house and an ancient surface near another house confirm a time span of **3950–3690 BCE** (medians; A_{model}=92.1; $A_{overall}$=89.2). Pit 3 with three stratified contexts dates to **3810–3730 BCE**, House 7 to **3890–3820 BCE** and the artefact from the ancient surface, which is probably associated with the use of House 9, to **3875–3690 BCE**. With respect to the dating intervals of the calibration curve, 3960–3780 BCE and 3790–3680 BCE are covered (Fig. 17).

In detail, the following observations and interpretations are valid (Rud *et al.* 2019a, 50–51; Suppl. 2). In Trench 3, three successive stages of the pit filling were dated with the samples Poz-109322, Poz-109323, and Beta-510927. The modelling of these dates resulted in a model with an overall probability of 76.5%, an acceptable range. According to this model, the backfill of the pit took place over a longer period between 3950–3860 BCE and 3849–3785 BCE (68.2%) or between 4032–3810 BCE

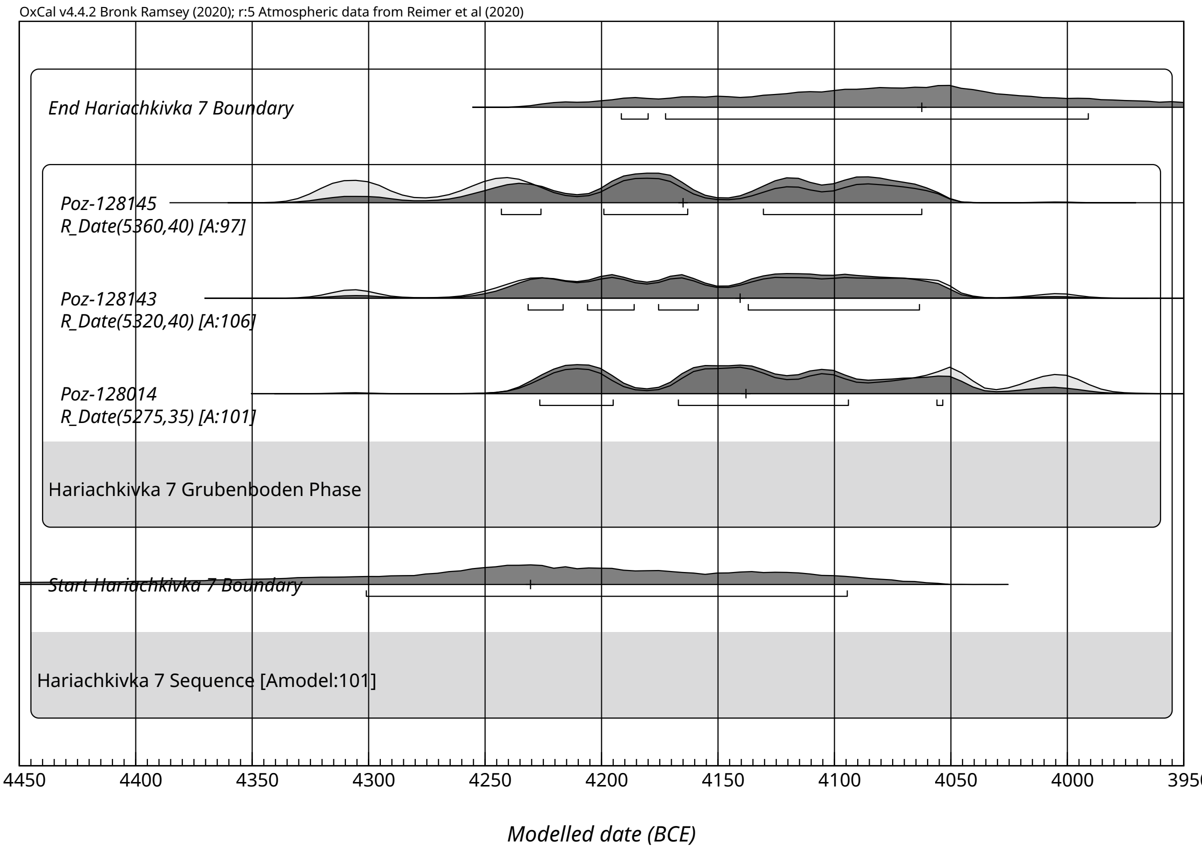


Figure 14. The Bayesian calibrations of Hariachkivka 7 (cf. Suppl. 1–2).

and 3949–3694 BCE (95.4%). The highest dating probability falls within a range of 75 years between 3890 BCE and 3815 BCE.

In Trench 4, the use-time of House 7 was dated with the four dates Poz-109324, Poz-109384, Poz-109450 and Beta-510929. These samples were found in different contexts in the lower and the upper floor of House 7 and the exterior space next to the house. The sample Poz-109378, which was found in the layer above the house debris, probably dates in the time after the use of House 7.

After exclusion of the outlier Beta-510929, the modelling of the dates resulted in the robust model with a probability of A_{model}=102. According to this model, House 7 was used over a period of 0–60 years between 3957–3878 BCE and 3919–3847 BCE (68.2%) or 0–190 years between 4051–3775 BCE and 3935–3781 BCE (95.4%). The post-use phase of House 7 falls in the range between 3919–3847 BCE and 3897–3766 BCE (68.2%) or between 3935–3781 BCE and 3936–3590 BCE. With the highest probability, the use of House 7 took place over a period of 35 years between 3910 BCE and 3875 BCE. The highest probability of the post-house-use activities took place over a period of 25 or 85 years between 3875 BCE and 3850 or 3790 BCE.

In Trench 5, only one sample (Poz-109379) could be successfully dated due to a lack of suitable sample material. The sample originates from a waste disposal area beside the house and probably dates the use of House 9. The sample dates in the range of 3960–3806 BCE (68.2%) or 3968–3798 BCE (95.4%). With the highest probabilities, the sample dates to 3950 BCE or in the period between 3870 BCE and 3820 BCE.

Summarizing the widely consistent results obtained in the different trenches, the settlement activities in Bilyi Kamin took place with the highest dating probability mainly during the 39th century BCE (Fig. 19). Considering a more reliable dating range of 68.2% probability, a 200-year use of the site from the middle of the 40th until the middle of the 38th century BCE is possible. The 2-σ dating range falls between about 4000 BCE and 3600 BCE.

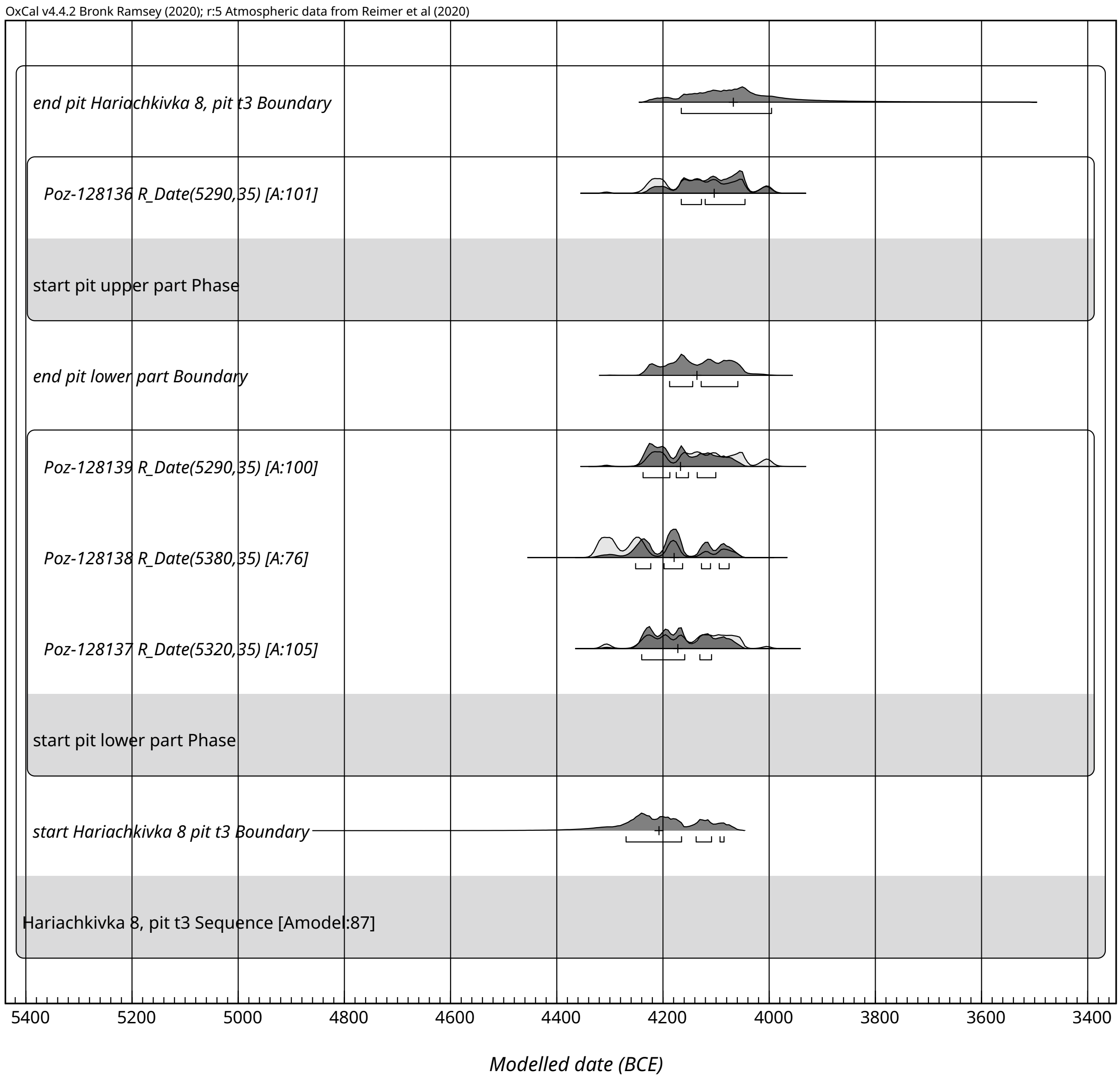


Figure 15 (above). The Bayesian calibrations of Hariachkivka 8, pit 3 (cf. Suppl. 1–2).

Figure 16. The Bayesian calibrations of Trostianchyk (cf. Suppl. 1–2: Fig. 17).
Due to the length of this figure, for ease of viewing it is only available online (https://doi.org/10.57892/100-55).

Viitivka (C1)

The 48-ha site Viitivka has large oval house rings that form a ring corridor. The geomagnetic survey revealed three mega-structures, more than 60 pits and about 40 burnt houses, likely in at least two concentric rings (Ohlrau 2020, 251, Fig. 157). A test trench of a pit provided six datable samples, which fit into a Bayesian model (Fig. 18). The most probable duration (medians; A_{model}=109.6; $A_{overall}$=110.0) of the pit from **3780–3630 BCE** is also due to 4 pit filling phases, ca. **3780–3750**, **3750–3710**, **3710–3680** and **3680–3640 BCE.** The datings fall within the dating intervals 3790–3720 BCE, 3720–3700 BCE, 3700–3660 BCE and 3660–3640 BCE.

Krynychky-Ferma (C2)

This site has a circle of houses around a free space and some houses and features outside of this structure, not really linked to the concentric inner principle (Chapter 14, this work, Vol. II). Five radiocarbon samples from test trenches of two pits were suitable. They are linked to the southern part of the inner concentric circle. The overall estimation indicates a duration of the dated pits between **3620 BCE**

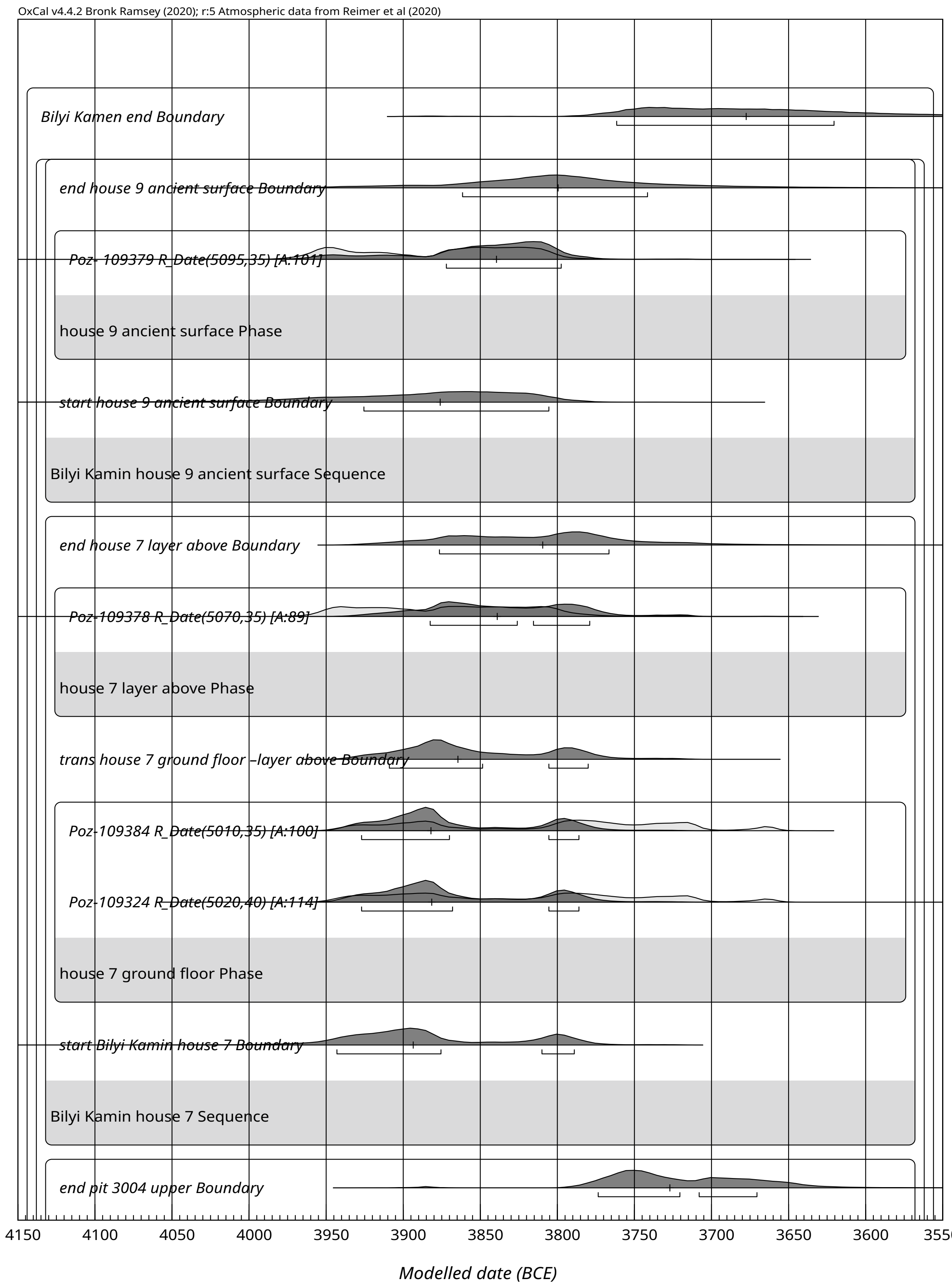


Figure 17A. The Bayesian calibrations of Bilyi Kamin, part 1 (cf. Suppl. 1–2).

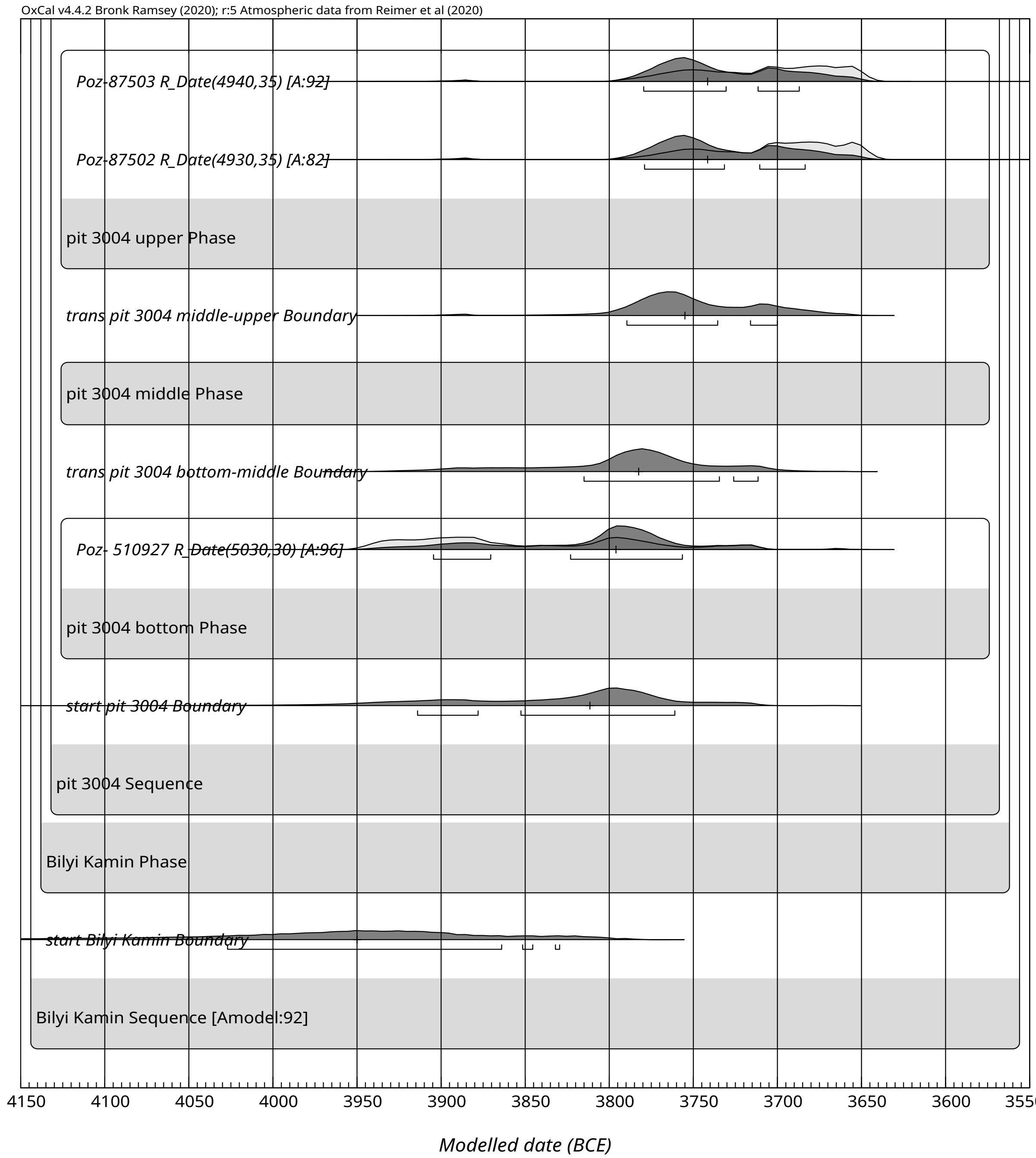


Figure 17B. The Bayesian calibrations of Bilyi Kamin, part 2 (cf. Suppl. 1–2).

and 3530 BCE (medians of the boundaries; A_{model}=102.3; $A_{overall}$=105.2; Fig. 19). If each pit is taken separately, the duration of Pit 1 is estimated from **3580–3560 BCE** and of Pit 2 even from **3580–3550 BCE** (medians of the boundaries). The described deviation is observed because of the dating intervals within the calibration curve (3640–3520, 3520–3380 BCE).

Summary

In the western Trypillia area we estimate Trypillia phases as follows: B1–B2 4270–3970 BCE; B2 3970–3960 BCE; C1 3950–3610 BCE and C2 3620–3520 BCE (Fig. 20).

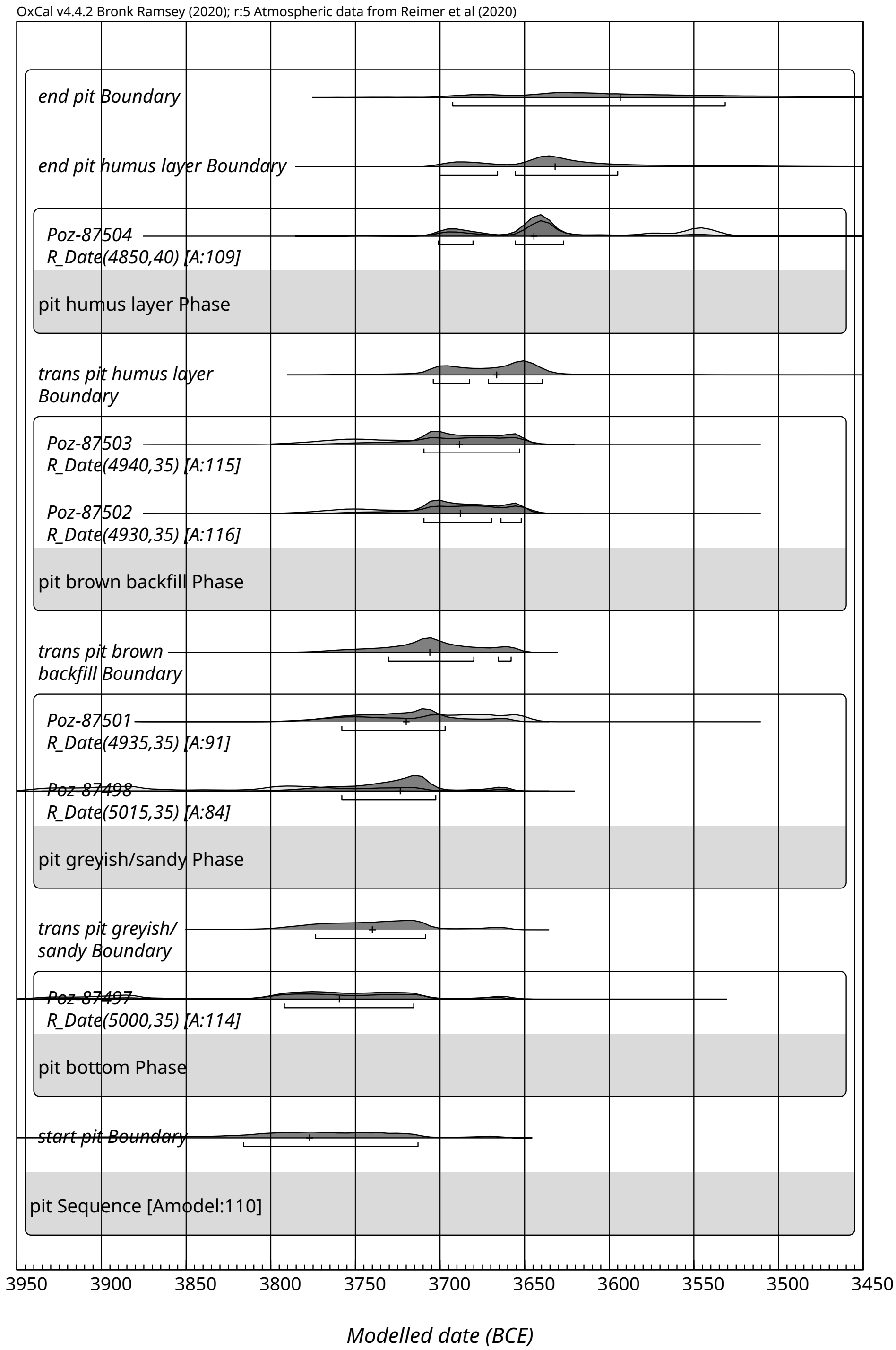


Figure 18. The Bayesian calibrations of Viitivka (cf. Suppl. 1–2).

Southern Bug-Dnieper interfluve (Central Ukraine)

The Dnieper Plateaus between the Dnieper and the Southern Bug form a landscape, in which a cluster of especially large mega-sites is present at the Sinyukha River Basin.

Grebenyukiv Yar (A3)

The 2-ha site has parallel house rows (Shatilo 2021, 149). One pit was dated based on stratigraphic order. Four dates belong to a time span from **4540–4390 BCE** (median; A_{model}=124.5; $A_{overall}$=123.7), belonging to the dating intervals **4550–4460 BCE**

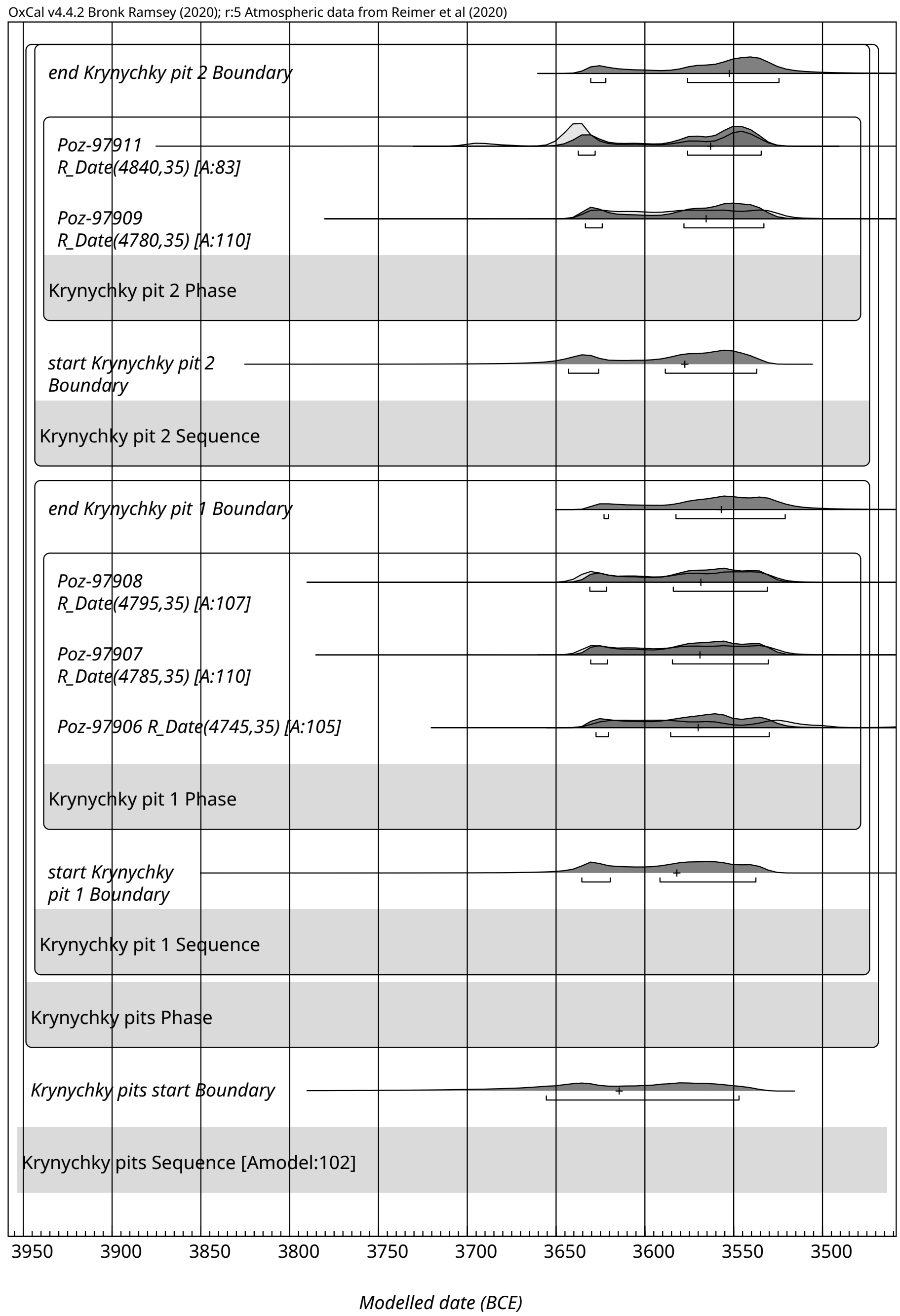


Figure 19. The Bayesian calibrations of Krynychky-Ferma (cf. Suppl. 1–2).

and **4460–4360 BCE**. The lower part of the pit falls into the lower calibration curve plateau, the upper part of the pit into the upper plateau (Fig. 21).

Veselyj Kut (B1–B2)

The 60-ha site with concentric planning, one big and probably five small mega-structures yielded eight datable samples, of which seven fall within the Trypillia range (Shatilo 2021, 146–148). Three of the dates belong to two layers of a pit and five to surface find concentrations at three houses. The date **4150–4000 BCE** (median of boundaries; A_{model}=94.3; $A_{overall}$=95.3) falls within the dating intervals 4230–4050 and 4050–3980 BCE. But in principle, the position on the steep part of the calibration curve at ca. 4050 BCE is plausible. In detail, Pit 1007 with its

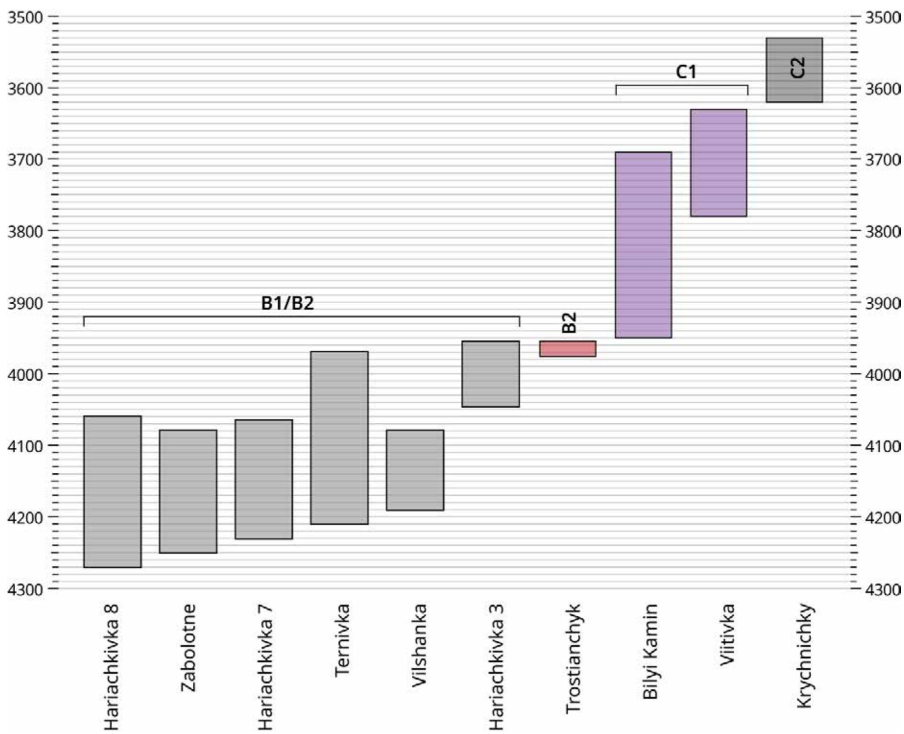
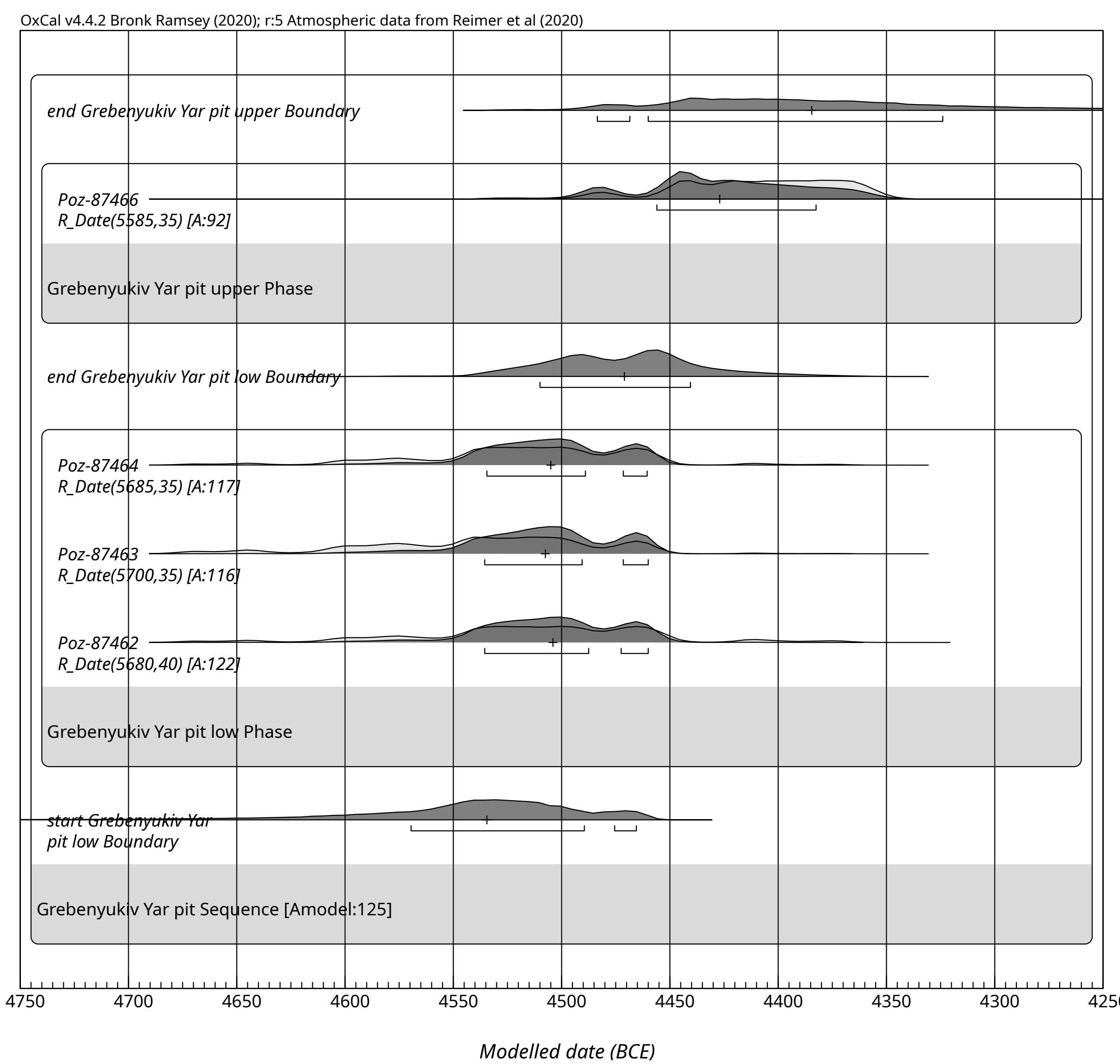


Figure 20. The comparison of Bayesian dates of individual sites from the Bug-Dniester interfluve.

Figure 21 (below). The Bayesian calibrations of Grebenyukiv Yar (cf. Suppl. 1–2).



internal stratigraphic information is dated to 4200–4030 BCE, thus in principle also covering the dating interval 4250–4050 BCE (Fig. 22).

Chyzhivka (B1 or B1/2)

First datings of the 20-ha site with a concentric layout and one central mega-structure belong to a pit, of which two datable samples belong to the period from ca. **4120–3950 BCE** (medians; cf. Suppl. 2: Fig. 2). In principle, the dates are restricted to the dating interval 4050–3980 BCE (Shatilo 2021, 148–149).

Volodymyrivka (B2)

From the 95-ha site with a concentric plan, which includes ten small and one large mega-structure from a test trench, only two samples were datable (Shatilo 2021, 145–146). They belong to two different layers of a pit. The overall dating ranges from **3930–3800 BCE** (medians; cf. Suppl. 2: Fig. 3).

Nebelivka (B2)[7]

With its 235 ha and 1445 verified houses, Nebelivka is relatively large on the one hand, but it has a barely settled inner area on the other hand, and, apart from the ring corridor, it hardly has the otherwise typical concentric house rings (Fig. 23). Due to the extensive research strategy of test pit excavations, many radiometric dates have been produced. They are reanalysed here and in contrast to the original publication, the differentiation between *termini post, ante* and *ad quem* was included into the analyses.

Archive and methods

94 radiometric dates are available from Nebelivka (Millard 2020; Suppl. 3). Due to the status of publications, they can easily be associated with contexts. For instance, the systematic presentation of the layers of the test pits, to which the radiometric samples can be assigned, is exemplary (Gaydarska *et al.* 2020a). In most cases, the find assemblages have not been processed and published. Therefore, it is not possible to associate the dates to the find inventories. However, this does not play a major role here for our questions on the internal development of the site.

Accordingly, we have assigned the dates based on their stratigraphic relationships to the three categories (*post*, *ad*, *ante*). Some specific restrictions can appear with regard to the quality of the samples, for example, reservoir effects of carnivores or old wood effects, such as is common for oak (*Quercus*). This was noted in the ^{14}C list in Supplement 3.

A reduction to *termini ad quem* leads to the reduction of the number of useable ^{14}C dates to 73, whereby the undefined sample material or the possibly problematic material has not yet been sorted out. The dates are more or less evenly spread over the entire settlement area of Nebelivka.

We aimed to determine the basic tendencies of the spatial-chronological distribution of domestic activities in Nebelivka. Thus, the following procedures were chosen:

1. Selection of the *termini ad quem* for the analysis.
2. Calibration of the radiometric data with Oxcal 4.0 according to the Intcal 2020 curve (Bronk Ramsey 2009a; Reimer *et al.* 2020). In addition to the 2-σ probability, the 1- σ probability and the median are calculated.
3. Mapping of the median of the radiometric dates in the settlement plan according to main calibration curve plateaus and slopes of the calibration curve (these

7 The results were partly already published (cf. Müller *et al.* 2022).

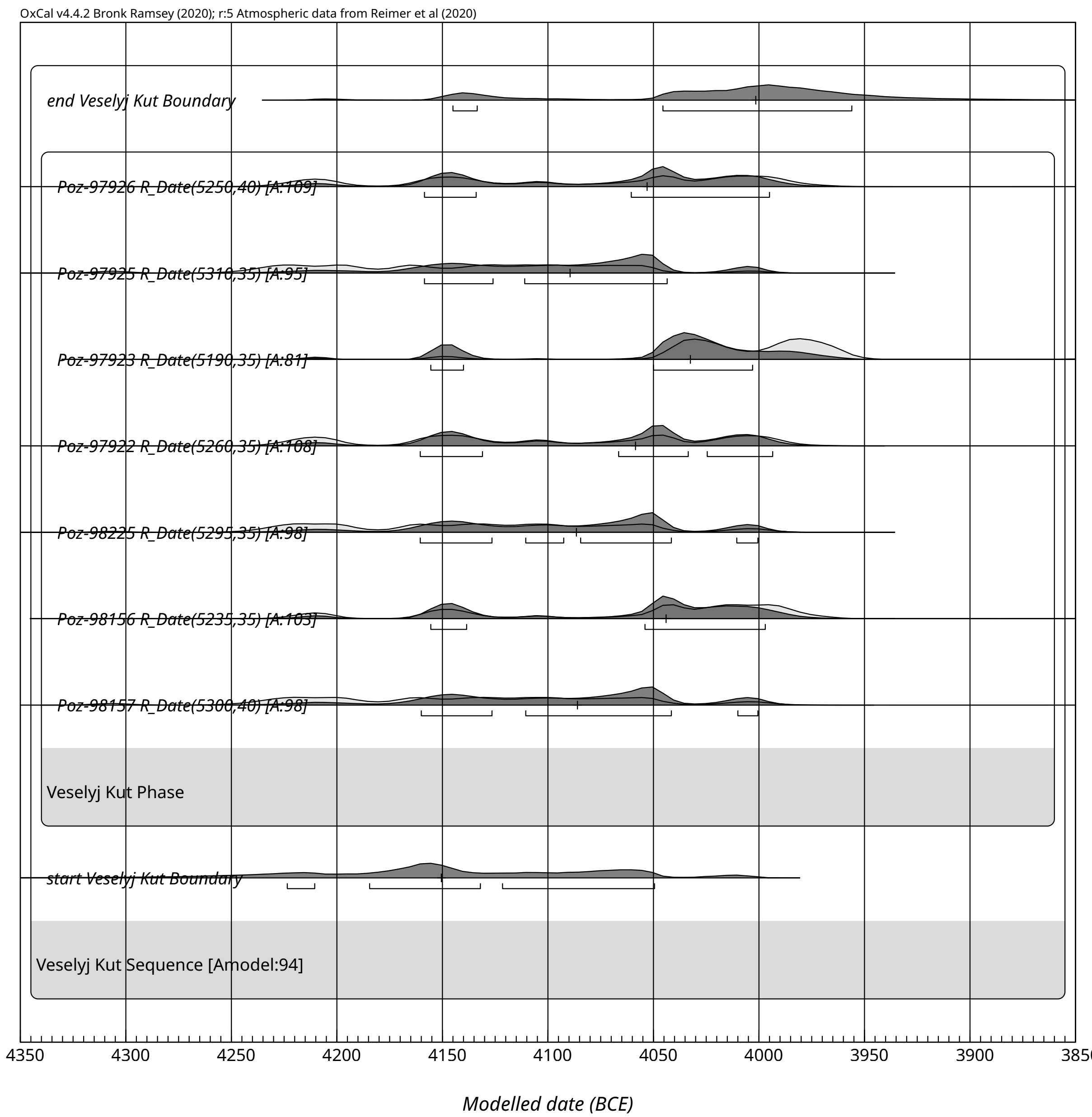


Figure 22. The Bayesian calibrations of Veselyj Kut (cf. Suppl. 1–2).

are: 4050 (–3975) –3950 BCE; 3950–3800 BCE; 3800–3700 BCE; 3700–3630 BCE; 3630–3500 BCE; after 2900–1700 BCE) in order to record the focal points of the respective activities in the respective contexts.

4. Interpretation of the observations. To this end, the main points of distribution are shown graphically and discussed with different parameters (*e.g.* lifespan of houses).

Here, the chosen methodological approach and the resulting analysis are only one component of our analyses. Bayesian dating approaches to contexts, where this is possible, was also applied (see below).

Results and interpretation of mapping ^{14}C dates

The spatial distribution of the medians of the *termini ad quod* dates according to the respective sections of the calibration curve provides a differentiated picture. The similarities and the differences can be described according to a differentiation of external occupancy (outside of the ring corridor), the occupancy of the outer house row of the ring corridor, of the inner row of the ring corridor and that of the internal settlement (within the ring corridor). Additionally, special spatial and functional units are observed, for example, a kiln or mega-structures[8].

The following outline emerges for spatial and chronological occupation trends at Nebelivka (cf. Tabs. 2–3; Fig. 23):

- From ca. 4050–3950 BCE, the few usable dates indicate occupancy of the outer and inner ring corridors and the inner area.
- From ca. 3950–3800 BCE, settlement of the outer and inner ring corridor as well as the inner area takes place. The large mega-structure is documented. The establishment of houses is twice as common in the inner row of the ring corridor as in the outer row of the ring corridor.
- From ca. 3800–3700 BCE, only the outer row of the ring corridor is still settled, whereas the inner row of the ring corridor is not settled and only one house lies in the inner area at the southern entrance. A smaller mega-structure is documented.
- From ca. 3700–3630 BCE, at a time when hardly any activity is verified, there are two houses in the outer row of the ring corridor that are documented by radiometric dating.

The interpretation of the identified tendencies is simple at first. The oldest house building activities in Nebelivka at ca. 4000 BCE prove that the basic concept of a ring corridor and the inner settlement that does not adhere to concentric rules is known: the few early ^{14}C dates are available from all three areas. After ca. 3950 BCE, the settlement of the inner concentric circles of the ring corridor and the inner area of the mega-site occurs – but also the settlement of the outer circle of the ring corridor. This focus of house building activities changes after 3800 BCE with a new spatial concept: the establishment of new houses is almost exclusively limited to the outer concentric circle of the ring corridor. Even the few house constructions at the end of the occupancy time after ca. 3700 BCE (and before 3600 BCE) are built in the outer circle of the ring corridor.

If we convert the absolute number of dates in the time segments into relative numerical values (per ten years), the high proportion of building activities is particularly clear for the second half of the 40th and during the 39th century BCE. Subsequently, a decrease follows in the 38th century BCE and an end of the activities during the 37th century BCE (Fig. 24).

With these relative dates, we are additionally able to calculate the absolute number of houses in Nebelivka (1445; cf. Hale 2020, 129, Tab. 4.2) with a simple model. First, we assume an average lifespan of 50 years for the houses (cf. Diachenko 2016; Millard 2020, 256; Ohlrau 2020, 233–236). When calculating the number of houses, the respective determined domestic house activities per 50 years were considered, added together, divided by the total number of geophysically determined houses and then finally multiplied again by the relative value per 50 years (cf. formula described above for Stolniceni). According to the results, ca. 75 simultaneously existing houses were calculated for 4000 BCE, ca. 330 for 3875 BCE, ca. 135 for 3750 BCE and 28 for 3675 BCE (Fig. 25).

The graph also presents the variation if assuming an average lifespan of 25 and 75 years for the houses, so that a margin of error can be seen. If we continue to assume that there were 5–10 residents per house, then ca. 375–750 persons lived in Nebelivka around 4000 BCE, ca. 1650–3300 persons around 3875 BCE, ca. 675–1350 persons around 3750 BCE and still 140–280 persons around 3675 BCE (Fig. 25).

8 Furthermore, we differentiate more technically radial segments according to the catchment areas of the mega-structures. However, these do not play a role in the further evaluation (cf. Tab. 3).

Interval BCE	Mega-site segments	Outer row	Inner row	Inner area	Others
		of ring corridor			
4050–3950		3	1	1	
	M8		1		
	M17	1			
	M15	1			
	M2	1			
	M6			1	
3950–3800		9	18	6	mega
	M8	1	7		
	M9	2			
	M10	1	1	2	
	M27/3/4		2		
	M13	1	1	2	
	M15	2			
	M2/3	2	3 (pit, big mega)	2	big mega, pit
	M4		3		
	M5		1		
3800–3700		8		1	mega
	M6	1			
	M7	1			
	M8	1			
	M17	1			
	M10/18	1			mega
	M13			1	
	M15	2			
	M2	1	(pit)		pit
3700–3630		2			
	M8	1			
	M10	1			
3630–3500				(indfeat)	Industrial feature
< 2900		1			mega big, mega
	M2/3	1			big mega
	M11				mega
sum		23	19	8	5

Table 2. The number of occupancies in Nebelivka for individual areas of the calibration curve (cf. Suppl. 3).

With regard to the simultaneous houses, the calculated maximum number roughly corresponds to the results of (Millard 2020, 256). Due to the qualitative differentiation of the radiometric dates according to the depositional qualities, it was now also possible to determine the spatial and temporal dynamics of developments at Nebelivka.

Results and interpretation of Bayesian calibration

While we have so far done the single-date calibration and the mapping of the results by time intervals, in the following we will do the Bayesian calibrations of contexts with more than one date and of those with stratigraphy. This was the case

n ^{14}C	Without stratigraphy	Stratigraphy	Single tpq	n
1	32			32
2	2	5		7
3	3	2		5
4	1	1 + MS		2+M
5				0
6		1		1
Single			9	9
Houses n	38	9 + MS	9	56 + MS
Houses directly dated	38	9+MS		47 + MS

Table 3. Nebelivka: the number of ^{14}C dates per context (cf. Suppl. 3).

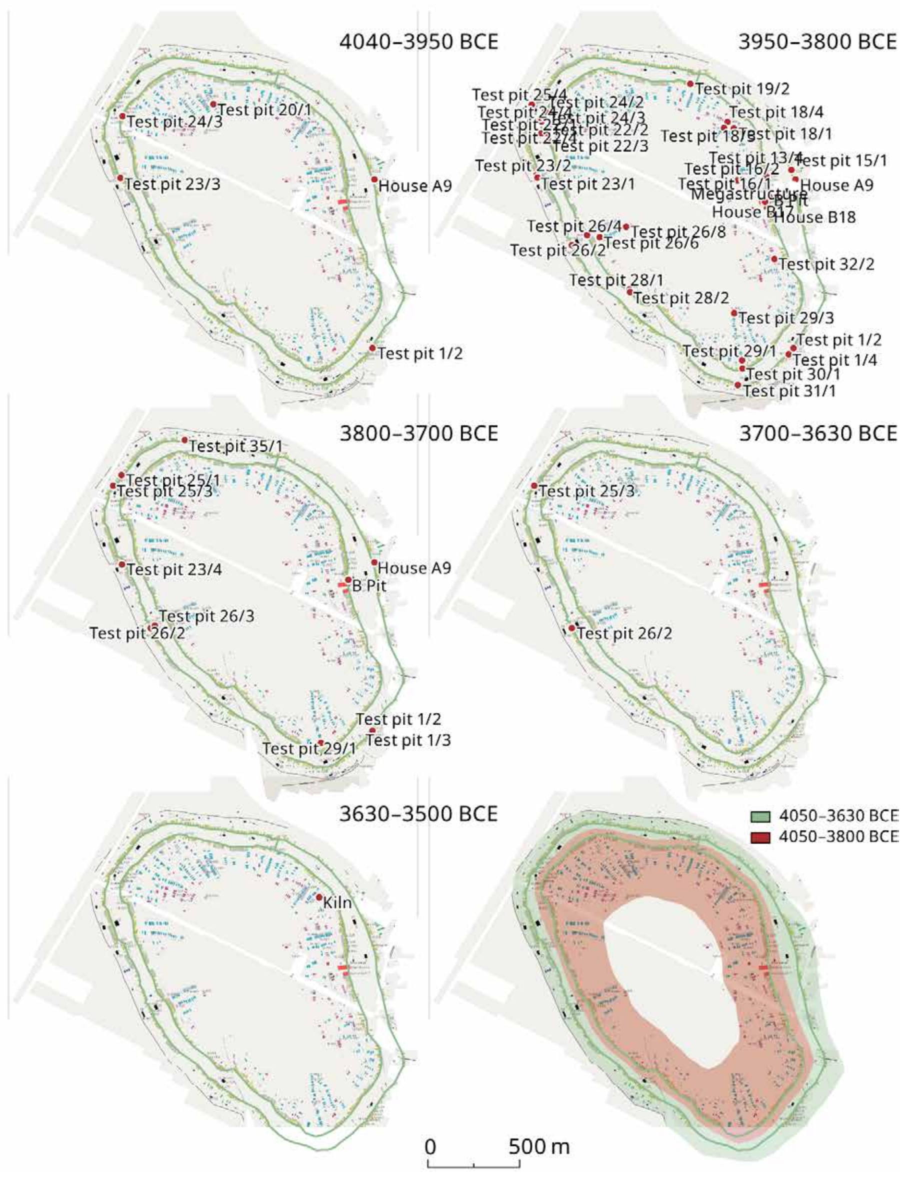


Figure 23. Nebelivka: radiometric dates of termini ad quem *and the settlement model.*

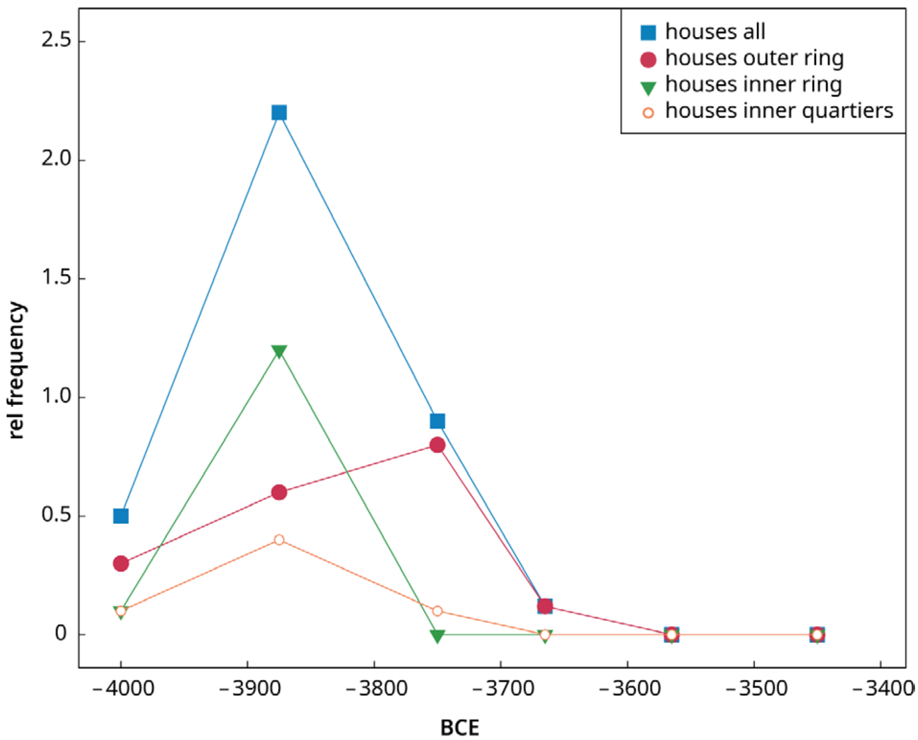


Figure 24. Nebelivka: the relative number of houses (conversion of the dated houses on a linear time scale).

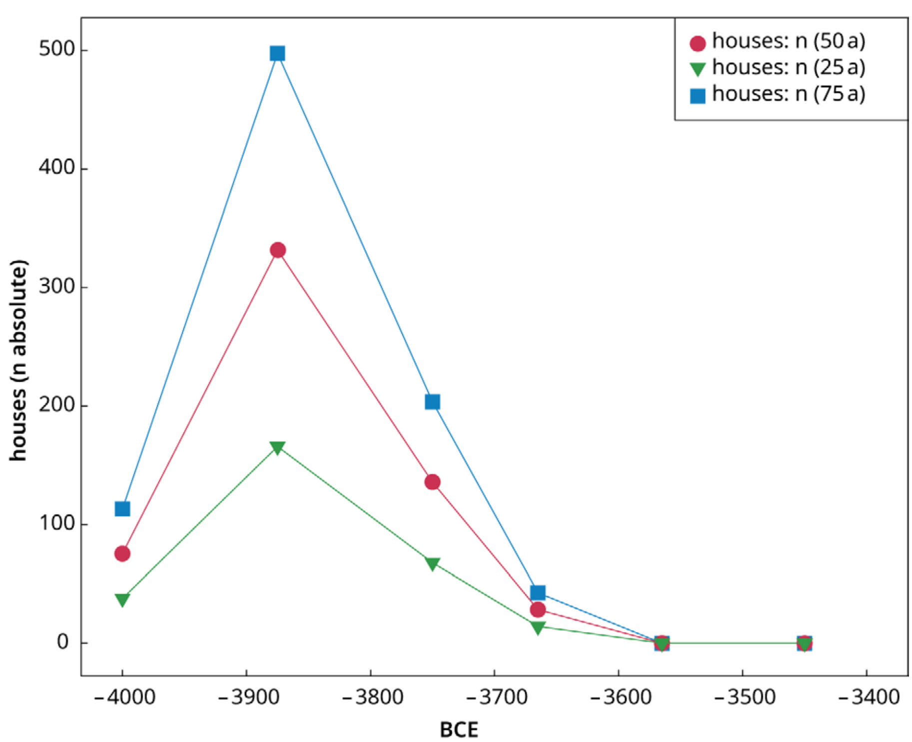


Figure 25. Nebelivka: the absolute number of houses (n) for the assumed use of the houses for 25, 50 and 75 years (a).

at 15 locations, including the test trenches, two of the excavated houses and the large mega-structure (Tab. 3)[9]. In detail, the following results of Bayesian dating of contexts with few ^{14}C dates are valid (cf. Suppl. 2):

House A9. Three dates, with unclear stratigraphic relationship to each other, represent the phase of use. The Bayesian calibrated duration by median values ranges from **3935–3795 BCE** (A_{model}=112.9; $A_{overall}$=112.3; Suppl. 2: Fig. 4).

House B17 (Videiko and Burdo 2020). Based on the data, it is assumed that OxA-29667 (depth data 56 cm) was found below the *ploshadka* (up to 30 cm deep). The assignment of OxA-29600 (K6 H11) is not possible and the bone specimen not specified. The Bayesian calibrated duration by median value is set to **3962–3775 BCE** (pure ^{14}C data range: 3949–3866 BCE (limits) with medians 3866 and 3872 BCE; A_{model}=103.3; $A_{overall}$=103.5).

House B18. One date is available (K6), probably of the use of the house (3960–3800 BCE, median 3865 BCE).

Mega-structure (Gaydarska *et al.* 2020b, 194–211). Only three dates are available: OxA-31745 associated with the 'mega 2 construction phase' (bone species not identified); the two other dates from the 'mega 3 use time' are older, but in the model this does not play a direct role (Suppl. 2: Fig. 5): The Bayesian calibrated duration by median values is set to **3923–3823 BCE** overall, of the use phase **3869–3823 BCE**, and of the construction phase **3923–3869 BCE** (A_{model}=107.8; $A_{overall}$=106.2).

House Test Pit 1/2. The structure provides two dates of one sample (OxA-29576, OxA-29577) in Context 3, which in combination date the house use to **3931–3713 (median 3793) BCE**. A further date is stratigraphically unclear.

House Test Pit 13/4. The date OxA-29664 belongs to the upper layer and probably characterises a phase of use, whereas OxA 29346 comes from Layer 5 and is a *terminus post quem* (albeit oak with possible old wood effect). Nevertheless, the Bayesian model (A_{model}=102.8 / $A_{overall}$=103.2) is conclusive (Fig. 26). The Bayesian calibrated duration of the use of the house by median values ranges from **3786–3678 BCE** (A_{model}=102.8; $A_{overall}$=103.2).

House Test Pit 16/2. This house provides two dates (OxA-29347, OxA-29348) of one sample in Context 3, which, if combined, provide an estimate of house use from **3949–3805 (median 3863) BCE**.

House Test Pit 22/2. The date OxA 29592 belongs to the upper layer and probably characterises a phase of use. OxA 29666 derives from Layer 5 and is a *terminus post quem*. The Bayesian model is conclusive (A_{model}=100.4 / $A_{overall}$=100.3; Fig. 27). The Bayesian calibrated duration of the use of the house by median values is set to **3882–3813 BCE**.

House Test Pit 24/2. The structure provides three dates in Context 3 (OxA-31635, OxA-31636, OxA-31637), which together result in a conclusive Bayesian model (A_{model}=98.6; $A_{overall}$=100.1). The Bayesian calibrated duration of the use of the house by median values is set to **3935–3810 BCE**.

House Test Pit 24/3. The date Poz 72470 belongs to the lower layer of use (burnt clay), OxA 31638 and OxA-31639 are from Context 3 and represent the house use. The Bayesian model is conclusive (A_{model}=114.4 / $A_{overall}$=112.5; Fig. 28). The Bayesian calibrated duration of the use of the house by median values is set to **4038–3852 BCE**. The exceptional much older date was dated at the Poznan lab.

House Test Pit 25/3. The house provides three dates from Context 4 (OxA-31642, OxA-31663 (these two originate from one sample) and Poz-72471), which together result in a conclusive Bayesian model (A_{model}=93.5 / $A_{overall}$=95.3). The Bayesian

9 Data-quality: From the Houses B17, 18/4, 19/2, 19/4, 20/1, 22/3, 23/4, 25/4, 27/4, 28/2, 31/1, and 35/1, there are only data available which were obtained from problematic sample material (bone not determined, pig, *Quercus*).

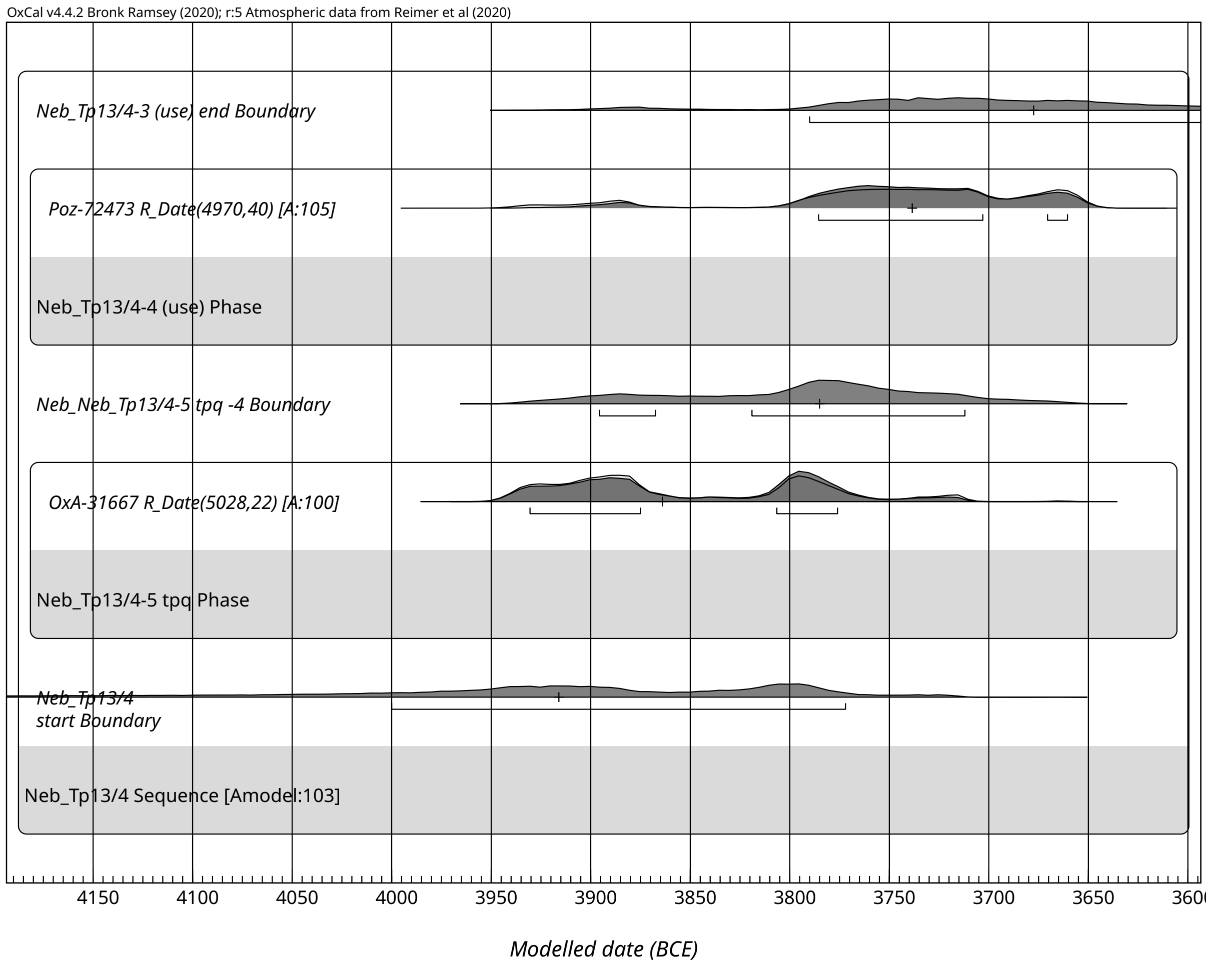


Figure 26. The Bayesian calibrations of Nebelivka House 13/4 (cf. Suppl. 1–3).

calibrated duration of the use of the house by median values is set to **3789–3634 (median 3712) BCE** (Suppl. 2: Fig. 7).

House Test Pit 25/1. There are two dates. OxA-31664 belongs to the upper layer and probably characterises a phase of use, but this is a pig bone. OxA-31665 derives from Context 5 and is a *terminus ante quem*. Nevertheless, the Bayesian model (A_{model}=100.6; $A_{overall}$=100.6) is conclusive. The Bayesian calibrated duration of the use of the house by median values ranges from **3881–3815 BCE**.

House Test Pit 26/2. Three dates are associated with two phases of house use. Bayesian dating does not lead to a useful model, because the stratigraphically older phase has the youngest date Poz-72472 (poor agreement: A_{model}=51.4; $A_{overall}$=51.8). Without this Poznan date, the model is conclusive (A_{model}=106.4 / $A_{overall}$=105). Thus, the Bayesian calibrated duration of the use of the house by median values is set to **3906–3731 BCE** (Suppl. 2: Fig. 8).

House Test Pit 26/3. Two dates with a good fit represent a *terminus ante quem* and use-phase. Thus, the Bayesian calibrated duration of the use of the house by median values ranges from **3786–3678 BCE**.

House Test Pit 26/4. Four data form a conclusive Bayesian model (A_{model}=104.6 / $A_{overall}$=106.6). The Bayesian calibrated duration of the use of the house by median values is set to **3893–3846 BCE**, of the tpq from 3931–3893 BCE (Suppl. 2: Fig. 9).

House Test Pit 30/1. With the two data, a conclusive Bayesian model is provided. The Bayesian calibrated duration of the use of the house by median values ranges from **3864–3814 BCE**.

House Test Pit 29/4. Six data are provided, of which 2 are re-measurements (combine function in use). Activities obviously took place after the house duration

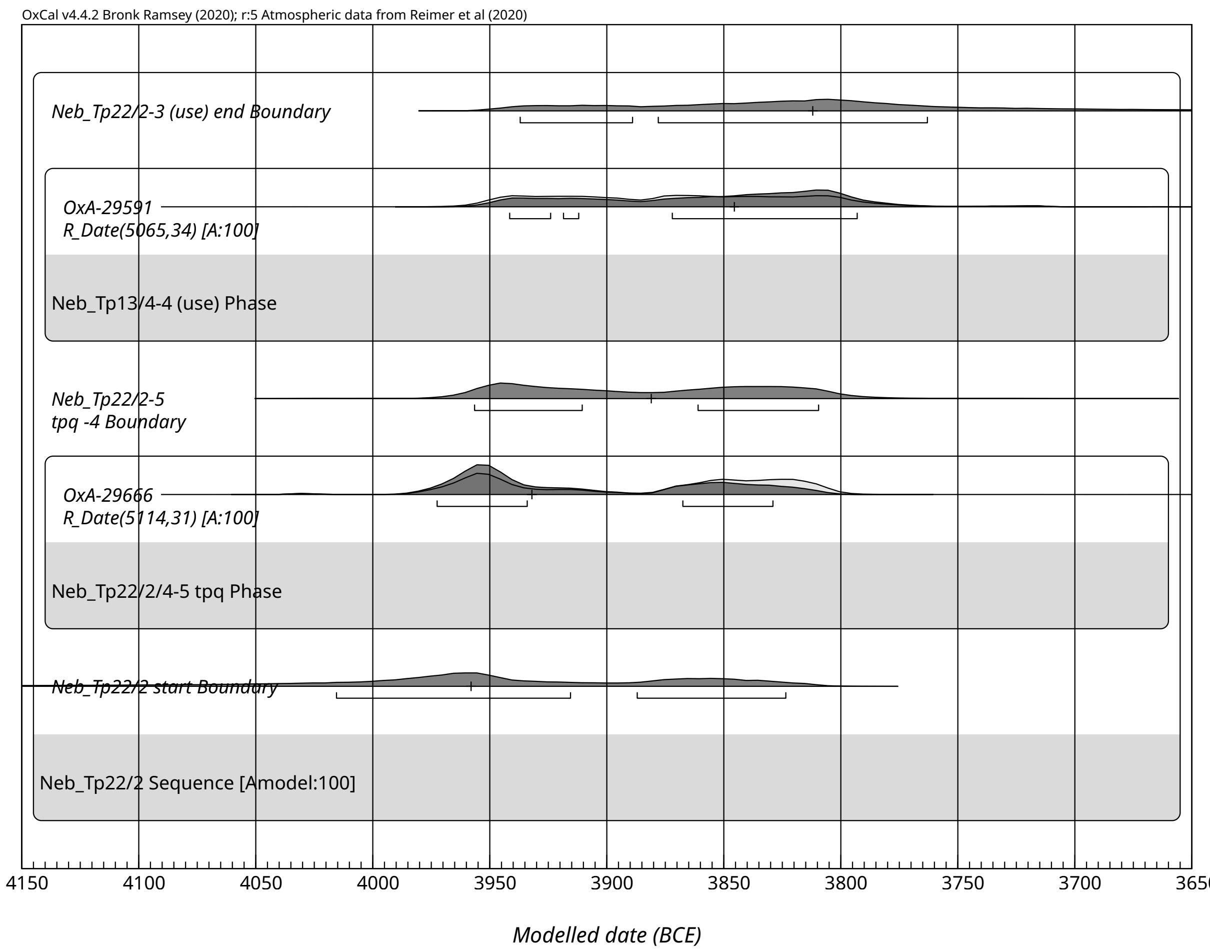


Figure 27. The Bayesian calibrations of Nebelivka House 22/2 (cf. Suppl. 1–3).

(Layer 1) and during 2 phases of use (Layers 3–4). The Bayesian calibrated duration of the use of the house by median values is set to **3922–3858 BCE** (A_{model}=87; $A_{overall}$=92.6; Fig. 29).

In principle, the results do not deviate from those presented via the mapping of individual radiocarbon data (see above). In this respect, if considering the *termini post quem* and *ante quem* for the sharpening of the time intervals of the 15 houses, the obtained results confirm the basic tendency of the development of the Nebelivka site.

Furthermore, it can be stated that the 14 tpq-dates – 11 probable domesticated animals in addition to two indeterminate bones and one oak sample – belong to the time interval ca. 3950–3800 BCE. Thus, if these samples also indicate the use of domestic sites, the modelling of occupation density would be even more concentrated in the time period before 3800 BCE (Fig. 30). The medians of the boundaries place the main occupation from ca. **3920–3825 BCE** (A_{model}=81.9; $A_{overall}$=67.2).

Nebelivka: Overall results and interpretation – the *organisation of house generations*

A detailed spatial examination of the *termini ad quem* in individual areas of the settlement confirms the already proposed model.

In the settlement, the ^{14}C dates cluster spatially in specific areas (Fig. 31). In all areas, an older house is found (Phase 1: 4050–3950 BCE), followed by an occupation of the rows in the following Phase 2 (3950–3800) and a further occupation in Phase 3 (3800–3700 BCE). For example, in the NW with Test Pit 24/3, we recognise a house of Phase 1, which is followed by 6 dated houses in the inner ring corridor ring and one in the outer ring corridor ring in Phase 2. In the outer ring, the

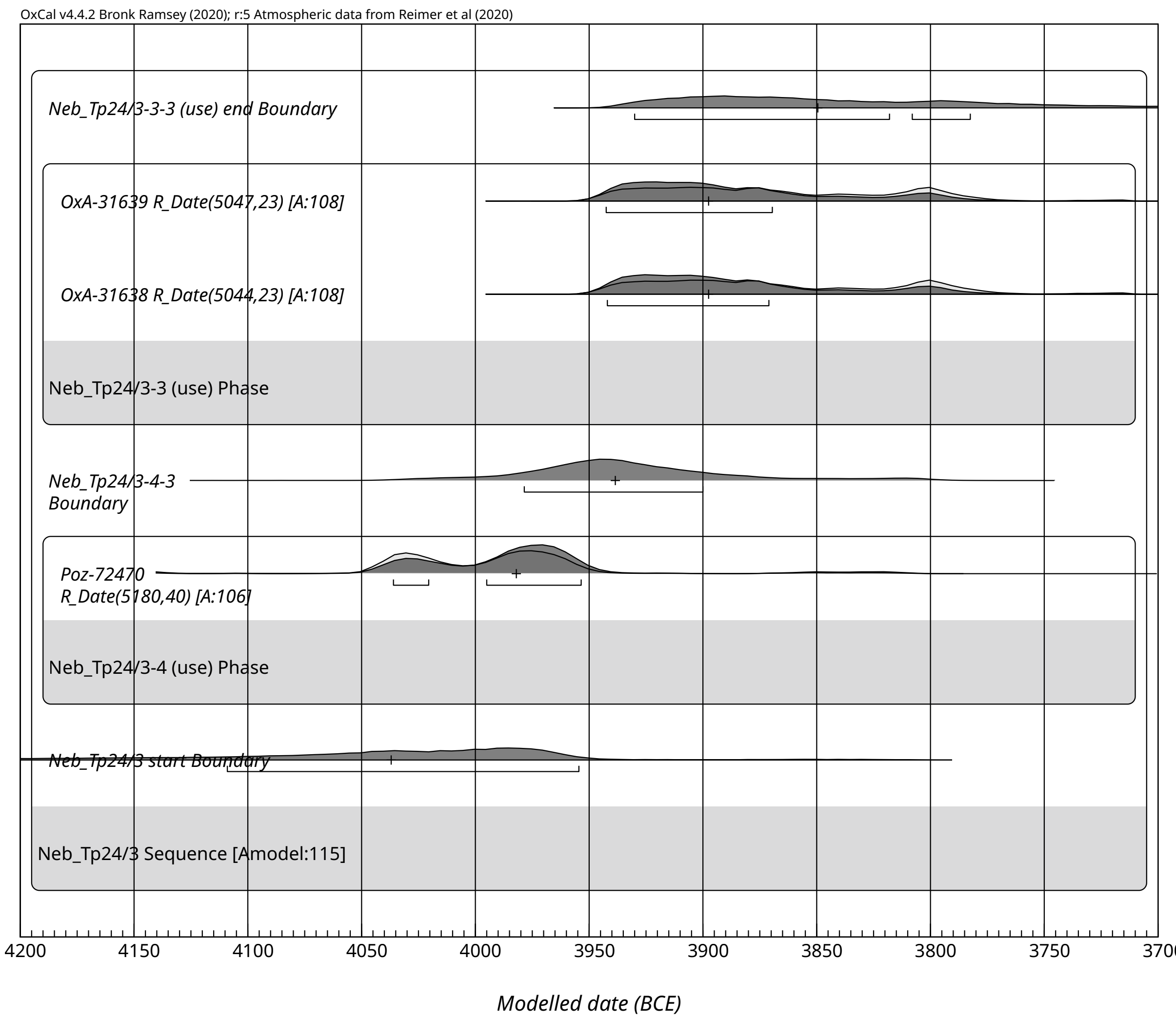


Figure 28. The Bayesian calibrations of Nebelivka House 24/3 (cf. Suppl. 1–3).

houses Test Pit 25/3 and Test Pit 25/1 are the last new foundations in Phase 3 (ca. 3800–3700 BCE). In a comparable form, this pattern is repeated (but without new houses in Phase 3) in the NE, in the area of the mega-structure, and in the west. In the south, we find all three house foundation phases represented, even with closely neighbouring houses in the outer ring.

As far as the dated mega-structures are concerned, the large and the directly neighbouring mega-structure House 17 are contemporaneous in Phase 2 (3950–3800 BCE), the smaller Mega-structure 23/3 is younger (Phase 3: 3800–3700 BCE).

With this detailed information and the possibility to describe the internal spatial occupation process, Nebelivka will be generally comparable with other mega-sites.

Pishchana (B2, early C1)

The 15–16 ha large site (Shatilo 2021, 143–144; assemblages not published) yielded seven datable samples from test trenches, of which one did not fit the final model (Fig. 32). Five used dates belong to two houses and one to a pit. While the overall estimation links the data to the time span **4010–3900 BCE** (medians of the boundaries; A_{model}=121.1; $A_{overall}$=122.1), the two houses did probably exist between **3960–3930 BCE** and **3980–3950 BCE**, while the pit, which is associated with the first house, had a duration from **3980–3960 BCE**. The data covers the dating intervals 4040–3980, 3980–3950 and 3950–3890 BCE, but is mainly restricted to the

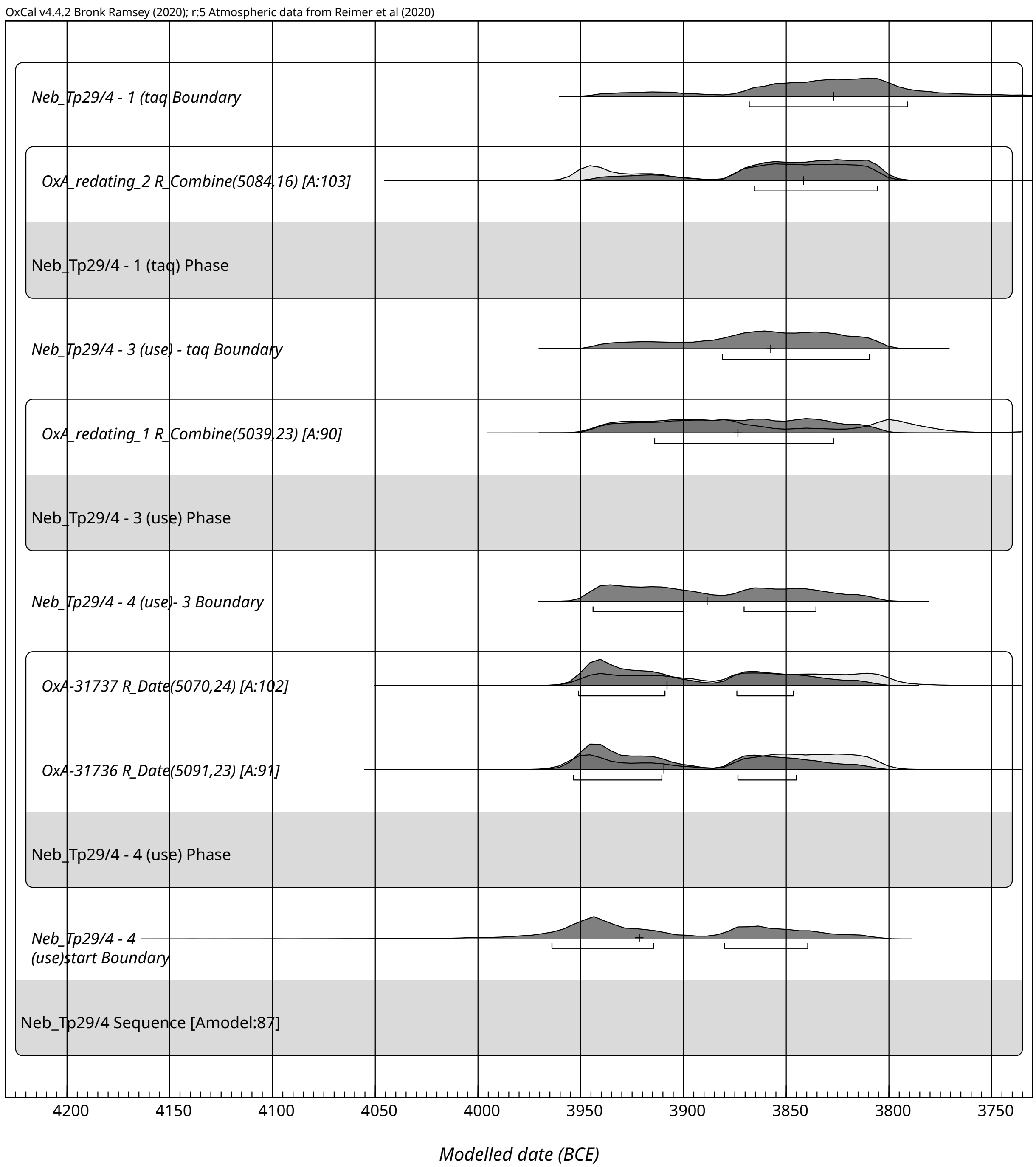


Figure 29. The Bayesian calibrations of Nebelivka House 29/4 (cf. Suppl. 1–3).

Figure 30. The Bayesian calibrations of Nebelivka, all features (cf. Suppl. 1–3, including Suppl. 2: Fig. 6). ***Due to the length of this figure, for ease of viewing it is only available online (https://doi.org/10.57892/100-55).***

first two dating intervals. In principle, the steep part of the calibration curve is mostly covered (3980–3950 BCE).

Rohy (B2–C1)

Rohy is a site measuring 5.3 ha and is composed of mainly two concentric house rings and an empty inner space (Ohlrau 2020, 244–245). The excavation of a test pit revealed three samples for ^{14}C dating (Chapter 13, this work, Vol. I). According to medians, the pit was filled during the time span **3710–3530 BCE** (Suppl. 2: Fig. 10; A_{model}=114.7; $A_{overall}$=113.9).

Dobrovody (C1)

The 100-ha mega-site yielded radiometric data from a mega-structure and a kiln (Shatilo 2021, 141–142). Of the six suitable dates, five are used in the general model since a date from the Kiel lab did not fit into the model (Fig. 33). Altogether, the site is dated between **3820 BCE and 3720 BCE**, with the kiln **from 3790–3760 BCE** and the mega-structure **from 3790–3760 BCE** (medians; A_{model}=112.3; $A_{overall}$=113.2). The individual Bayesian modelling of the kiln displays a duration from **3830–3700 BCE** and the mega-structure from **3890–3720 BCE.**

The dates cover the data intervals 3940–3780 and 3780–3720 BCE. Nevertheless, most of the data is restricted to the steep part of the calibration curve at 3790 BCE.

Moshuriv 1 (C1)

From the 1-ha site that consists of two house rings and houses also in the central area, three datable samples belonging to one pit were analysed (Ohlrau 2020, 241–243, Fig. 149; Shatilo 2021, 144–145). In principle, the pit is dated from **3940–3630 BCE** with two dates in the dating interval 3790–3660 BCE and one in the dating interval 3960–3790 BCE (Suppl. 2: Fig. 11; A_{model}=94; $A_{overall}$=93.4).

Moshuriv 2 (Smaglievi Berehy) (C1)

The plan of the site is difficult to explain: a kind of outer house ring seems to be visible (Ohlrau 2020, 244–247, Fig. 152; Chapter 13, this work, Vol. I). Radiocarbon dates from a pit confirmed a date around **3935–3625 BCE**.

Maidanetske (C1)

Encompassing 200 ha in size and numerous excavation activities, Maidanetske is one of the very well-researched Trypillia mega-sites (Müller *et al.* 2017; Ohlrau 2020; Figs. 34–43). The number of houses could be reconstructed to 2932 (Ohlrau 2020, 64, Tab. 7). Even if there are more than 90 radiometric datings available for Maidanetske at the moment, the detailed analysis is quite difficult. This is true because of the wiggle and plateau structure of the calibration curve. In principle, we observe a steep dating interval from ca. 3990–3950 BCE, followed by a dating interval with a wiggle plateau from 3950–3780 BCE, another dating interval from 3780–3730 BCE including a plateau, a further dating interval from 3730–3640 BCE including a positive and a negative steep part, and a dating interval with a steep part from 3640–3550 BCE. As such, the dating evidence depends very much on the security of the dates and internal stratigraphy within the different contexts. Due to the quantity of ^{14}C dates, individual Bayesian dating for single contexts is possible as well as a mapping of the results, with which the internal development of the mega-site can be roughly reconstructed.

Results and interpretation of mapping ^{14}C dates

Method and spatial arrangement of the site

Of the 85 dates from Maidanetske[10], most can be identified as *termini ad quem* and only a few as *termini ante quem* or *post quem*[11]. In the following, we will first look at the data according to the wiggle areas individually in terms of their contexts

10 In addition to the new AMS dates, among the data there is a conventional date from the Berlin laboratory from undetermined charcoal, which came from the south-west of the site (Bln-2087). This is not included in the analysis.

11 Poz-97625 from the topsoil and Poz-60196 from geotrench 70 are to be noted as *termini ante quem* for the settlement activities, whereas Poz-60298 from trench 72 is regarded as a *terminus post quem*.

Figure 31A–F. Nebelivka: chronology of different districts (cf. Suppl. 1–3).

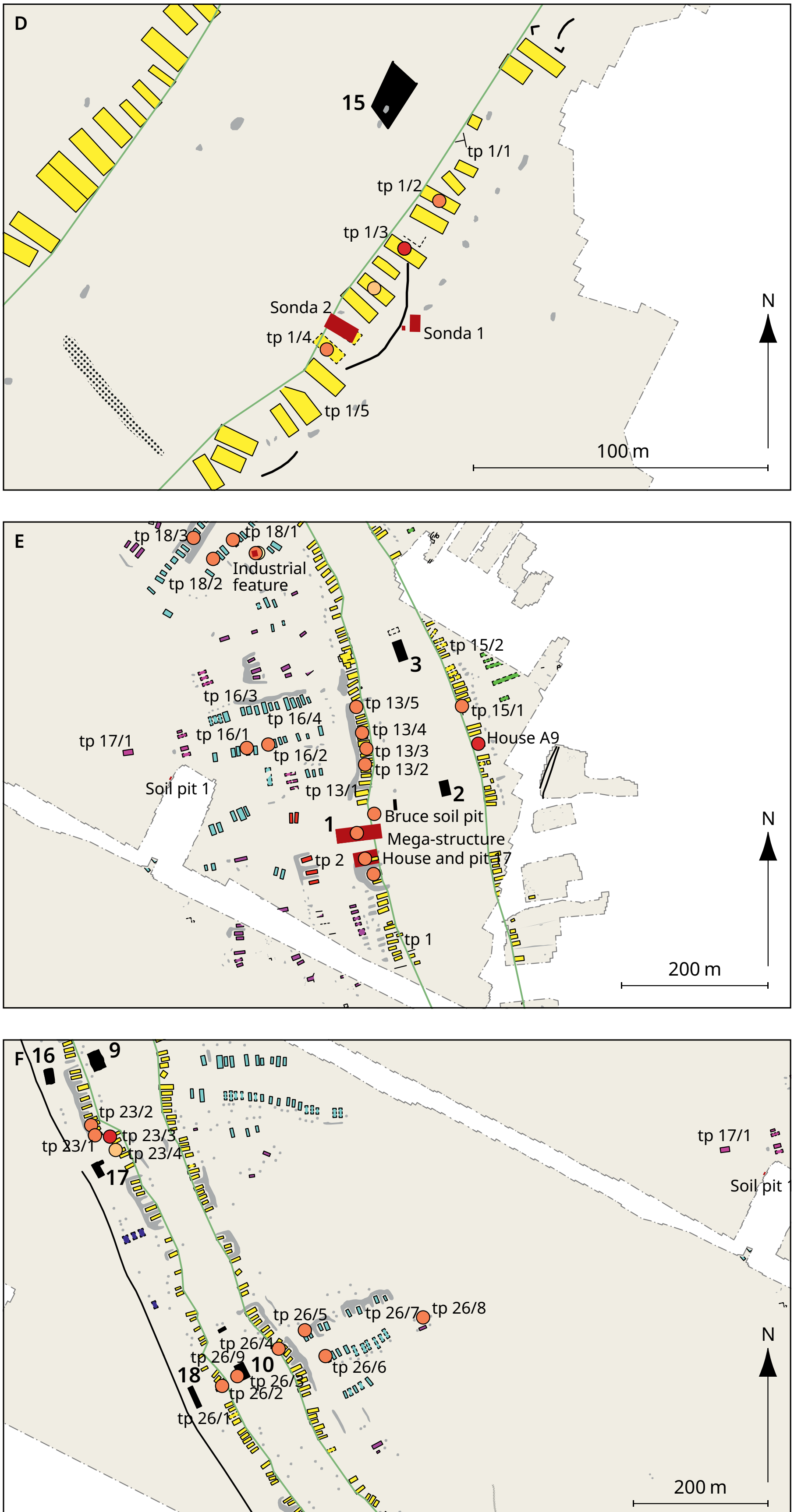


Figure 31A–F, continued.

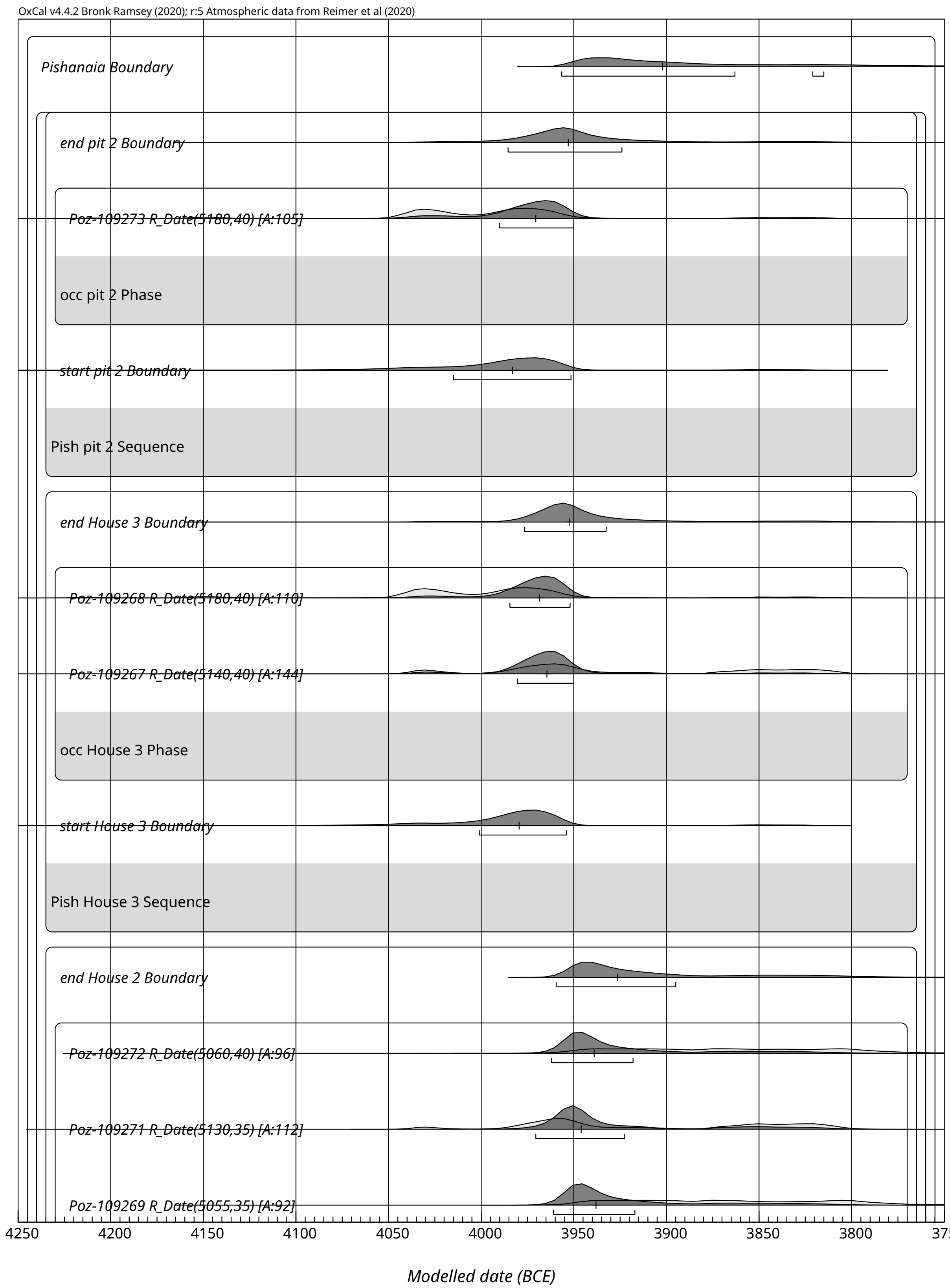


Figure 32. The Bayesian calibrations of Pishchana (cf. Suppl. 1–2).

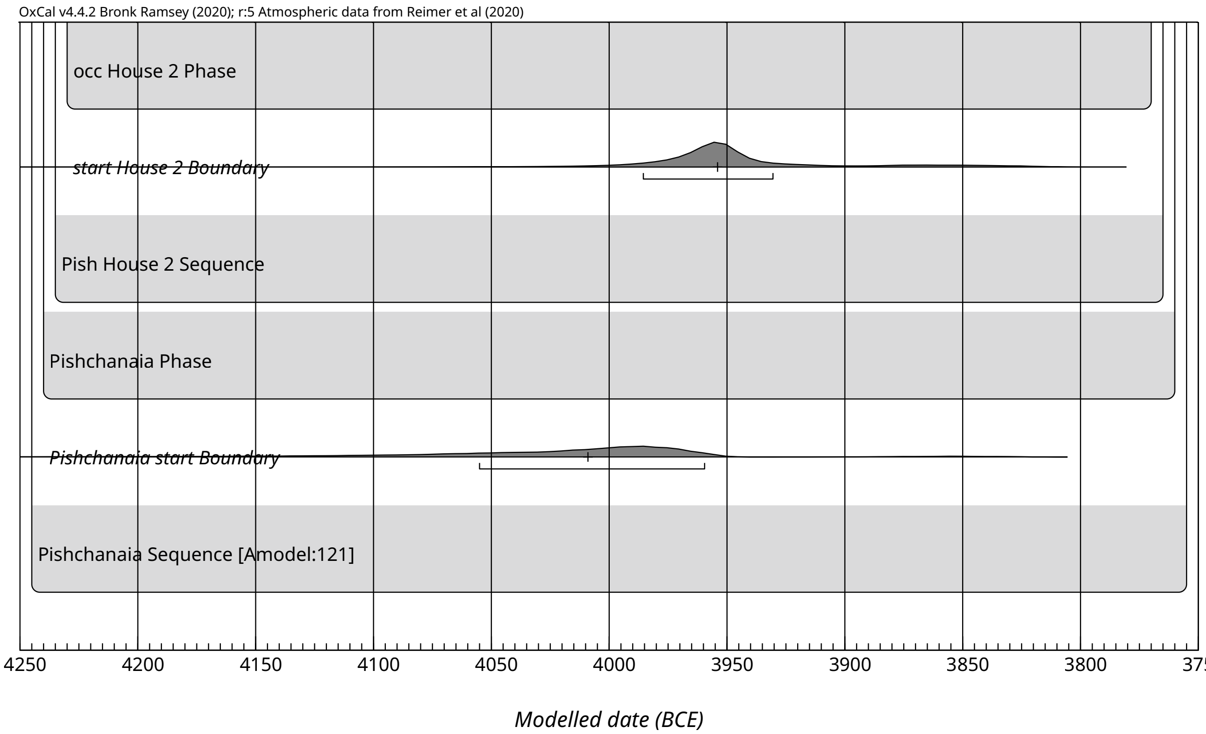


Figure 32, continued.

and spatial distribution in the settlement plan (for the detailed method cf. previous section of this chapter on Nebelivka).

With the excavation strategy of main and special trenches, large areas of the entire settlement were recorded, but due to the accessibility of the site, the excavation trenches concentrate on a south-south-western and north-north-eastern area designated here as 'SSW' and 'NNE'. In the SSW area, at least 9 concentric rows of houses could be identified (Fig. 34; Müller *et al.* 2016a, 135, Fig. 1), in the north-east also numerous rows of houses (Fig. 35). Here the situation is more complex due to the second or third Maidanetske settlement (house rows 1–3) and the radial settlement structure with houses having a gable orientation parallel to radial entrances. In addition, some of the concentric house rows are not continuously laid out and are correspondingly difficult to differentiate over long distances. Accordingly, we differentiate 14 rows of houses, whose numbering, except for the rows of the ring corridor (4–5), does not have to correspond to the numbering of the rows of houses in the SSW.

It also makes sense to divide the entire settlement into certain overlapping spatial units (from outside to inside) due to the empty central square, the ring corridor and Trenches 1 and 2: Outer Area 1 outside Ditch 1, Outer Area 2 between Ditch 1 and Ditch 2, Outer Area 3 between Ditch 2 and the ring corridor, the ring corridor, Inner Area 1 with the rows of houses and quarters following the ring corridor, and Inner Area 2 at the inner boundary of the settlement (Tab. 4; Fig. 35). With this information, a description of the development in Maidanetske is possible.

Maidanetske Phase 4000–3800 BCE

The two formally oldest dates are from the wiggle section at ca. 4050–3950 BCE (Fig. 36). There is a date from Pit 26 of House 44 of SSW Row 1 (Trench 52) in the SSW, and a date from the potter's kiln (Trench 80) in the NE. If we add early dates with a median older than ca. 3900 BCE, we find another date from the filling of the western ditch in the NNE (Poz-87561), another from Pit 26 of House 44 (SSW Row 1, Poz-60347, though oak), one from the oldest backfill phase of Pit 25 (Trench 50) of the outer ring corridor, *i.e.* SSW Row 4 (Poz-60189). From this distribution of data, René Ohlrau (2020, 226–227, Fig. 143) concluded that the settlement begins with

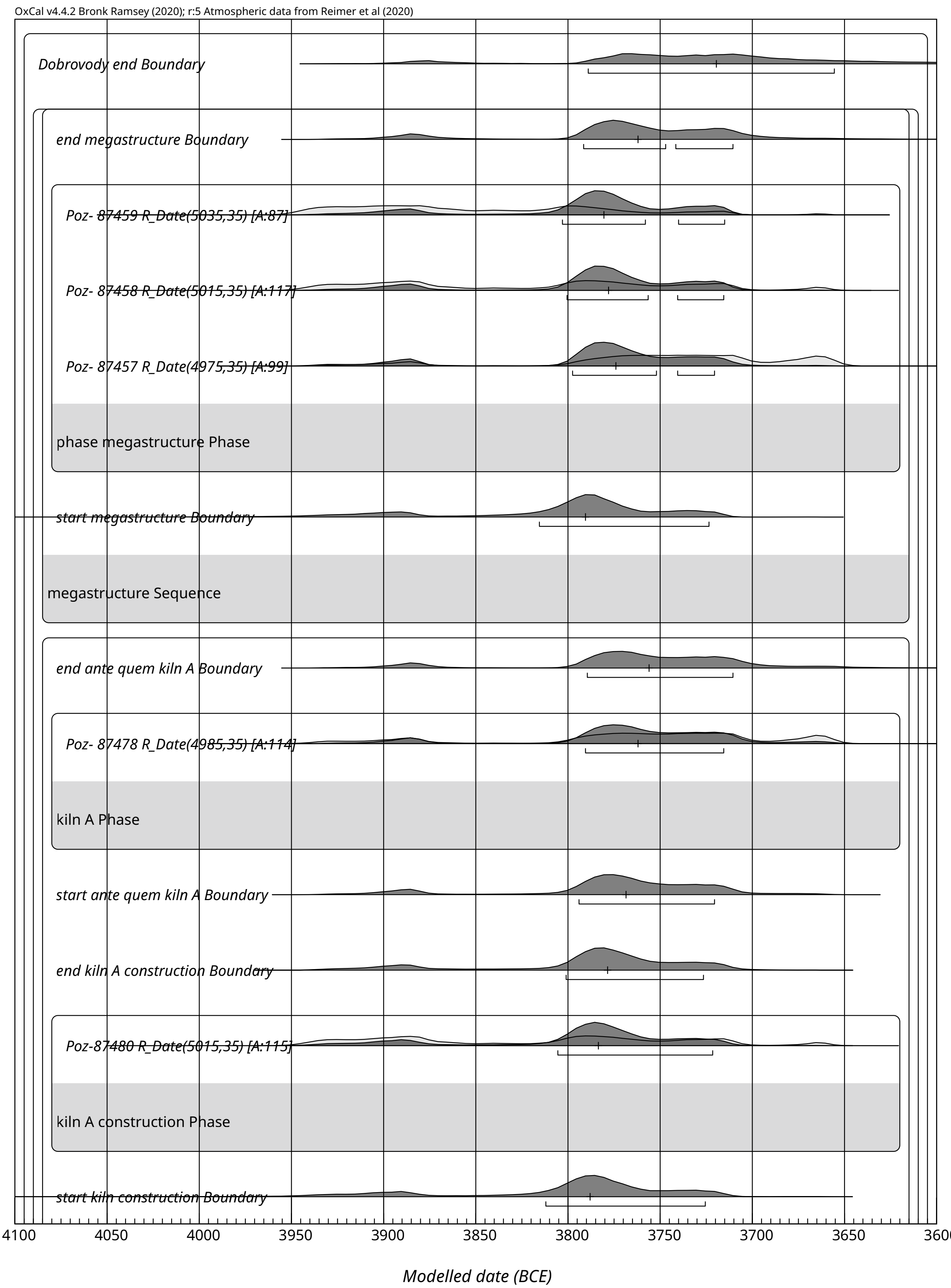


Figure 33. The Bayesian calibrations of Dobrovody (cf. Suppl. 1–2).

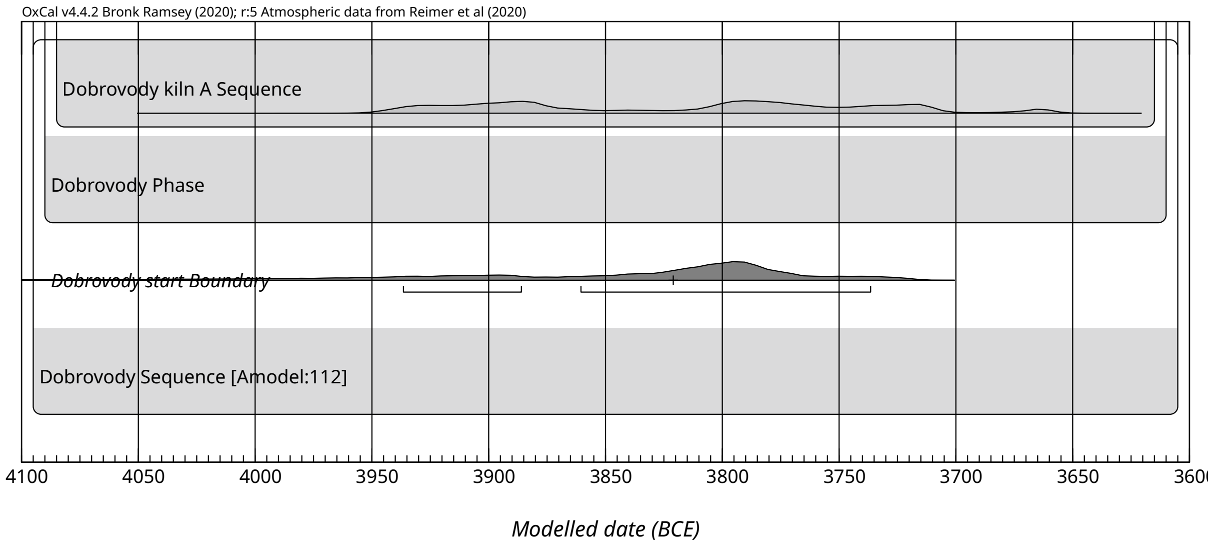


Figure 33, continued.

the marking of the enclosure and the establishment of the infrastructure (kiln). In addition, the dating of the pit infills from SSW House Rows 1 and 4 probably also shows that the settlement of Maidanetske had already been occupied at this time.

Apart from the early dates (>3900 BCE), if we consider the entire period 3950–3800 BCE, there are 34 dates from 14 features at nine localities spread over wide areas of the settlement. In a spatial view from the exterior to the interior of the settlement, data from the western and eastern ditch segments of Ditch 1 and from Pit 32 from the same trench are among the most spatially outwardly located activity evidence. This could indicate that Outer Area 1 and 2 were not occupied at least until ca. 3700 BCE.[12]

The dates of Pit 26, which belong to House 44 of SSW House Row 1, originate from the Outer Area 3 between Ditch 1 and the ring corridor. We also know a date from House 44 that directly dates the use of the house.

The data of Pit 25 (belonging to House 12) already belongs to the ring corridor, namely to the outer house row (SSW House Row 4). The excavated Mega-structure 3 is located in the ring corridor. The use of the mega-structure is documented with three dates. The data comes from the waste of the wall construction. Pit 33, located next to Mega-structure 3, also dates to the period mentioned here. We can therefore assume an intensive use of the mega-structure. Pit 27 (SSW Row 5) can possibly be counted as part of the inner house ring of the ring corridor. However, it is located on the inner side of SSW Row 5 and could already belong to the Inner Area 1, just because of its special functionality. Here, an open square measuring approx. 30 m in diameter, framed by pits, emerges, which lies between the outer ring corridor row (SSW Row 5) and SSW House Row 6.

This Inner Area 1 includes dates from Pits 28, 29 and 30 associated with the excavated pottery kiln and those directly from Houses 54 and 60. Pit 30 and House 60 belong to NNE House Row 12, with House 54 (NNE Row 11). The aforementioned houses are located on two radial paths that lead into the feature-free inner square. Pits 28, 29 and 30 (partly containing waste from pottery production) are located – also similar to the situation described at the ring corridor – in a square again about 30 m in diameter, which again seems to have specific functions. This is the area where the kiln infrastructure already existed early on.

12 However, Pit 32, which is located directly in the eastern segment of the ditch, is assigned to House 67 by René Ohlrau (2020, 228, Fig. 144). House 67 is located in the NNE House row 2 outside Ditch 1 and thus already in Area 2.

Figure 34. Maidanetske: dating of the 9 house rows in the SSW area (according to Müller et al. *2016a, 135, Fig. 1).*

In summary, we realise that Maidanetske becomes the focus of planning activities probably from ca. 3970 BCE (median earliest data). By ca. 3900 BCE, approximately two generations had laid down the basic concept, at least for the settlement areas of the areas enclosed by Ditch 1, and the first houses were built in the Outer Area 3. The innermost settled area of the entire settlement (Inner Area 2) is obviously not yet settled.

Maidanetske Phase 3800–3700 BCE

For the period 3800–3700 BCE, 30 dates are available from 19 features. All areas of the large settlement are recorded (Fig. 36A and B).

Spatially farthest out in *Outer Area 1* is a dating from House 64. Possibly a new settlement attempt was made in the north. For the NNE Section 101 with House 64, a row of houses is documented which we do not necessarily associate with Maidanestke 1. The orientation points to differently oriented settlement activity in the north of the main settlement.

Further inside, House 67 was occupied in the *Outer Area 2* of the actual NNW House Row 2 near the eastern ditch segment. There are also 5 dates from this house. From the Outer Area 3, we know dates from House 44 (SSW House Row 1) and the associated Pit 26, from the *ring corridor* those of Mega-structure 3 with associated pits and Pit 25 belonging to House 12. Again, there are dates from Pit 27, which may have to be connected with the inner house row of the ring corridor. Data from Houses 60, 61 and 62, and also from the potter's kiln, are verified for Inner Area 1, those from Houses 52 (SSW House ring 8), 53 (SSW House ring 9), 57 (NNE House Row 14), 58 (NNE House Row 13) and 59 (House Row 14) from the *Inner Area 2.*

Thus, with the Outer Areas 1 and 2 and the Inner Area 2, new areas of Maidanetske are settled, which were not previously covered by ^{14}C dating. Compared to all other phases, the largest spatial expansion of settlement activities is realised.

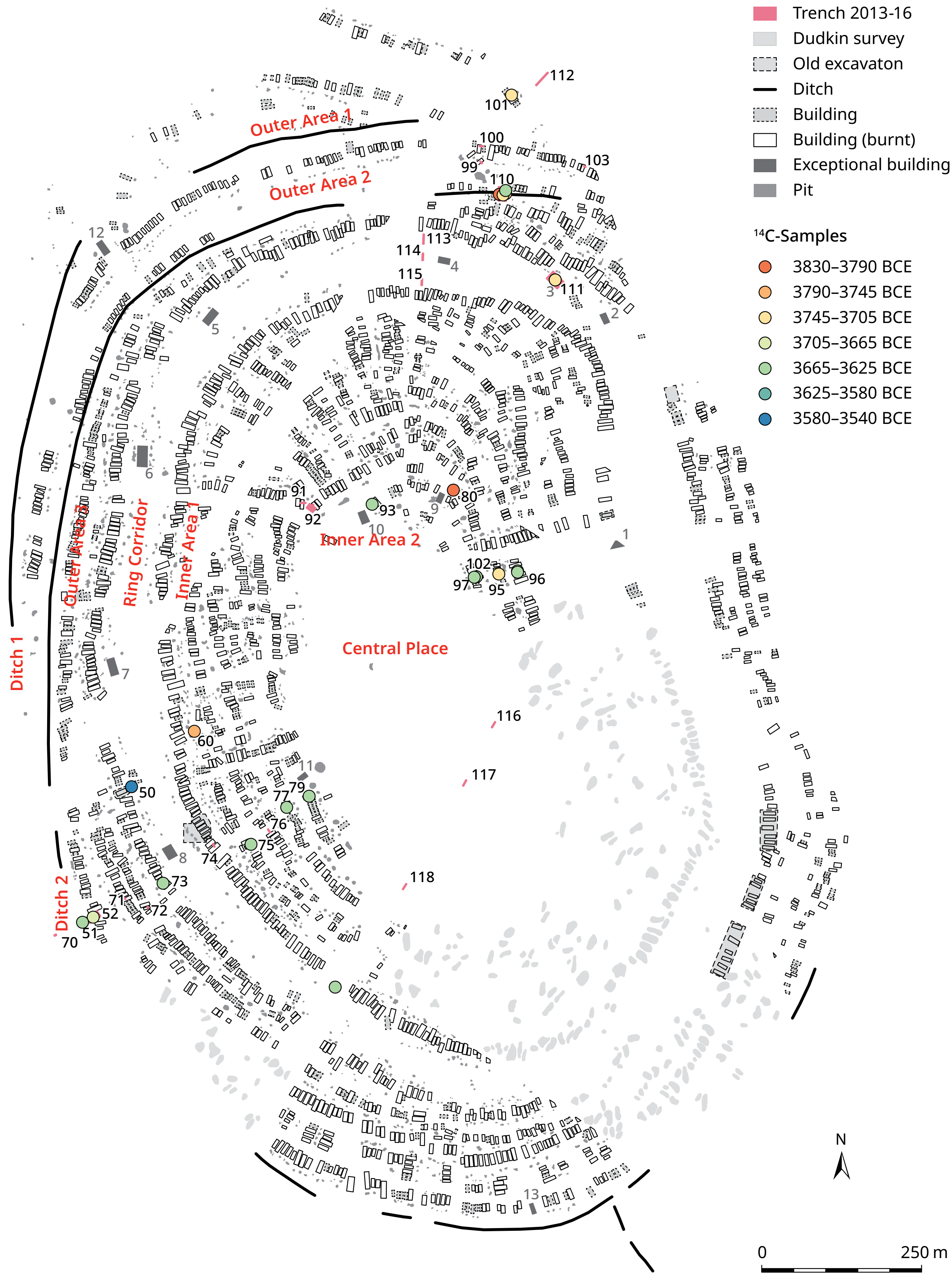


Figure 35. Maidanetske: general plan and distribution of radiometric dates (cf. Suppl. 1–2).

Interval BCE	Mega-site segments	Outer area 1 (to ditch 1)	Outer area 2 (between ditch 1 and 2)	Ditch 2	Outer area 3 (between ditch 2 and ring-corridor)	Ring-corridor		Inner area 1 (between ring-corridor and inner rings)	Inner area 2 (inner rows 13/14, 9/8)	Pottery kiln
						Outer	Inner			
4050–3950	Mai				1					1
	S80 (kiln ph3)									1
	Pit 26 (tr52 (H44)				1					
3950–3800				5	3	7	4	13		
3950–3900	W ditch			1						
	Pit 25 (tr50 H12)					1				
	Pit 26 (tr52 H44)				1					
3900–3800	W ditch			1						
	E ditch			2						
	Pit 32 (tr110 H67)			1						
	Pit 26 (tr52 H44)				1					
	H44 (tr51)				1					
	Pit 25 (tr50 H12)					2				
	Mega 3 (tr 111)					3				
	Pit 33 (tr111)					1				
	Pit 27 (tr60)						4			
	H60 (tr95)							1		
	Pit 30 (tr 80 kiln ph 3)							2		
	Pit 29 (tr 80 kiln ph 1)							4		
	H54 (tr92)							5		
	Pit 28 (tr 80 kiln ph 1)							1		
3800–3700		1	1	5	2	8	2	5	6	
	H64 (tr101)	1								
	H67 (tr110)		1							
	Editch			5						
	H44 (tr51)				1					
	Pit26 (H44, tr52)				1					
	Mega 3 (tr 111)					3				
	Pit34 (tr111/2) 1					1				
	Pit35 /pit(tr111/3)					2				
	Pit25 (tr50 H12)					2				
	Pit27 (tr60)						2			
	H62 (tr96)							1		
	H61 (tr96)							2		
	Kiln end							1		
	H57 (tr93)								1	
	H58 (tr93)								2	
	H52 (tr77)								1	
	H60 (tr95)							1		
	H59 (tr94/102)								1	
	H53 (tr79)								1	
3700–3630			1	2	1	2			1	
	H67(tr110)		1							
	Editch			2						
	Pit26 (H44, tr52)				1					
	H47/48 /tr 73)					1				
	HZh					1				
	Tr79 ts								1	
Sum		1	2	12	7	17	6	18	7	1

Table 4. The number of occupancies in Maidanetske for individual areas of the calibration curve (cf. Suppl. 2).

Maidanetske Phase 3700–3630 BCE

The seven dates from the 3700–3630 BCE curve segment are spatially scattered over the entire area of the large settlement, but direct *termini ad quem* are only represented between Ditch 2 and the ring corridor (Fig. 37). These are two dates from the eastern ditch segment, from Pit 26 southwest of House 44 (Trench 52) of SSW House Row 1 and those to the outer row of the ring corridor with House 47/48 and House E (SSW House Row 4). The dates for House 67 (NNE House Row 2) and for Mega-structure 3 are probably *termini ante quem*, as is the case with a date from trench 79. Obviously, therefore, only minor activities can still be detected at Ditch 2 and the outer ring corridor, while Mega-structure 3, for example, is no longer in use.

Maidanetske Phase 3630–3500 BCE

The dates with a median of 3630–3500 BCE are from the topsoil (Poz-60352), soil organic residue (Poz-60198) and from an upper pit fill (Poz-60175; Fig. 37). Among the six even younger dates, Poz-60351 and Poz-60160 are from stratigraphic contexts that are difficult to interpret, Poz-60201 is a date from a topsoil, Poz-60298 is from a buried soil, and Poz-60197 is soil organic material. Only the date Poz-87547 dates a sample from a clear feature (ground floor under a platform), but in the overall context it is probably too young for the feature and possibly an intrusion. Accordingly, dates younger than ca. 3630 BCE are excluded from the analysis. Nevertheless, it remains striking that, with the exception of Poz- 87547, all younger dates cluster only in the SSW, especially also the three dates from 3630–3500 BCE. It is possible that some of this activity is related to the kurgan above SSW House Row 5 (Ohlrau 2020, 38, Fig. 10).

Results

The spatial distribution of the medians of the *termini ad quod* data according to the respective sections of the calibration curve provides a differentiated picture. The similarities and differences can be described by distinguishing the occupation and use of the different rows of houses and the infrastructure.

The following time-line emerges for a spatial and chronological occupation trend in Maidanetske (cf. Tab. 4; Fig. 38):

- From ca. 3970–3900 BCE, the few usable dates refer to an occupation of Ditch 1, of the inner part of Outer Area 3, of the ring corridor and the kiln. First houses are built in the Outer Area 3.
- Around 3900–3800 BCE, the occupation takes place from Ditch 2 to the Inner Area 1. Mega-structure 3 is also documented for the first time.
- Around 3800–3700 BCE, the above-mentioned settlement areas were supplemented by further inner rows of houses of the Inner Area 2 and those of the Outer Areas 1–2, so that now the largest extension of the mega-site was reached.
- From ca. 3700–3630 BCE, all activity is reduced to the area between and including Ditch 2 and the outer ring corridor.
- Later dates should be viewed with caution. The spatial proximity to the kurgan above SSW House Row 5 points to the possibility that they derive from activities that are related to the kurgan.

In consequence, after the first conceptual spatial design, we recognise intense settlement activities in the 39th century BCE with an expansion inwards and possibly outwards in the 38th century BCE.

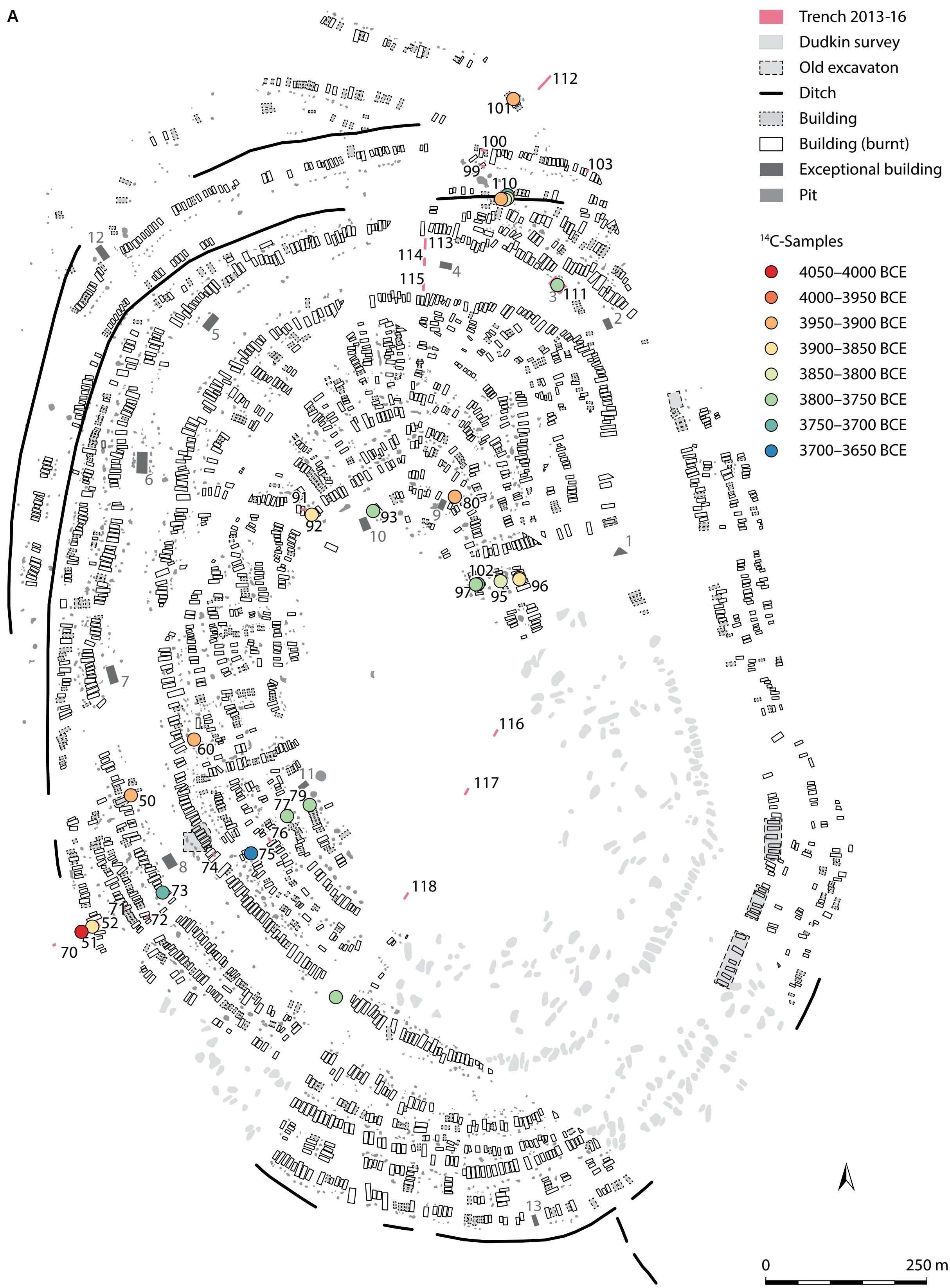


Figure 36. Maidanetske: distribution of early radiometric dates (cf. Suppl. 1–2). (A) according to 50-year time intervals; (B) according to the wiggle structure. Numbers indicate trenches.

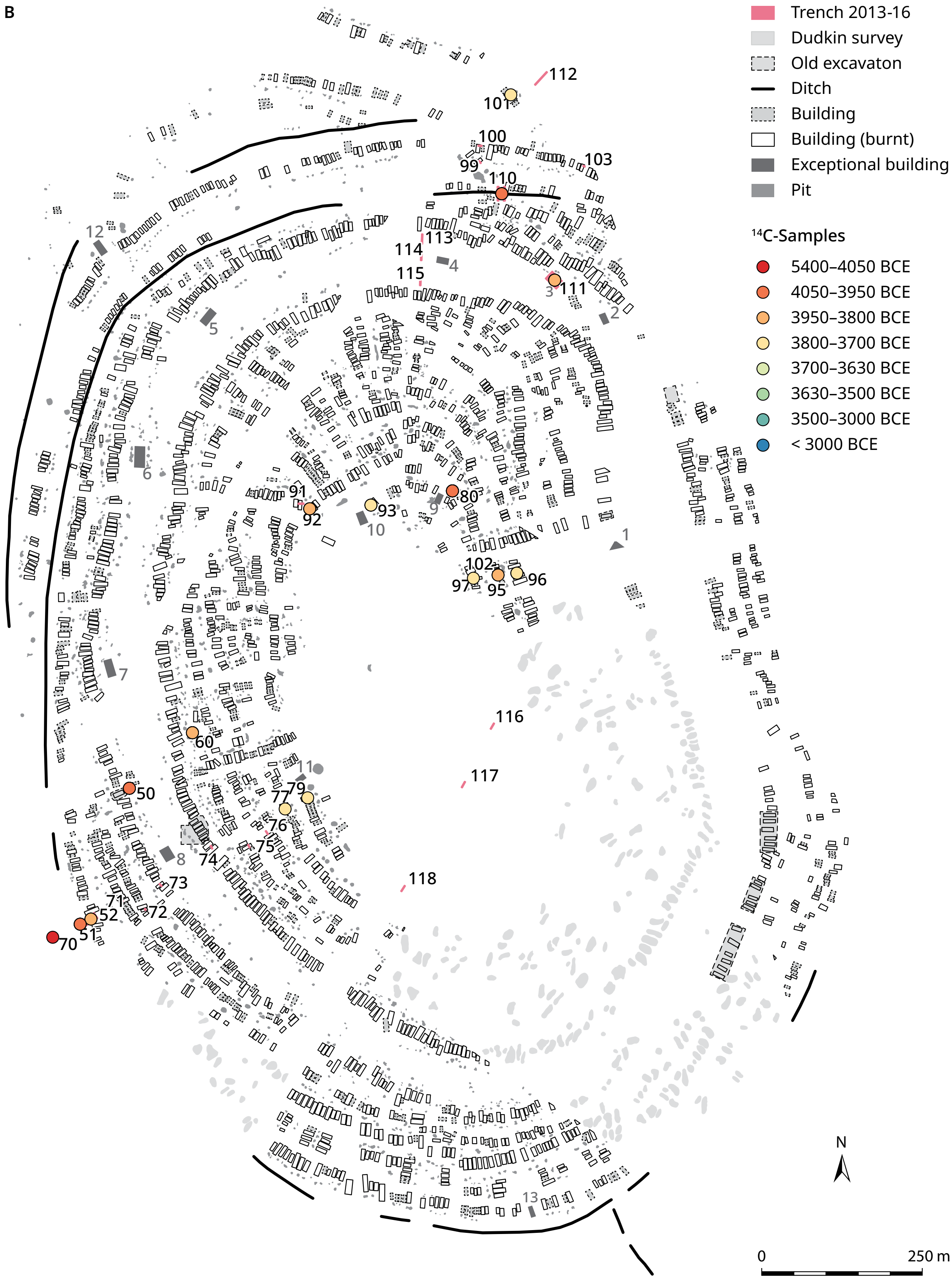


Figure 36, continued.

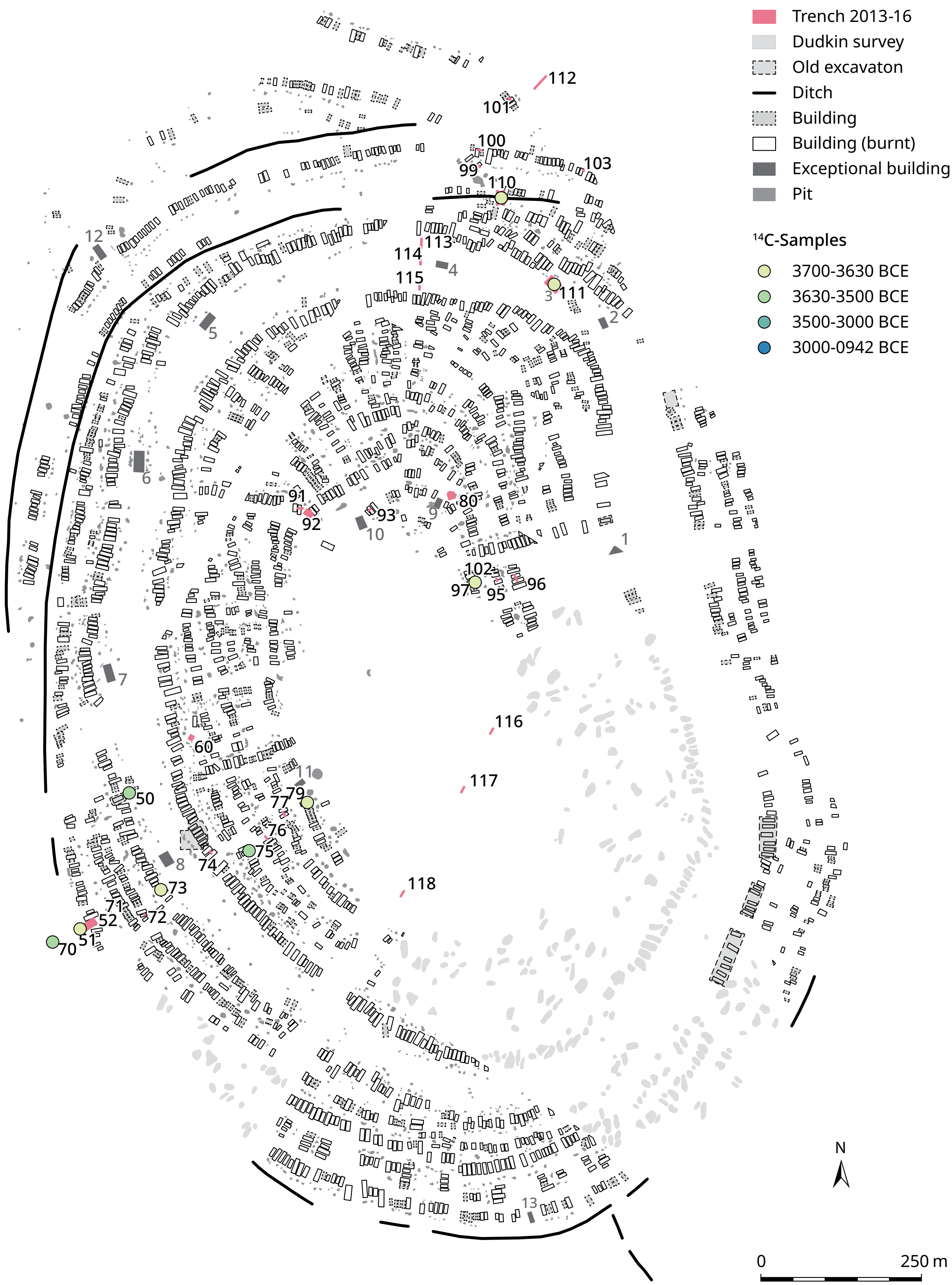


Figure 37. Maidanetske: distribution of late radiometric dates (cf. Suppl. 1–2).

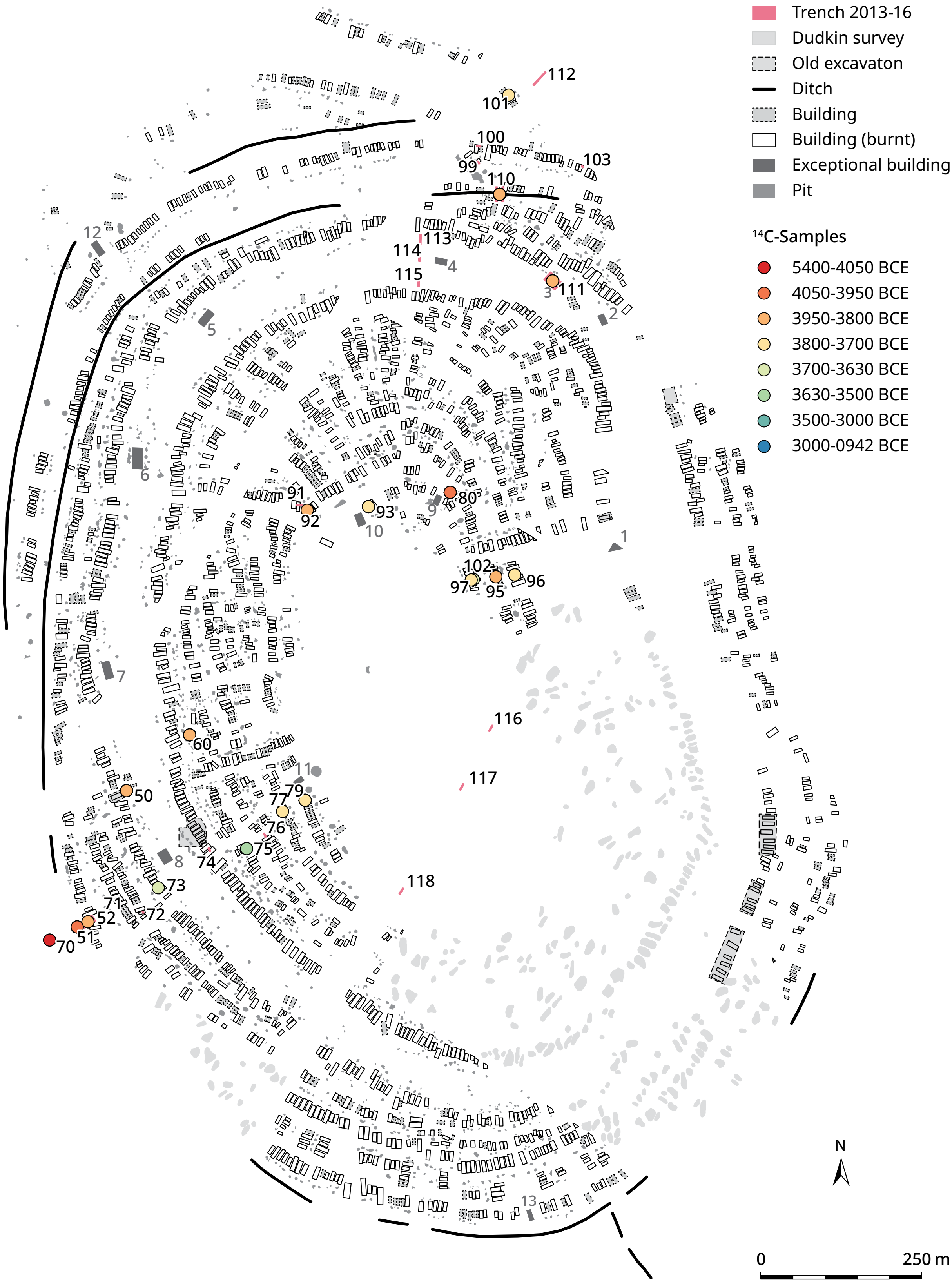


Figure 38. Maidanetske: spatial and chronological occupation trend (cf. Suppl. 1–2).

Kiln** (Kiln ph1/2 + Pit 2)* ***3940–3870 BCE*: Kiln Ph 3 + Pit 3 3870–3810 BCE, activities near kiln 3810–3755 BCE, also including 2 dates on the calibration interval 3990–3950 BCE*
Ditch system (western ditch 3905–3815 BCE; eastern ditch 3815–3720 BCE)*, earliest dates are within the dating interval after 3950–3800 BCE*
Pit trench 52 ***(Pit 26 4010–3640 (3960, 3740) BCE)*** *with one date on the dating interval 3990–3950 BCE*
*Pit trench 50 (****Pit 25 3910–3540 BCE****: 1b 3910–3800 BCE; 2a 3800–3680 BCE; 2b 3680–3540 BCE*
*Pit trench 60 (****Pit complex 27 3910–3780 BCE****: 60 ARCH-2 (3910–3845 BCE) and 60 ARCH-3 (3845–3780 BCE), remains from houses*
House 44 *Trench 51/52* ***3765–3680 BCE****: construction 3850–3765 (3795) BCE; use 3765–3680 (3725) BCE; cf. Ohlrau 2020, 206–207.*
House 47/48 *Trench 73a/b: waste area 3705–3380 BCE. Poz 60199 probably house 47: 3705–3640 (3680) BCE*
House 50 *Trench 75 only* terminus ante quem*: 3655–3650 BCE*
House 52 *Trench 77* ***3780–3660 (3735) BCE***
House 53 *Trench 79 3****760–3650 (3700) BCE***
House 54 *Trench 92 3****900–3850 BCE****: use 3900–3880 BCE; burning 3880–3850 BCE*
House 58 *Trench 93* ***3780–3660 (3735) BCE***
House 59 *Trench 94* ***3785–3660 (3740) BCE***
House 60 *Trench 95* ***3895–3675 BCE****: use 3785–3655 (3740) BCE (Poz 87535); occupation 3945–3710 (3845) BCE*
House 61 *Trench 96* ***3860–3685 BCE***
House 62 *Trench 96* ***3895–3660 (3770) BCE***
House 64 *Trench 101* ***3910–3710 (3790) BCE***
House 65 *Trench 102* ***3710–3635 (3680) BCE***
House 67 House trench 110 3830–3625 BCE: *House 67 and pit 3830–3715 (3790) BCE; occupation house 67 3715–3625 BCE*
Mega-structure 3745–3715 BCE: *Pits beneath mega-structure 3775–3745 BCE*

Table 5. Maidanetske: results of Bayesian calibrations of single features (cf. Suppl. 1–2).

Results of Bayesian calibration

In addition to the mapping of single dates, Bayesian dating of contexts was carried out where possible. In addition, there are individual contexts for which only single dates are available. For an overall mapping, the chronological boundaries of these dates were used. The mapping at the beginning and at the end of the features, mostly houses, gives an impression of the development in Maidanetske. The results of the Bayesian dating are summarised in Table 5, including the previous dating by René Ohlrau (2020, 203–230).

If we compile the dates according to the *older* boundaries of Bayesian dating, dates before 3900 BCE show up first in Pit 26 (Trench 52), in the kiln and finally in the ditch, followed by Pit 25 (Trench 50) and Pit 27 (Trench 60)[13]. Obviously, the basic concept or scheme of the settlement is laid out from the very beginning of activities at the site.

Whether House 64 in the northern area outside the settlement actually dates so early should be left open here. The spatial representation also indicates that there are activities from the entire area of the settlement during the entire period of occupation, but only after 3800 BCE also in the innermost area (Fig. 39). In this respect, a later occupation of the inner areas of the mega-site is indicated. If we map the most *recent* boundaries, we record the abandonment or desertion of certain areas of the settlement. According to this, we can assume desertion within the

13 There are tendencies that some activities start quite early. This is true for:
- the kiln (kiln Ph 1/2 + Pit 2 3940–3870 BCE, kiln Ph 3 + Pit 3 3870–3810 BCE, activities near kiln 3810–3755 BCE), also including 2 dates on the calibration interval 3990–3950 BCE,
- the ditch system (western ditch 3905–3815 BCE, eastern ditch 3815–3720 BCE), but the earliest dates are within the dating interval after 3950–3800 BCE
- and the Pit 26, Trench 52 (**Pit 26 4010–3640 BCE (3960, 3740)**) with one date on the dating interval 3990–3950 BCE.

Beside these early activities with the kiln, the ritual depositions in Pit 26 and the construction of the ditch, other houses and pits started around 3800 BCE, slightly differentiated in earlier and later ones.

settlement between ca. 3850 BCE and 3700 BCE mainly in the NNE, while delayed by several generations the SSW and the inner area (Fig. 40). This is in line with the spatial distribution of the single dates, which was described above (cf. Figs. 36–38).

The general Bayesian sequence of Maidanetske dates ends up with a model (A_{model}=70.9; $A_{overall}$=68.8) that implies a duration from ca. 3910–3600 BCE, which is in line with the results described thus far (Fig. 41). The Bayesian dating for single contexts and the critical mapping of individual dates falls into a similar range (ca. 3970–3630 BCE).

Results

The spatial distribution of the medians of the *termini ad quod* data according to the respective sections of the calibration curve, the Bayesian sequences of the contexts and the combined Bayesian dating of all Maidanetske dates provides a differentiated picture. Shortly before 3900 BCE, Ditch 1, the inner part of Outer Area 3, the ring corridor and the kiln are occupied and used. First houses are built in the Outer Area 3. From ca. 3900–3800 BCE, the occupation takes place from Ditch 2 to the Inner Area 1. Mega-structure 3 is also documented for the first time. Around 3800–3700 BCE, the above-mentioned settlement areas were supplemented by further inner rows of houses of the Inner Area 2 and those of the Outer Areas 1–2, so that now the largest extension of the mega-site was reached. At ca. 3700–3630 BCE, all activity is reduced to the area between and including Ditch 2 and the outer ring corridor. In conclusion, after the first conceptual spatial design, we recognise intense settlement activities in the 39th century BCE with an expansion inwards in the 38th century BCE.

The interpretation of the identified tendencies is simple at first. The few early ^{14}C dates (until 3900 BCE) are available from the entire ditch, the outer area between Ditch 1 and the ring corridor, from the outer ring corridor and the from inner area with the kiln. Moreover, until ca. 3800 BCE, the area between Ditch 1 and the Inner Area 1 is settled. Until 3700 BCE, the occupation of both the Outer Areas 1 and 2 and the Inner Area 2 also takes place. This is the most extensive occupation, which is reduced again in density until 3630 BCE.

If we convert the absolute number of dates in the time segments into relative numerical values (per ten years), a high proportion of building activities is particularly clear for the 39th century, but especially for the 38th century BCE. Subsequently, a decrease and end of the activities follow in the 37th century BCE (Fig. 42).

With these relative dates, we are additionally able to calculate the absolute number of houses in Maidanetske (2932; cf. Ohlrau 2020, 64, Tab. 7) with a simple model. First, we assume an average lifespan of 50 years for the houses (cf. Diachenko 2016; Millard 2020, 256; Ohlrau 2020, 233–236). Secondly, we calculate the number of contemporary houses according to the formula already described for Stolniceni (see previous section in this chapter on Stolniceni). According to the results, ca. 65 simultaneously existing houses were calculated for 4000 BCE, ca. 130 for 3925 BCE, ca. 1042 for 3850 BCE and 28 for 3675 BCE (Fig. 43).

The graph also presents the variation if assuming an average lifespan of 25 and 75 years for the houses, so that a margin of error can be seen. If we continue to assume that there were five residents per house, then ca. 160–490 persons lived in Maidanetske around 4000 BCE, ca. 325–975 persons around 3925 BCE, ca. 2600–7820 persons around 3850 BCE, ca. 3580–10750 persons around 3750 BCE and still 650–1950 persons around 3650 BCE. Around 3750 BCE, the highest number of inhabitants with 7200 (5 residents per house as calculated here) to 14,400 (10 residents per house) persons was reached. As the general Bayesian model for Maidanetske indicates a duration of the site, which is about 8.8% shorter than calculated by the multiple model (3910–3600 BCE (310 years) in contrast to 3970–3630 BCE (340 years)), the number of inhabitants might be even 8.8% higher: at the highest peak between 3900 and 11700 inhabitants (ca. 3750 BCE).

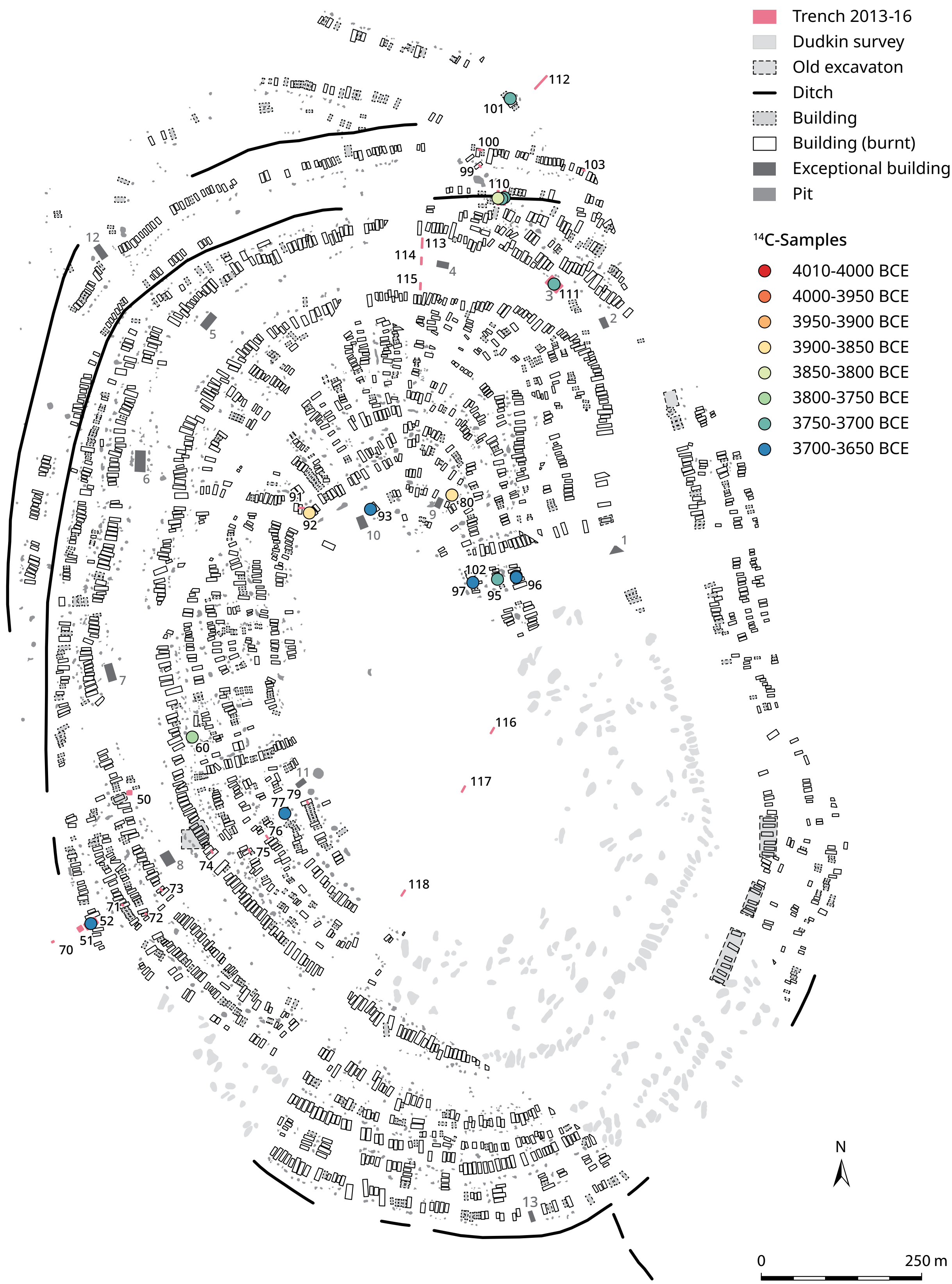


Figure 39. Maidanetske: distribution of early features (medians) according to the distribution of Bayesian calculations (cf. Suppl. 1–2).

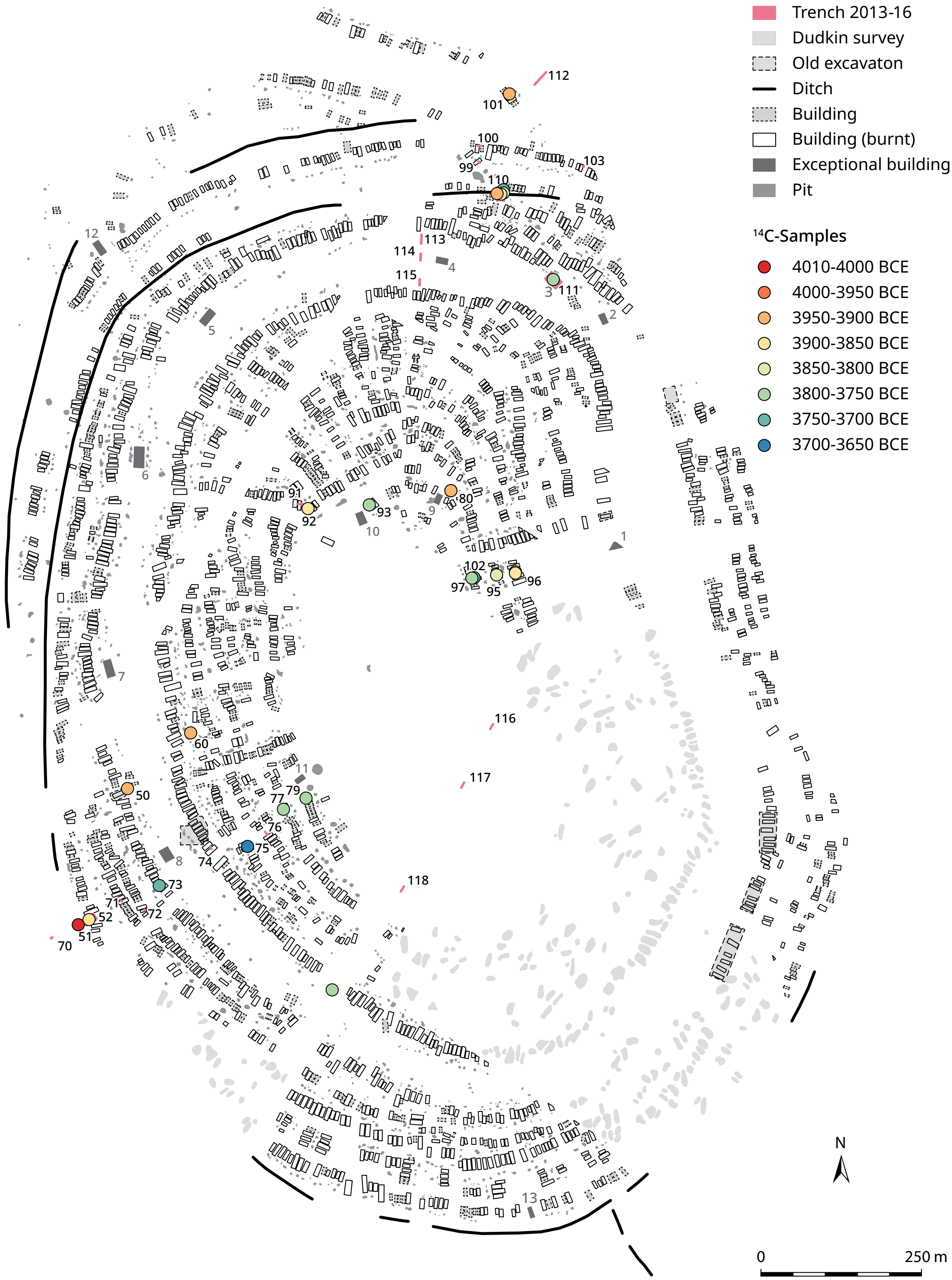


Figure 40. Maidanetske: distribution of late features (medians) according to the distribution of Bayesian calculations (cf. Suppl. 1–2).

Figure 41. The Bayesian calibrations of Maidanetske, all features (cf. Suppl. 1–2).

Due to the length of this figure, for ease of viewing it is only available online via the LandMan portal.

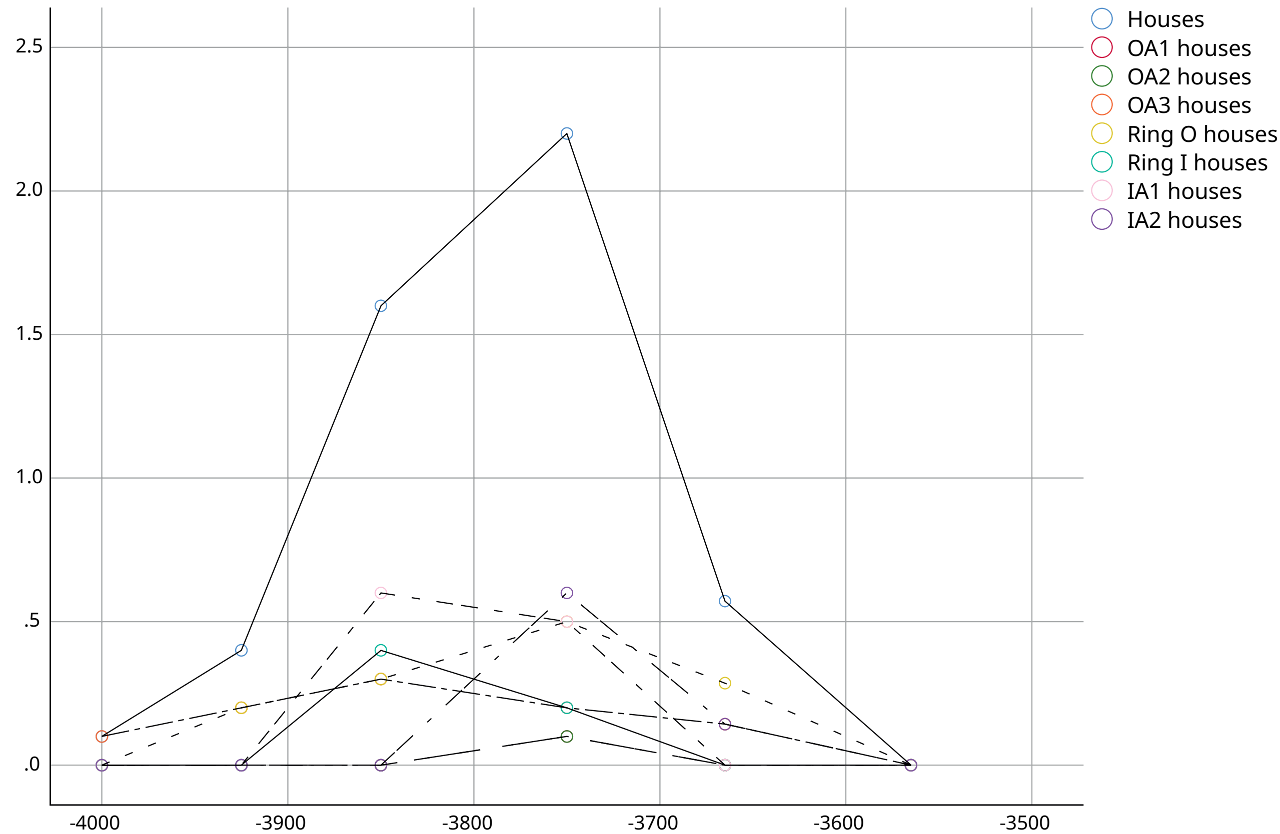


Figure 42. Maidanetske: the relative number of houses (conversion of the dated houses on a linear time scale). Key: A Area; I Inner; O Outer.

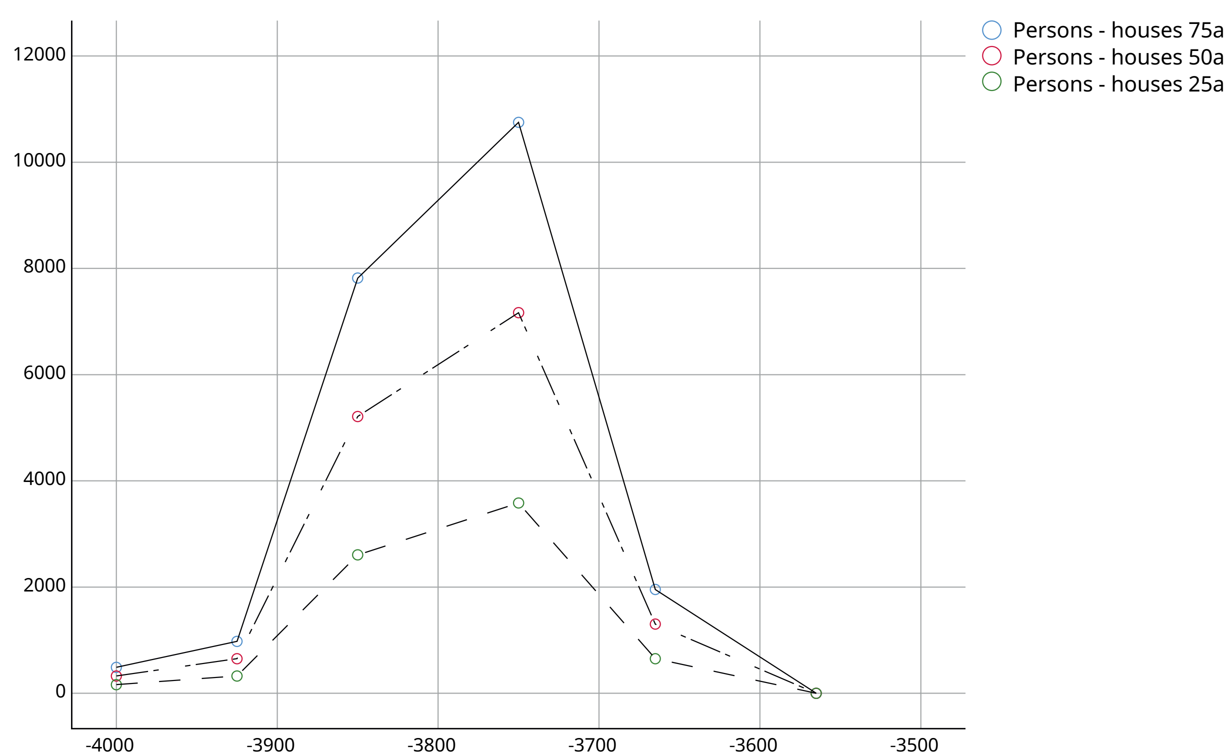


Figure 43. Maidanetske: the absolute number of houses (n) for the assumed use of the houses for 25, 50 and 75 years (a).

Talianki (C1)

Figure 44. The Bayesian calibrations of Talianki (cf. Suppl. 1–2 and Suppl. 2: Fig. 19). ***Due to the length of this figure, for ease of viewing it is only available online (https:// doi. org/10.57892/100-55).***

The 320-ha site with 2200 houses and concentric planning, but without mega-structures, has provided 43 suitable samples from at least from 17 houses and one kiln (Ohlrau *et al.* 2016, 211, Tab. 5; Shatilo 2021, 101–103). Nearly all data fall into the dating intervals 3820–3780, 3780–3720, 3720–3700 and 3700–3660 BCE. Even if there is a small possibility of an older dating to 3940 BCE, this seems to be excluded by the estimated probabilities. The highest probability for the existence of the site spans from ca. **3825–3650 BCE**. A joint calibration has a model probability of A_{model}=72.7 / $A_{overall}$=61.8 – it is still within the range of values that are acceptable (Dury 2021).[14] The resulting duration probabilities of the houses and the kiln[15] are displayed in Figures 44 and 45.

From the structure of the calibration curve, at least a differentiation of three house phases is possible:

Phase A: 3810–3790 BCE: House 47 (3810–3790); **Phase B: 3780–3720 BCE**: House 50 (3800–3710), House 49 (3775–3700), House 46 (3790–3730), House 45 (3800–3710), House 43 (3760–3710), House 42 (3780–3720), House 40 (3750–3690), House 29 (3765–3690), House 19 (3770–3715), House 35 (3765–3675); **Phase C: 3720–3670 BCE**: House 48 (3760–3670), House 41 (3720–3680), House 28 (3710–3670), House 27 (3710–3640), House 37 (3765–3680), House 30 (3765–3675). The kiln is dated to **3805–3750 BCE.**

Even if the assignment to direct contexts in Talianki seems difficult, since the sample material for ^{14}C dating was taken from older excavations, we recognise a certain pattern at least in the NNW of the settlement (Fig. 46). Thus, with individual dates, three houses of House Row 1, which is in fact the outermost part of the ring corridor, date from 3900–3800 BCE and, with another radial house and a date from a pottery kiln, represent the oldest features. One house from House Row 2 and two from House Row 3 date to the following century. A house from House Row 1, dating at the same time, proves that this row of houses is now also being further settled. Further houses of House Rows 2, 3 and 5 belong to the period 3700–3630 BCE. Between 3630 and 3500 BCE, House Row 1 in the north is finally completed by another house. In the period thereafter, two more houses of House Rows 2 and 4 are found before the settlement is abandoned.

Thus, the data might indicate a tendency to start domestic activities from the outside to the inside, on the one hand, and an occupation of the house rows during all phases on the other. Thus, in the south there is also another house from 3700–3630 BCE and two more from 3630–3500 BCE belonging to House Row 1.

With these dates and the same approach, which was applied for Stolniceni, Nebelivka and Maidanetske, we are additionally able to calculate the absolute number of contemporaneous houses in Talianki (2200; cf. Ohlrau *et al.* 2016, 211, Tab. 5) with a simple model. First, we again assume an average lifespan of 50 years for the houses (cf. Diachenko 2016; Millard 2020, 256; Ohlrau 2020, 233–236). According to the results, ca. 465 simultaneously existing houses were calculated for 3825 BCE, ca. 580 for 3750 BCE, 810 for 3665 BCE, 230 for 3560 BCE, and 115 for 3440 BCE (Figs. 47, 48).

The graph also presents the variation if assuming an average lifespan of 25 and 75 years for the houses, so that a margin of error can be seen. If we continue

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14 Excluded were Poz-109314 (5070,40) for House 19; Ki-15994 (4550,70) for House 40; OxA-19840 (5048,33) for House 41; Poz-109311 (4560,40) for House 42; Poz-82479 (4630,40) for House 49.

15 House 9 (3635–3530).- House 19 (3770–3715).- House 27 (3710–3640) 3695*.- House 28 3710–3640 3697.- House 29 3765–3690 3720.- House 30 (3765–3675) 3710.- House 35 (3765–3675).- 3710.- House 37 (3765–3680) 3715.- House 40 (3750–3690) 49 3.- House 41 (3720–3680) 37 3.- House 42 (3780–3720) 45 4.- House 43 (3760–3710) 44 3.- House 45 (3800–3710) 3760.- House 46 (3790–3730); 43 2.- House 47 (3810–3790) 19 3.- House 48 (3760–3670),3701.- House 50 (3800–3710) 3760.- Kiln F 3805–3750).

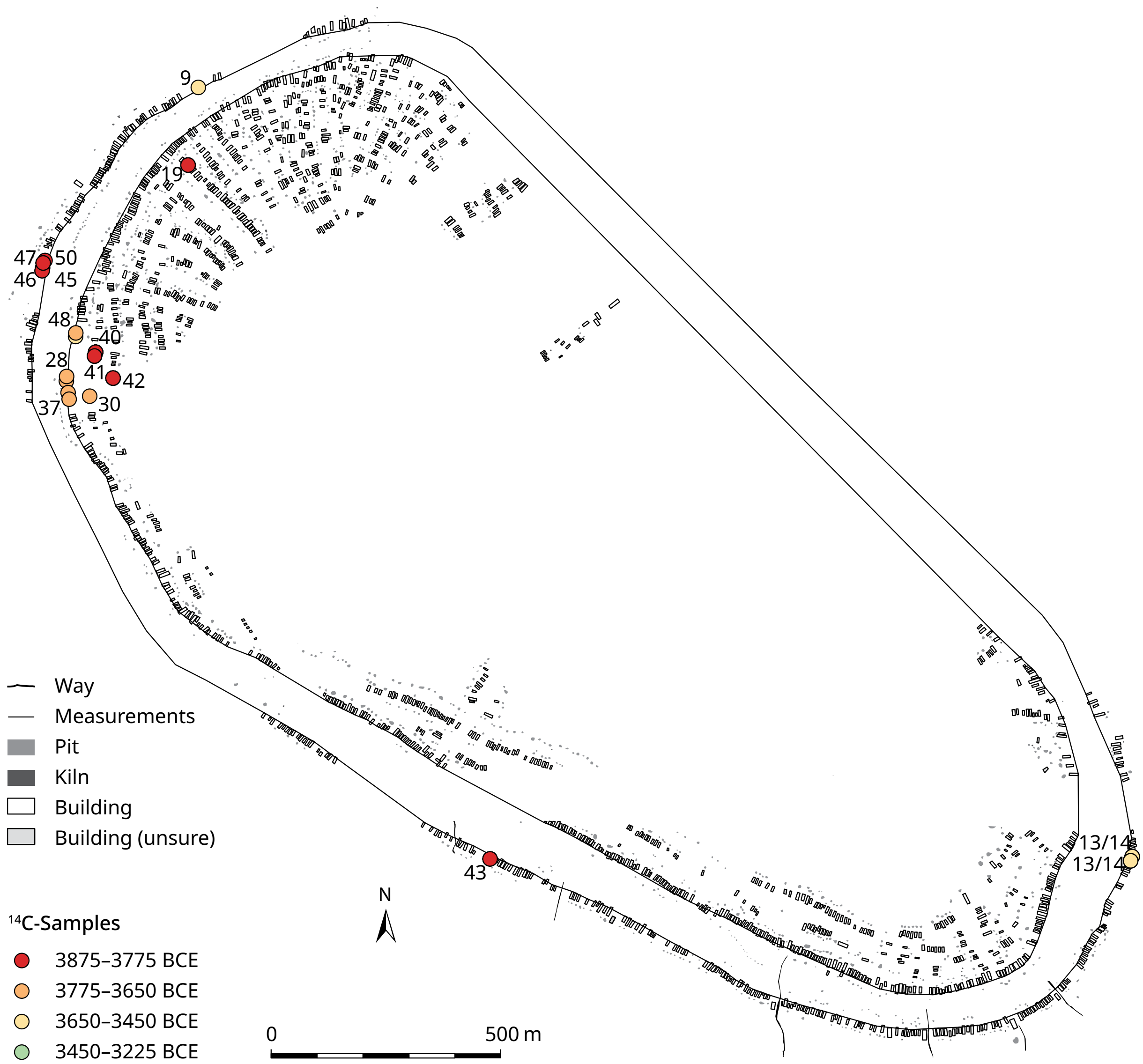


Figure 45. Talianki: distribution of late radiometric dates (cf. Suppl. 1–2). Numbers indicate trenches.

to assume that there were five residents per house, then ca. 1160–3470 persons lived in Talianki around 3875 BCE, ca. 1450–4340 persons around 3750 BCE, ca. 2030–6080 persons around 3675 BCE, ca. 580–1740 around 3560 BCE, and still 290–870 persons around 3500 BCE. In contrast to the longer occupation, which is indicated by the single dates (ca. 3950–3500 BCE: 450 years[16]), the general Bayesian model for the whole site ends up with a much shorter time span (3825–3650 BCE: 175 years). As the time span is 275 years shorter, the calculated population might be increased by 61%. Therefore, at the peak of the occupation around 3675 BCE, we would expect 3270–9780 inhabitants.

Kosenivka (C1–C2)

At the 100-ha site, 26 ^{14}C dates have been produced that belong – with one exception of an unknown origin – to House 3 and House 6 (Shatilo 2021, 137–140; Fuchs *et al.* 2024). The context and quality of the dates are special, as both human individuals and an animal specimen from a house have been dated. Thus, a deeper

16 Excluding the last phase, 3500–3380 BCE, which is probably due to later intrusions.

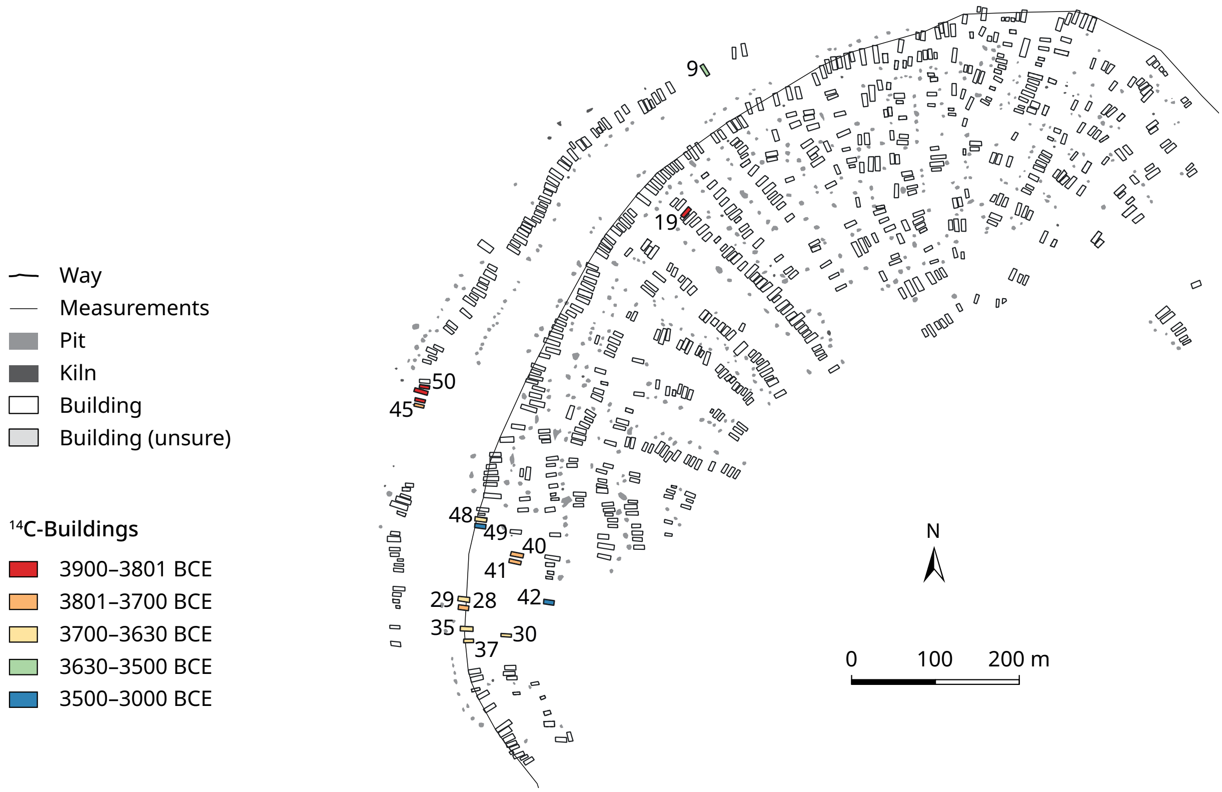


Figure 46. Talianki, NNW area: distribution of radiometric dates (cf. Suppl. 1–2).

analysis and a discussion of the data are relevant for the closer estimation of house duration as well (Fig. 49).

The dates were measured in three different laboratories, one of which differs slightly in average age, but not significantly. The sum calibration (2σ) of dates obtained for House 6 measured by the Poznan Laboratory spans a maximum range of 4240–3375 BCE, within which the date from the Leibniz Laboratory for the cereal grain from House 3 also falls (KIA-56328, 3710–3636 BCE). However, the sum calibration of the other five samples from House 3 results into a slightly younger age with a maximum span of 3645–3375 BCE (2σ; Fig. 49). Thus, an inter-laboratory discrepancy might be indicated.

House 0036

The 20 bone samples resemble eleven specimens, two of them burnt, from at least five human individuals and nine faunal specimens (Fuchs *et al.* 2024, Tab. 4). Based on the carbon and nitrogen isotopic values, we can exclude a major reservoir effect due to the consumption of aquatic food sources (Fuchs *et al.* 2024). After calibration, the human and faunal sample groups do not differ statistically, thus a comparable dating can be assumed. One calcined sample (individual 2, Poz-11086) pre-dates the other human samples. Due to the absence of stratigraphic evidence for this bone representing an older deposition, there is likely an offset explained by the 'old-wood effect'. In contrast, the oldest date of the occipital bone from individual 7 (Poz-131529, 3630–3374 BCE) coincides with its stratigraphically younger age as found in an upper layer. Thus, this could represent a later deposition. Apart from these two dates from individuals 2 and 7, the other samples resulted in a statistically consistent time range between ca. 3800 and 3600 BCE.

To improve the interpretative value of the results, we applied Bayesian modelling (Fig. 49) considering the one stratigraphic information and by separating human and faunal samples as two different. Sequences were created by separating (i) the youngest date with the stratigraphically younger age, (ii) the broader dated

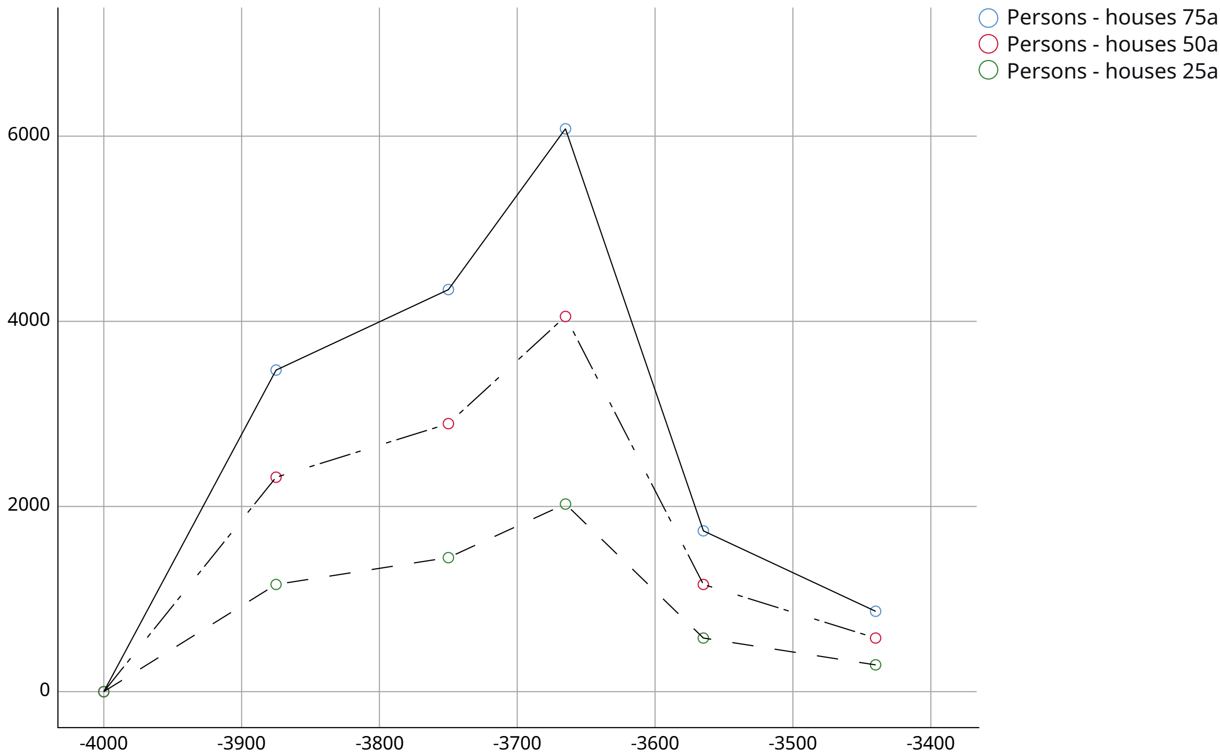


Figure 47. Talianki: the relative number of houses (conversion of the dated houses on a linear time scale).

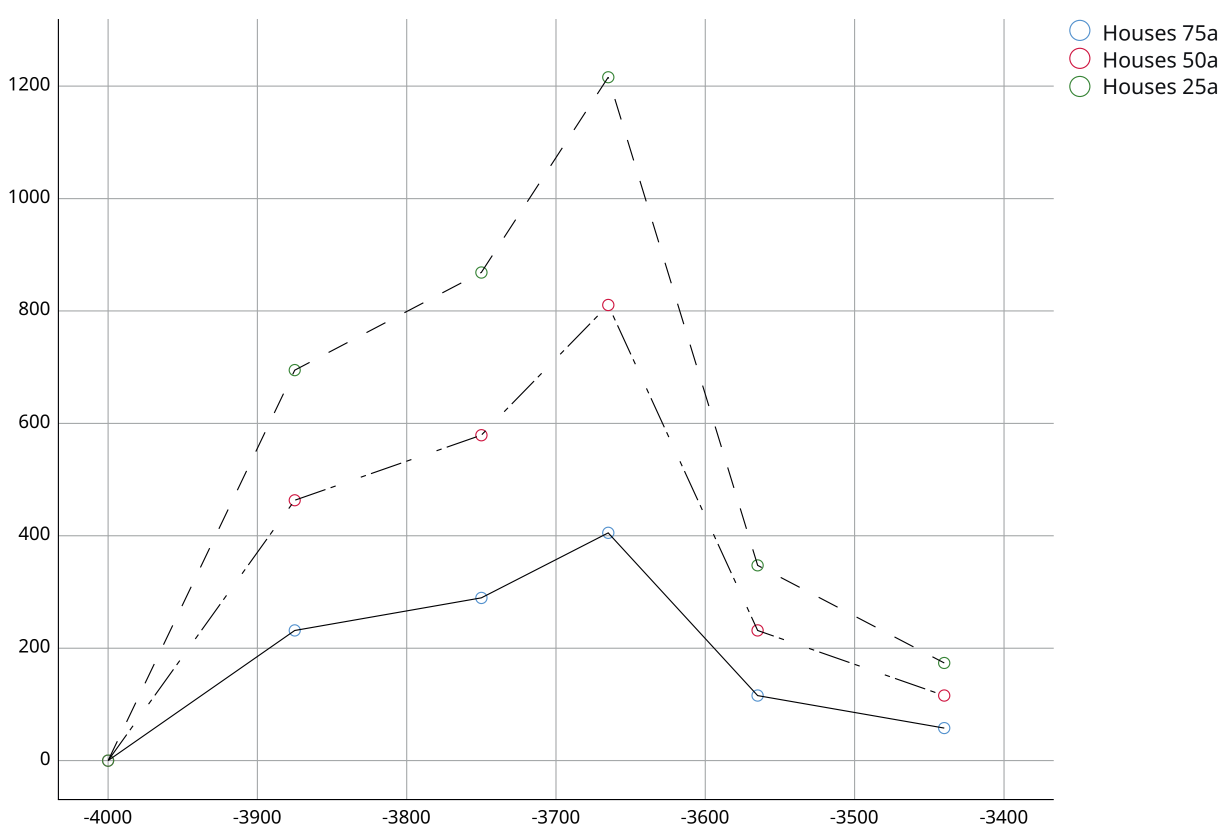


Figure 48. Talianki: the absolute number of houses (n) for the assumed use of the houses for 25, 50 and 75 years (a).

human samples and (iii) the faunal samples (OxCal functions boundary, phase and sequence, calculating 1σ and median values; Fig. 49). The model generated a high statistical significance (A_{model}=120.9 / $A_{overall}$=111.1)[17]. The main results are:

- The humans (individuals 3, 5, and 6) and animals represented by the analysed samples died approximately between 3690 and 3620 BCE (calculated median interval 79 years).
- The animals died between ca. 3660 and 3645 BCE (calculated median interval 11 years), the humans (individuals 3, 5, and 6, ++) between ca. 3670 and 3635 BCE (calculated median interval 37 years).
- The human skull bone was probably deposited on the upper layer of the already burnt house; thus individual 7 died between ca. 3620 and 3380 BCE (median 3500 BCE).

Figure 49. The Bayesian calibrations of Kosenivka (cf. Suppl. 1–2).
Due to the length of this figure, for ease of viewing it is only available online (https://doi.org/10.57892/100-55).

The shorter intervals of the animals can be explained by their shorter lifespan in comparison to humans. Cattle, for instance, were usually slaughtered at 10 years of age, while eight out of nine human samples from this model stem from adult individuals.

Overall, the data are statistically close enough that the calculated lifetimes of the animal and human individuals associated with House 6 are probably more consistent with the human results than with the overall calculation. It is very likely that individuals 4–6, plus potentially those represented by isolated bones (5/6++), died during the occupation period of the house. Only individual 7 died ca. 130 years later, and its skull bone was deposited probably after the house was already abandoned.

House 3

As mentioned above, the date of the cereal grain analysed at the Leibniz Laboratory fits with the dates obtained for House 6, while the faunal bones analysed at the Penn State Laboratory have a longer probability span towards a younger age. Altogether, the samples for House 3 date from ca. 3675–3535 BCE. Giving more significance to the cereal grain date, since a laboratory bias is strongly indicated, the house was in use from ca. 3702–3640 (median 3680) BCE, thus contemporary with House 6 (Fig. 49).

Settlement Kosenivka

On the basis of dates measured at the Leibniz Laboratory and the Poznan Laboratory, we conclude that Houses 3 and 6, including humans, animals and cereals, existed somewhat contemporaneously between 3700 BCE and 3620 BCE (medians). Further activities on the site took place some generations later (the deposition of the skull bone, the faunal bone from an unknown context), probably around 3500 BCE. Thus, our results place the settlement Kosenivka in late Trypillia C1 and some activities in C2, but mainly in the final phase of Middle Trypillia. Overall, these results support the hypothesis of Kruts and colleagues that the humans represented by the skeletal remains found in House 6 died at the same time, possibly in a fire (Kruts *et al.* 2005; Fuchs *et al.* 2024).

Sharin 3 (C2)

The destroyed small site yielded different samples from a rescue excavation, which date to the Bronze Age and C2. Four datable samples belong to Trypillia C2 contexts that are difficult to define (Shatilo 2021, 140). They date from **3740–3510 BCE** (Fig. 50).

17 One of the arm bones, Poz-109981, does not fit. But since the two dates from the same frontal bone failed when applying the OxCal function combine, we consider them an analytical bias.

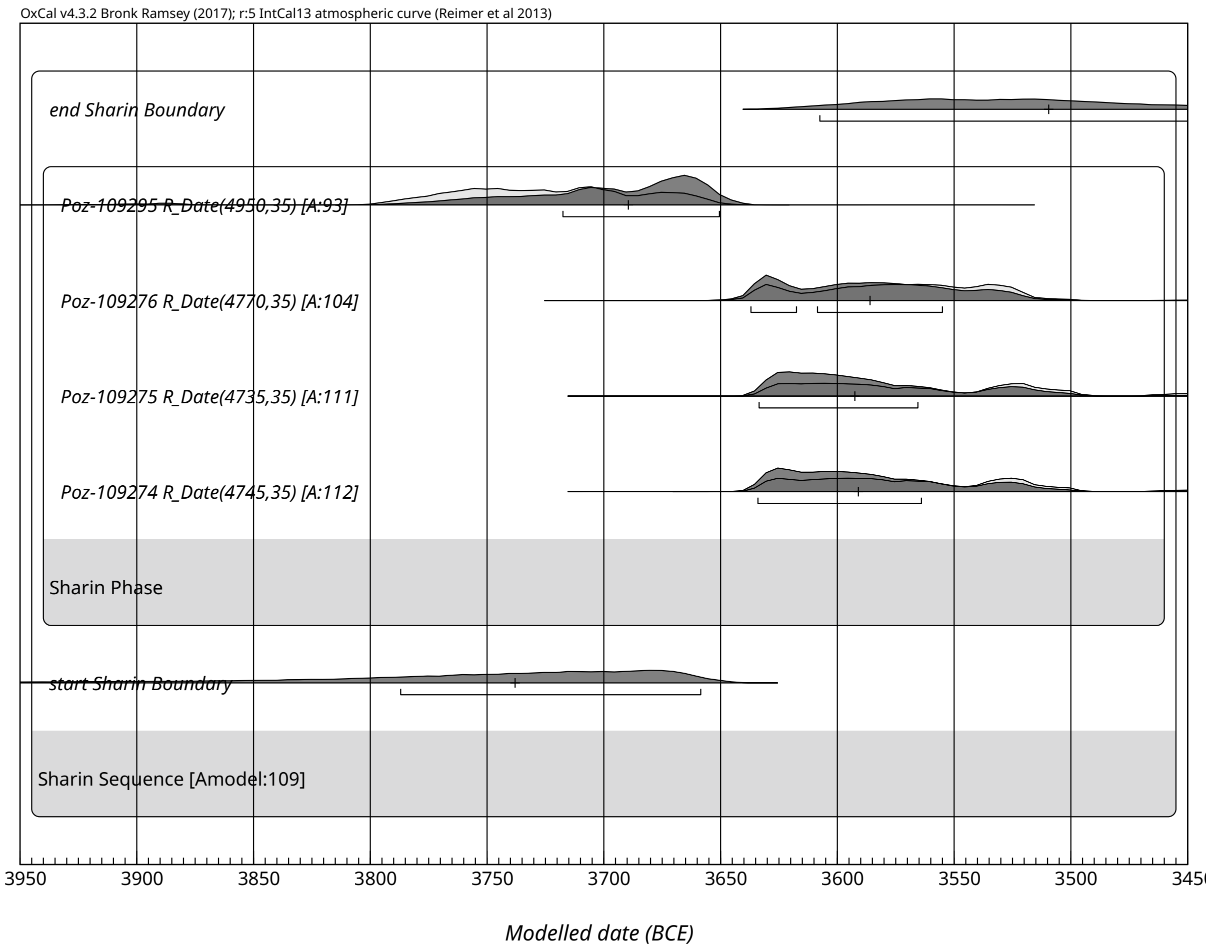


Figure 50. The Bayesian calibrations of Sharin 3 (cf. Suppl. 1–2).

Summary

In the eastern Trypillia area we would estimate Trypillia as follows: A3 4540–4380 BCE; B1/2 4130–3910 BCE; B2 4020–3800; C1 3970–3625 BCE and C2 3740–3510 BCE (Fig. 51).

Contemporaneity of houses and other structures

Obstacles

As the settlement behaviour uses available space to build houses at a distance to older houses, useful stratigraphy is normally missing for dating purposes. Furthermore, samples for dating are often lacking because of acid soil conditions or high burning temperatures. In consequence, most Bayesian models for single houses are based on only a few samples in a very simple stratigraphy. Thus, a dwelling is usually associated with a pit at a small distance from one of the house's broadsides. Accordingly, a house place is indicated by the stratigraphy of a pit, which also could inform us about the occupation of the house in the vicinity.

As an example, Maidanetske House 44 has a stratigraphy with 3 archaeological layers of different depositional processes (Müller *et al.* 2017, 36–37, Tab. 4, Fig. 15). Moreover, the nearby Pit 26 (Trench 52) displays different layers, for which again different depositional processes are known. As such, we can differentiate between *termini post quem*, *ad quem* and *ante quem*. In consequence, a rough dating of the house from 3800–3650 BCE is highly probable (Fig. 52). If we link information from both units, a plausible Bayesian model is calculated (A_{model}=99.3., $A_{overall}$=99). According to this model (Ohlrau 2020, Fig. 123), the construction pit was

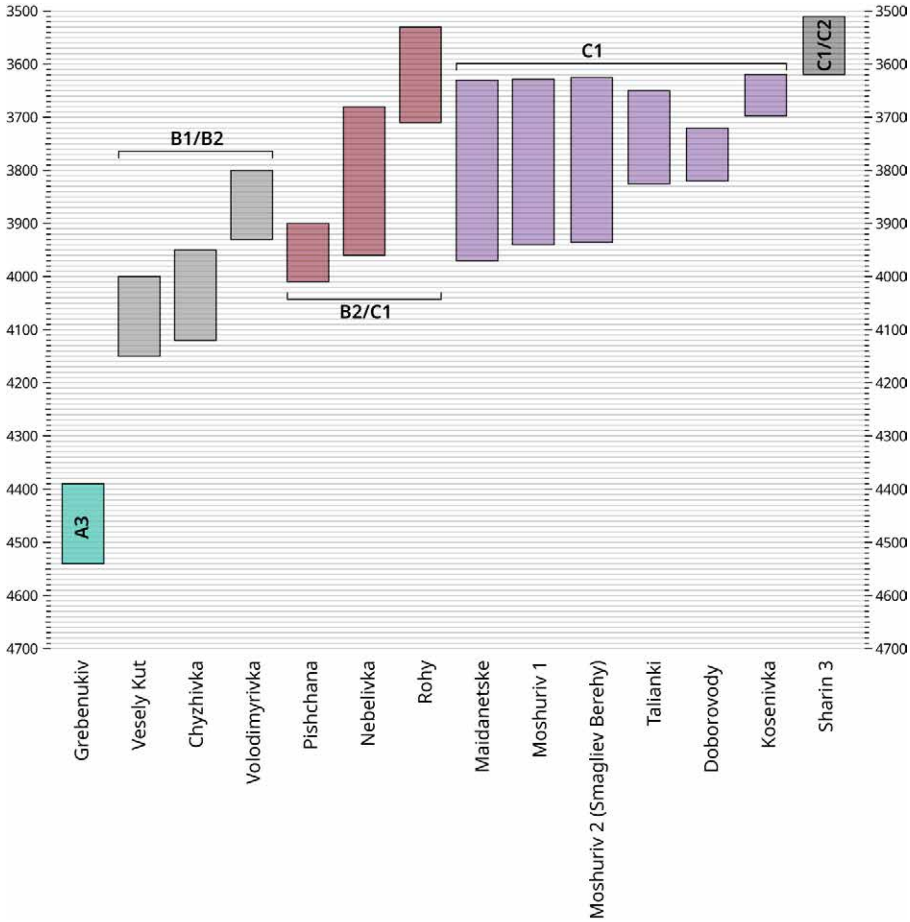


Figure 51. The comparison of Bayesian dates of individual sites from the Southern Bug-Dnieper interfluve.

dug prior to 3775–3730 (68.2%) or 3795–3700 modelled BCE (95.4%) respectively, while the house was in use in the time between 3750 BCE and 3710 BCE (68.2%) or 3780 and 3665 modelled BCE (95.4%), respectively. The occupational layer shows general activity in the area between 3780 BCE and 3700 BCE (68.2%) or 3905 BCE and 3655 BCE (95.4%), respectively.

House durations

^{14}C dates are available for numerous houses/mega-structures. However, we only know of more than three ^{14}C dates for 31 houses/mega-structures, which are listed in Table 6. In Oxcal, the chronological construction or usage period of the individual units and the interval of duration were calculated for the different cases. In order to improve the display for the identification of trends, the median of the modelled 1-σ duration or the 1-σ limits and the median of the duration of the interval were recorded in each case.

Different observations can be made:

- The more ^{14}C dates, the shorter the modelled lifetime of the houses and mega-structures. From about 4 available ^{14}C dates onwards, however, the value levels off (Tab. 7).
- The median values of duration hardly differ between >3 ^{14}C dates and those units including 3 ^{14}C dates. The base set is 11 to 24, the median amounts to 30–40.5 years duration (Tab. 8).
- The duration of the houses in Maidanetske and Talianki indicates a prolongation of the median values from about 30 years to about 70 years. In Nebelivka, no trends can be observed (Fig. 53).

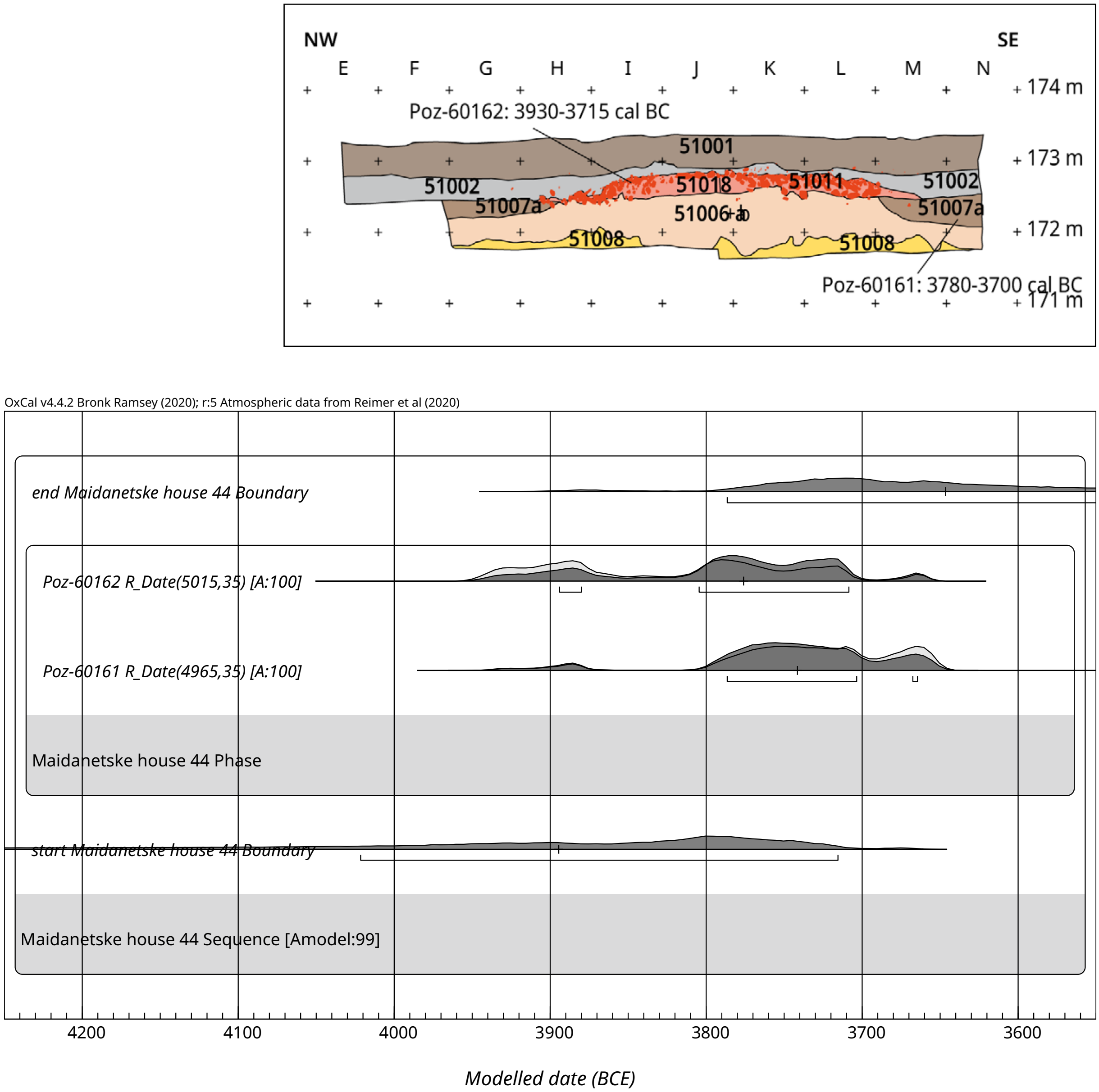


Figure 52. Bayesian dating of Maidanetske House 44: (A) Location of the samples (Müller et al. 2017, 36–37, Tab. 4, Fig. 15) and (B) Bayesian modelling.

- The general representation, including all cases, also indicates an increase in the lifespan of houses and a decrease in the lifespan of mega-structures over time (Fig. 54).
- Mega-structures seem to exist for a shorter time than houses. However, only 3 examples are available (Tab. 9). In summary, even if the number of ^{14}C dates is small, the few examples indicate a use span for houses of usually about 30–35 years with a tendency to use houses longer in later phases (Suppl. 4; Fig. 53). Although the 2-σ values are different, the clear tendency points to an average house duration of ca. 60 years.

'A house constructed of timber is likely to be [used for] a few decades' (Millard 2020, 256), a conclusion from the TOTL Project, which has investigated the duration of Neolithic houses. A variation is observed from ca. 15–80 years (cf. Draşovean and Schier 2010 on Uivar, Romania).

House/ Mega-structure	1 sigma probability BCE	Duration (a)	n ^{14}C, Mod/Ind	Remark
Bilyi Kamin house 7	3865-3895 3915-3875	17 32	3 92.1 89.2 3 105.9 104.5	Integrated model Lonely model
Kosinivka house	3675-3650 3660-3645	11 11	6 110.4 116.3 6 121.9 131.9	Integrated model Lonely model
Mai house 54	3950-3880 3900-3850	70 27	5 oa 81.8 84.7	Ohlrau 201
Mai house 44	3765-3680	74	(4) 2 oa 81.8 84.7	
Mai house 67	3700-3635 3715-3625	65 93	3 oa 81.8 84.7	Ohlrau 214
Mai pit 60 Arch 3	3775-3710 3845-3780	65 48	5 oa 81.8 84.7	Interpretation as house debris
Mai house 53	3780-3690	80	3 oa 81.8 84.7	
Mai pit 60 Arch 2	3910-3760 3910-3845	150 48	5 oa 81.8 84.7	Interpretation as house debris
Neb house A9	3935-3800	125	3, 112.9 112.3	
Neb house B17	3960-3775	195	2, 103.3 103.5	Megastructure?
Neb tp 29/4 (3,4)	3920-3860	30	6, 87 92.6	2 intervalls of 15 years used in model, could also be 60 years
Neb tp 29/4 (3,4) house duration	3900-3855	30	6, 93.8 97.8	1 Interval calculated
Neb tp 24/3 (3,4)	4040-3850	180	3, 114.6 112.8	2 Intervals
Neb 24/2 (3)	3935-3810	103	3, 98,6 100,1	
Neb tp 25/3 (4)	3790-3635	165	3, 93.4 95.2	
Neb tp 26/4 (3)	3895-3845	30	4, 104.4 106.6	
Pishchana house 3	3980-3953 4085-3650	24 466	4 121.1 122.1 3, 87.7 87.9	Integrated model Lonely model
Pishchana house 2	3955-3930 3950-3810	23 122	3 121.1 122.1 3 99.3 99.9	Integrated model Lonely model
Stolniceni house 7	3880-3830 3810-3775	20 31	4, 118.9 117.6 6, 87.9 94.4	All, integrated Red. by 1 date
Talianki house 46	3790-3730	43	2, 72.7 61.8	Integrated model
Talianki house 47	3810-3790	19	3, 72.7 61.8	Integrated model
Talianki house 40	3750-3690	49	3, 72.7 61.8	Integrated model
Talianki house 41	3720-3680	37	3, 72.7 61.8	Integrated model
Talianki house 42	3780-3720	45	4, 72.7 61.8	Integrated model
Talianki house 43	3760-3710	44	3, 72.7 61.8	Integrated model
Talianki house 19	3770-3715	45	2, 72.7 61.8	Integrated model
Dobrovody MS	3790-3720 3900-3710	20 160	3 112.3 113.2 3 112.3 113.2	Integrated model Lonely model
Maid MS	3745-3715	20	9, oa 81.8 84.7	
Neb house B17	3960-3775	195	2, 103.3 103.5	Megastructure?
Neb MS 26/3	3785-3680	100	2, 102.7 103.1	Only 2 dates
Neb bMS	3925-3820	90	3, 107.8 106.2	2 Intervals for 2 phases calculated

Table 6. The duration of houses (cf. Suppl. 1–2: 4).

Table 7. ^{14}C dates and house duration (cf. Suppl. 4): The more ^{14}C dates, the shorter the calculated lifetime of the houses and mega-structures. From about 4 available ^{14}C dates onwards, however, the value levels off.

House lifespan (a)				
Duration		n	Standard Deviation	Median
n ^{14}C	Mean			
3	75.71	14	53.184	64.50
4	43.25	4	22.322	37.50
5	33.50	4	17.972	37.50
6	30.50	2	.707	30.50
9	20.00	1	.	20.00
Sum	57.92	25	45.578	44.00

Table 8. ^{14}C dates and house duration (cf. Suppl. 4): The mean, median and percentile values of duration for units with >2 ^{14}C dates.

House lifespan average (a)		
		Duration
n	Valid	25
Mean		57.92
Median		44.00
Percentile	25	25.50
	50	44.00
	75	85.00

Nevertheless, the analyses of seven houses in Maidanetske indicate high probabilities for the contemporaneity of houses within a timeframe of about less than one century. In cases where stratigraphic information is available, a house duration of less than 50 years is most probable (Houses 79, 54, 61). Pits, which are in many cases associated with the domestic houses and house places, indicate short lived periods. Elongated pits from enclosures yield ^{14}C dates which show short sequences.

Combining different models on the house sequences within concentric rows or within whole settlements, a contemporaneity of 40–60% of the houses is the one estimation with the highest probability.

Development of local mega-sites

With the 96 ^{14}C dates from Maidanetske, tendencies for different features of the settlement are indicated that aid in the reconstruction of the settlement development. The oldest radiocarbon dates (around 3990–3935 BCE, Phase 1) belong to one of the outer enclosures, and from the 3-channel-pottery-kiln, which is located nearer to the centre of the site. Further dating of dwellings indicate that the concentric space between the mentioned enclosure and the kiln was settled first from the innermost concentric circle (3935–3800 BCE, Phase 2), but a house was also constructed in the outermost circles, which does not follow the general later pattern. Remaining pits from this older settlement to the north of Maidanetske also date to Phase 2.

Later, the innermost part of the site is settled from ca. 3800–3700 BCE (Phase 3) as well as the inner and outer main ring up until the outer ring of houses right behind the inner enclosure. René Ohlrau (2020) discovered the peak occupation from ca. 3765–3710 BCE with the densest number of houses within the inner enclosure. The excavated mega-structure also belongs to this Phase 3. The excavated kiln and its pottery production ceased already around 3800 BCE and was not continued in Phase 3.

In a further development, the inner enclosures were levelled and a younger house was built on top (ca. 3700–3640 BCE, phase 4). Further younger dates belong to the outer parts of the site.

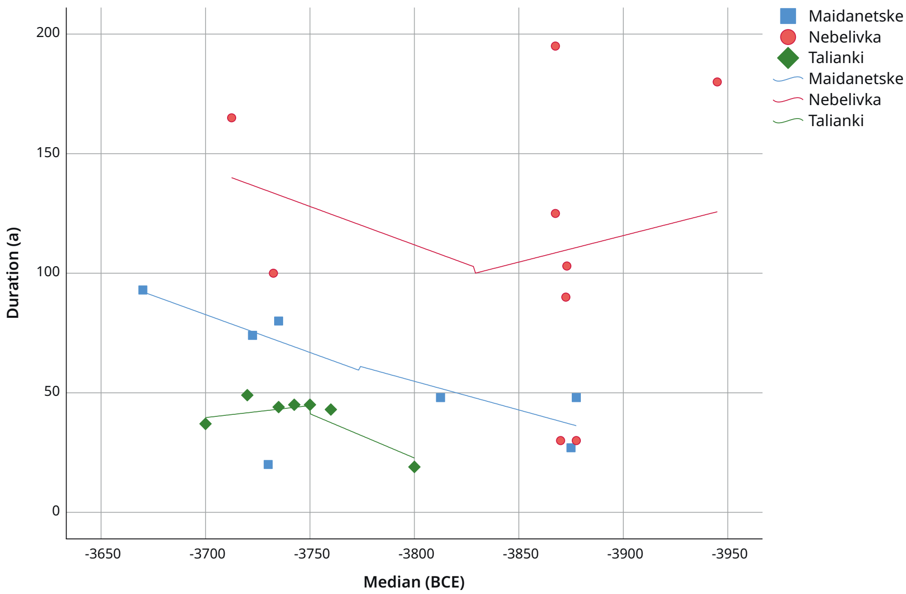


Figure 53. The calculated duration of the houses in Maidanetske, Talianki and Nebelivka. For Maidanetske and Talianki, a prolongation of the median values from about 30 years to about 70 years is indicated. In Nebelivka, no trends can be observed (cf. Suppl. 4).

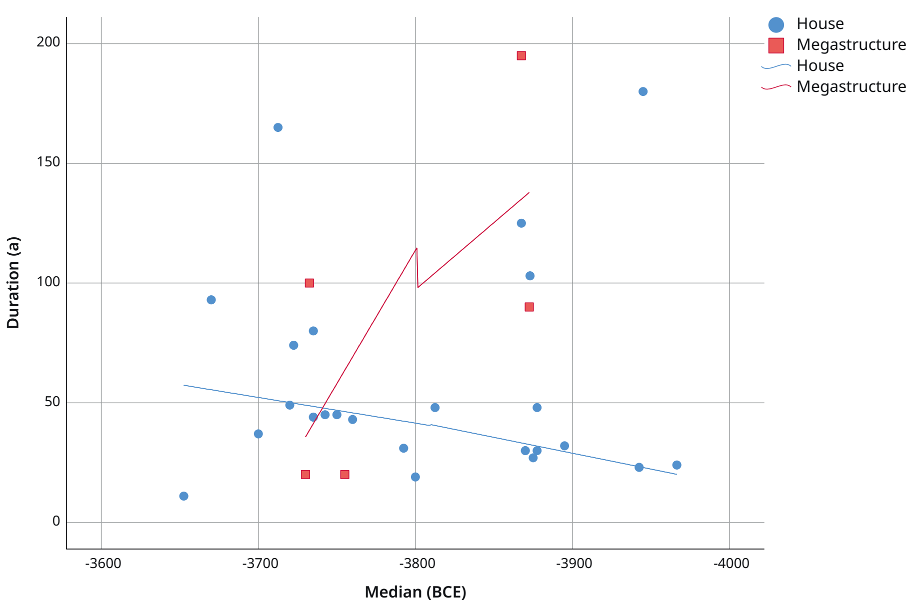


Figure 54. The calculated duration of the houses and mega-structures. The general representation including all cases indicates an increase in the lifespan of houses and a decrease in the lifespan of mega-structures over time (cf. Suppl. 4).

Duration (a)				
Duration		n	Standard Deviation	Median
Category	Mean			
Houses	59.91	22	46.73	40.50
Mega-structures	43.33	3	40.41	20.00
Sum	57.92	25	45.57	44.00

Table 9. The general duration of houses and mega-structures (cf. Suppl. 4).

In summary, the temporal-spatial distribution of the radiometric dates describes the establishment of a demarcation and infrastructure in the early phase of the settlement, followed by main settlement activities in the intermediate phase and a final phase with an occupation of lower intensity.

A comparable situation exists at other sites, where the number of radiometric dates is high enough for differentiations of the site biography. In Stolniceni, the outer enclosure and the kiln also yielded the oldest dates before the main occupation started. In Maidanetske, the kiln functioned earlier than the houses.

Beside the qualitative differences of the occupation phases, the modelled house durations of 19 dated houses in Maidanetske are taken for the estimation of the occupational time of these houses. In result, the duration of occupation lies probably in a time window of 25–75 years. Taking this into consideration and summing up the calibrated values for all sites, the number of contemporaneously occupied houses per phase is displayed in Figure 42.

Due to the previously known radiometric dates, the three large settlements – Nebelivka, Maidanetske and Talianki – coexisted for a long period of time, even if the core occupation of Nebelivka began earlier than Maidanetske and Talianki, and the latter two were occupied longer (cf. Shatilo 2021, 152, Fig. 55; Nebbia *et al.* 2018). By means of a structural comparison of the spatial-chronological processes at Talianki and Maidanetske, which were analysed and described elsewhere (Ohlrau 2020; Shatilo 2021), the following can be stated (Fig. 55):

- In all three settlements, the oldest dates are located at the outer boundary of the mega-sites. In Maidanetske, these dates are from the enclosure, in Talianki from the outermost concentric house row and in Nebelivka also from the outer house row. Unfortunately, it was not possible to gain radiometric dates from the outer enclosure at Nebelivka. Nevertheless, as in Maidanetske, an early construction of the outer boundaries of the settlement area can also be assumed here.
- In all three settlements, the radiometric dates indicate that both the concentric house circles and the inner quarters existed as a fundamental concept and could be settled. Both the investigations of Liudmyla Shatilo in Talianki and the spatial distribution of our ^{14}C dates in Nebelivka reveal that originally empty areas were progressively settled in the concentric rows of houses. This was also likely the case in Maidanetske.
- While corresponding settlement processes in Talianki and Maidanetske all included concentric circles and quarters, this is no longer the case after 3800 BCE in the inner area of Nebelivka, but only in the outer areas of the settlement.

From our point of view, the latter observation captures the crucial difference between Talianki and Maidanetske, on the one hand, and Nebelivka on the other: In all three cases, we observe a basic settlement planning concept right from the start of the settlements. While the settlement processes in Talianki and Maidanetske are intensified over time, these are already discontinued in Nebelivka after a few generations. The activities are limited to the periphery of the settlement, while the inner area no longer plays a role.

As a consequence, we can deduce that in contrast to Maidanetske and Talianki, Nebelivka was discontinued earlier. The original concept of a large settlement at Nebelivka, which pre-programmed an urban development with the creation of the 235-ha settlement area, the ring corridor and the quarters, was abandoned for reasons still unknown to us.

The population increase in Maidanetske around 3800 BCE, which occurred at the same time as the beginning of disintegration at Nebelivka, could indicate greater mobility between the mega-sites. Therefore, it is possible that other mega-sites could have profited in their development from the demise of Nebelivka.

The cause of Nebelivka's decline can, for example, be sought in the economic sphere. At first, no major differences can be detected between the three mega-sites considered here. The isotope values of domestic animals indicate that at least some of the animals in Nebelivka, in contrast to Maidanetske, still found more wooded areas in the surroundings (Makarewicz *et al.* 2022). Analyses of molluscs directly from archaeological features in Nebelivka, however, also verify a cleared landscape (Miller 2020). A pollen profile from the nearby canyon at Nebelivka (Albert *et al.* 2020) covers, according to the five accepted ^{14}C dates, the period between 4400 BCE and 3500 BCE. The pollen diagram indicates light forest cover before settlement with a mixed oak forest interspersed with pines. However, the settlement time of Nebelivka falls in a hiatus in the pollen profile between 4100 BCE and 3600 BCE, so that a further clearing and the appearance of settlement indicators, including micro-charcoal, are not documented. A sparse forest is also proven for the time after the settlement. In principle, other palaeoecological analyses point to a sustainable economy, which led, among other things, to the development of anthropogenic black soils (Dreibrodt *et al.* 2020). For Nebelivka, this cannot be verified, since the mega-site was abandoned relatively early.

If we compare the development of the three mega-sites where we are able to reconstruct the internal development, similarities and differences are obvious (Fig. 55):

1. The peak of the occupation falls in different centuries: the 39th century BCE in Nebelivka, the 38th century BCE in Maidanetske and the 37th century BCE in Talianki.
2. While Nebelivka reaches a population size of only less than 2000 inhabitants, Maidanetske reaches about 7000 inhabitants and Talianki 4000 inhabitants (average).
3. While in Nebelivka and Maidanetske the population increase and decrease reflect a boom and bust phase, in Talianki the overall-development makes a smoother impression.

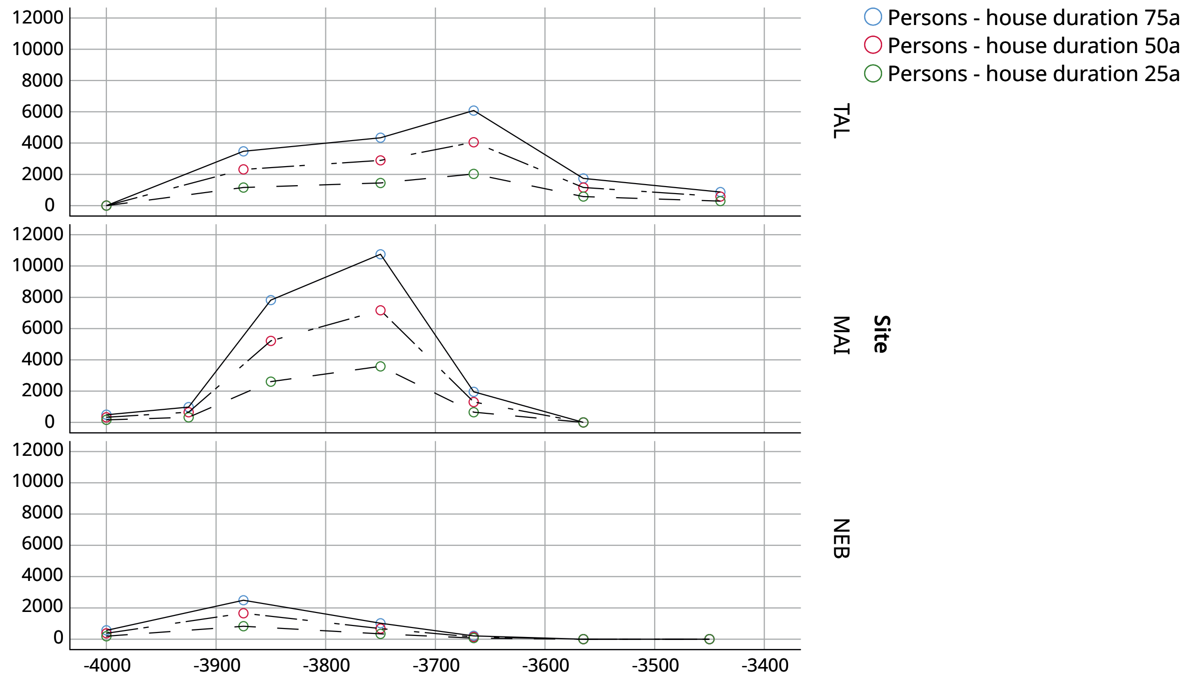
Nebelivka was lost. Therefore, it never reached the same population density as Talianki or Maidanetske, on the one hand, and did not have such a long period of settlement on the other. In the 38th century BCE, we observe ca. 1500 contemporaneously existing houses at Maidanetske, in Nebelivka only ca. 300. This shows differences in settlement – how it was originally conceived, enabling a corresponding densification of the residential areas (in Maidanetske), and a settlement (Nebelivka), which originally had a very similar concept, but whose housing densification never took place due to reasons yet unknown.

The temporal synchronisation of Trypillia phases

Figure 56 displays a comparison of Trypillia phases between the three regions, as visible from the radiometric dating used here. While in the west, Precucuteni 3/1 and Cucuteni A1 are dated between ca. 4700 BCE and 4300 BCE, in the east, Trypillia A3 dates from ca. 4540–4380 BCE, thus contemporary with CC A1. Trypillia B1 sites are dated in the west around 4300–4150 BCE. They are missing in the central region and are not dated in the east, where they might fall within the dating gap between A3 and B1/2.

Trypillia B1/2 existed probably contemporaneously around 4300–4000 BCE in the west and the middle region, starting later in the east, but lasting longer there (4130–3900 BCE). B2 is also known around 4050 BCE in the west, at 3970 BCE in the middle and 4020 BCE in the east. A more or less concurrent beginning of B2 seems to be possible, taking the dating uncertainties into account, while it seems to last until 3800 BCE in the east, but seems to cease much earlier in the middle (3900 BCE) and the west (3950 BCE). A contemporaneity is also implied by the start of C1 in all regions around 3970/3950 BCE. The end of C1 might be 75/100 years earlier in the west than in the middle region (3610 BCE) and the eastern regions (3625 BCE). Trypillia C2 is determined by a date from Kosenivka around 3620–3520 BCE for the east, contemporaneous with the middle region (3620–3520 BCE), but it may be later than in the west (3490–3040 BCE).

(A)



(B)

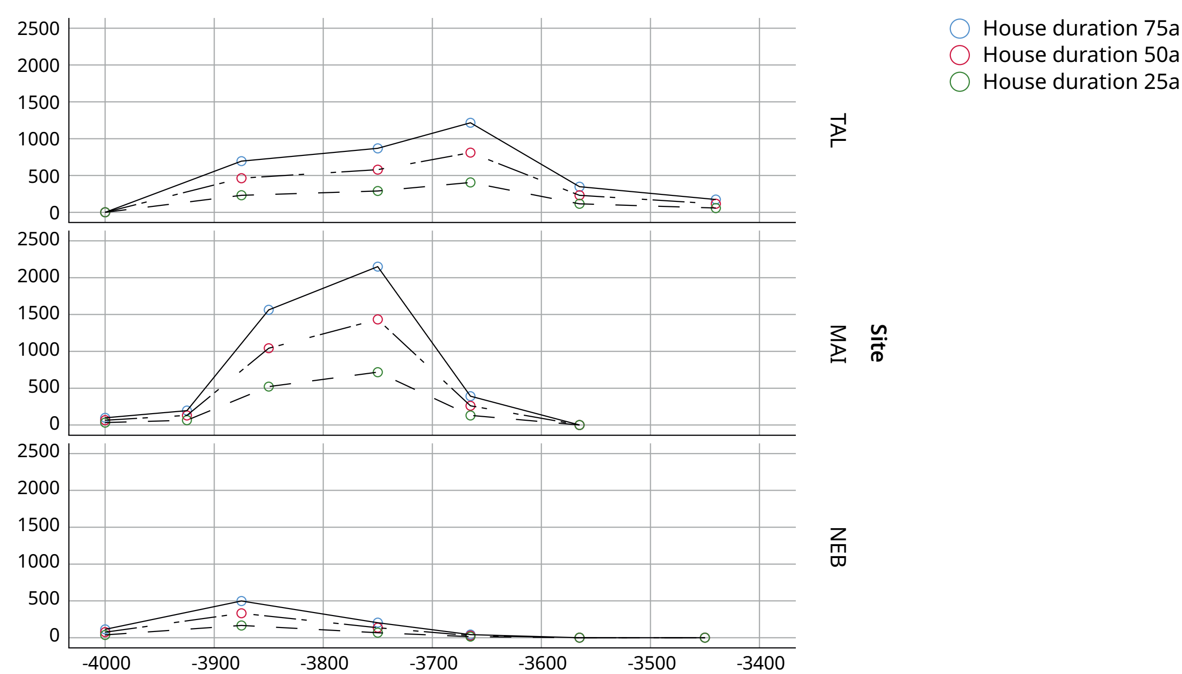


Figure 55. Occupation trends in Maidanetske, Nebelivka and Talianki over time (4000–3400 BCE): (A) absolute number of inhabitants (linear scale); (B) absolute number of contemporary houses; (C) absolute number of inhabitants (logarithmic scale).

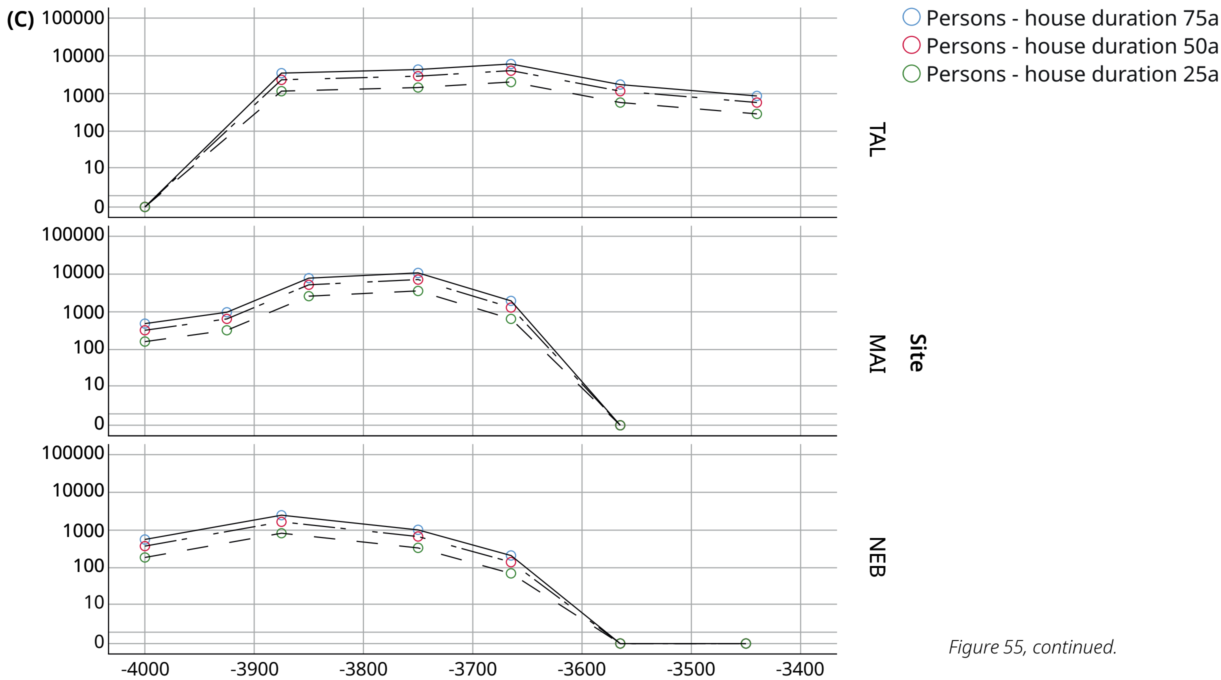


Figure 55, continued.

With the exception of B1/2, which seems to start about 150 years earlier in the west and the middle region than in the east, most of the other Trypillia phases started more or less contemporaneously.

Discussion and consequences

The investigation and analysis of ^{14}C data from Trypillia sites have above all also shown the potential for internal structuring of settlement dynamics in the individual settlements. Thus, with sufficient ^{14}C dates, it is possible to evaluate the local settlement developments, but also those of mega-sites in relation to each other. As a result, the settlement biographies are basically similar, but also variable per site, *e.g.* with regard to population trends. For example, while Maidanetske and Talianki show an increasingly dense settlement, the 'large' settlement Nebelivka breaks off quite early. Accordingly, the number of inhabitants in this mega-site is rather low and comparable to those of larger medium-sized settlements (Stolniceni).

In the four settlements where an internal subdivision was possible due to the extent of the study and the number of ^{14}C dates, an increasing occupation of the inner space, *i.e.* increasingly from the outside to the inside, could be observed.

At the household level, approximations of the lifespan of houses could be evaluated. Even though strong variations can be observed, the average lifespan of a house stabilises at 40–50 years. Where observable (Maidanetske and Talianki), there are indications of an increase in the lifespan of houses the later they are built. This could be explained by a certain scarcity of resources.

On a typochronological level, it could be shown that a continuity from PCC 3/1 to C1 is demonstrable in the 'west', whereas this is not the case in the central and eastern Trypillia test regions. Obviously, especially Trypillia B1/2 commences about 150 years earlier in the west and in the middle region than in the east. Trypillia B2 and C1, on the other hand, appear more or less simultaneously from west to east, tending to appear even slightly earlier in the east. Possibly, we are thus made aware of the spread of new concepts (according to Harper *et al.* 2023 on the intensive agrarian mode of production) from west to east and then innovative processes in

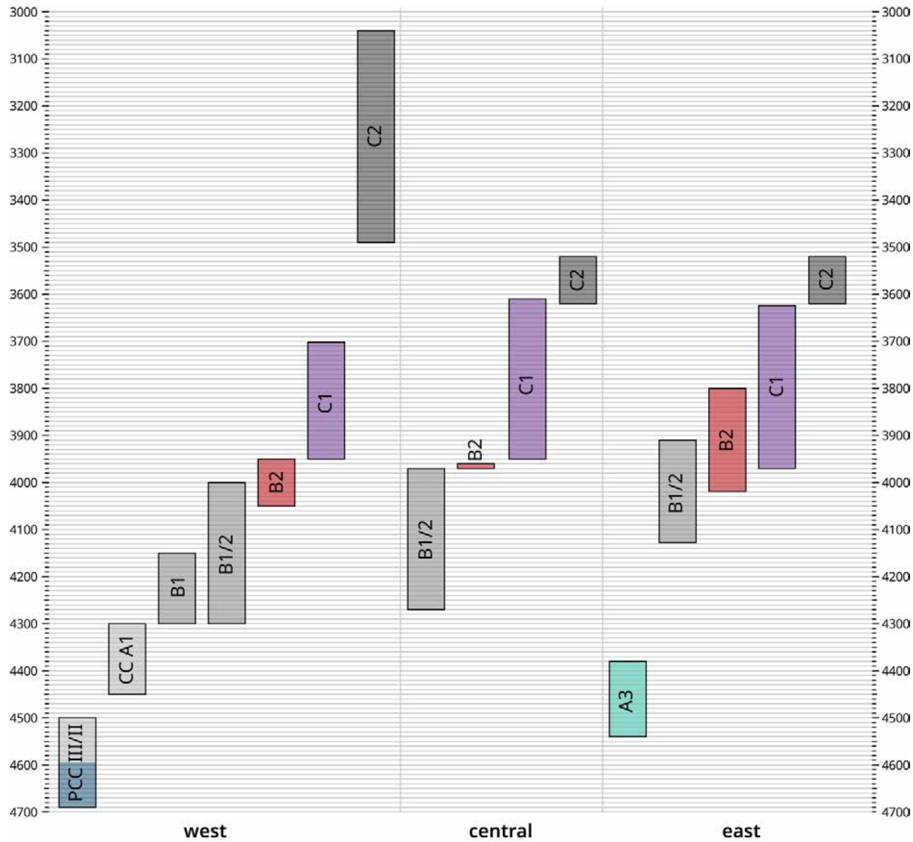


Figure 56. The comparison of the dating of phases BCE from the Middle-Dniester region, Southern Bug-Dniester interfluve, and the Southern Bug-Dnieper interfluve.

the former marginal areas of the east, which also influence the west. The changes towards Trypillia C2 could also spread from east to west. Thus, if we initially recognise a fundamentally open communication system in which, in particular around 4300–4130 BCE, new – also economic – impulses reach the east from the west and in which the new mega-site principles spread relatively simultaneously, it is the diversifications around 3620–3500 BCE that contribute to the dissolution of the larger structures from east to west.

The decisive gain of the investigations carried out here, however, is above all to allow detailed statements on settlement processes at the level of settlements. This makes it easier to divide settlements into phases, which help to answer economic, demographic and political or social questions in a much more condensed way.

Supplementary materials

The supplementary materials are freely available online under a CC BY 4.0 licence, in the Kiel University research data repository opendata@uni-kiel.de: https://doi.org/10.57892/100-55

Supplement 1. List of Trypillia ^{14}C data.
Supplement 2. Oxcal files, additional figures and data collections.
Supplement 3. Nebelivka. Classified radiocarbon dates.
Supplement 4. Calculated house durations.

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