

Appendix 1.

Detailed Methodology and Model Results

Opovo Revisited. Reconstructing Settlement Development and Social Structures in the Late Neolithic Site of Opovo Ugar-Bajbuk, Serbia

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This appendix provides the detailed methods, calculations, and supplementary results that support the analyses presented in Wilkes et al. 2026 (henceforth referred to as main article). It is intended to document the analytical procedures in greater detail and to ensure the transparency and reproducibility of the study. Section 1 presents the methodology and results of the population modelling, including the assumptions, constraints, and simulation outcomes used to reconstruct and discuss potential demographic developments at Opovo. Section 2 explains the calculation of the Gini index based on house sizes and considers the effects of chronological uncertainty through Monte Carlo simulations. Section 3 outlines the methods used to estimate ditch volumes and the labour investment required for their construction. Section 4 documents the location and layout of the excavation trench opened during the 2024 field season. Section 5 describes the identification and interpretation of geomagnetic anomalies and evaluates the consistency of house interpretations produced by different researchers. Section 6 presents the full radiocarbon model, alternative model configurations, and the detailed OxCal results used to establish the site's chronology. In addition, this appendix contains supplementary tables, figures, statistical summaries, and model outputs that could not be included in the main article. Formulae referred to in the text are provided where necessary. The R scripts and OxCal code used for the analyses are included in the supplementary material (Appendix 2). Together, the contents of this appendix provide the methodological foundation for the interpretations presented in the study.

Main abbreviations:

Acomb = agreement index of combined radiocarbon dates
Amodel = overall agreement index of the radiocarbon model
Aoverall = overall agreement index of the complete Bayesian model
CI = confidence interval
DP = drilling point
K = carrying capacity
L = house lifespan

nT = nanotesla
P0 = initial population
P(t) = population size at time t
r = population growth rate
S = household size
T = settlement duration

1. Population Modelling – Methodology

In this study, the population development and size were modelled following the approach of Marko Porčić and Mladen Nikolić (Porčić, Nikolić 2016; Porčić, Nikolić 2021). The basis of this approach is the logistic growth model, which reflects common patterns in population dynamics. In particular, it accounts for the limits of an environment or social system, known as the carrying capacity. Logistic growth assumes that populations far below the carrying capacity grow exponentially. As the population approaches the midpoint, growth becomes linear and eventually slows down, forming an S-shaped curve. Growth stagnates as it nears the carrying capacity.

The logistic growth formula used is:

$$P(t) = \frac{K}{1 + \left(\frac{K - P_0}{P_0}\right) e^{-rt}}$$

where $P(t)$ is the population at time t , P_0 is the initial population, K the carrying capacity, r the growth rate, and t the time.

In both Porčić and Nikolić work (Porčić, Nikolić 2016; Porčić, Nikolić 2021) and this study, population size is not taken directly from historical records but estimated from the number of houses in a settlement. This approach requires several considerations. In Late Neolithic sites like Opovo, the visible houses from magnetic surveys often belong to different phases of the settlement and are unlikely to have existed all at once. Each house has a limited lifespan and is eventually replaced. To account for this, Porčić and Nikolić developed a formula to calculate the total number of houses that contributed to the settlement's population over time (Porčić, Nikolić 2021, 479):

$$\sum_{i=0}^{T/L-1} \frac{P_{i-L}}{S}$$

where T is the settlement duration, L is the lifetime of houses, P_i is the size of the population at moment i for $i \in \{0, 1, \dots, T-1\}$, and S the average number of inhabitants per house.

By combining the logistic growth model with a house accumulation formula, we can estimate both the population trajectory over time and the total number of houses deposited during the settlement's occupation. This approach follows two settlement development scenarios adapted from Porčić, Nikolić 2021, originally based on Schacht 1984:

- Model 1 (Rapid Abandonment): Population grows logistically until a sudden abandonment occurs.
- Model 2 (Gradual Abandonment): Population initially grows, but at some point during the settlement's lifespan, growth slows down or becomes negative, leading to a gradual decline.

In this study, we conducted one million simulations for both scenarios, using a range of parameter combinations. These generated numerous possible population trajectories and associated house counts. We then applied a set of constraints to filter the simulations, retaining only those that most plausibly reflect the demographic development of Opovo.

The following section outlines the key assumptions used in the logistic growth and house accumulation models, along with the constraints applied to identify valid simulations.

1.1. Model Assumptions

Initial Population (P_0): Sampled from a range of 100 to 500 individuals. This range is based on the early appearance of ditch c, which likely required significant labour. Our analysis shows that a population of 200 could feasibly complete its construction within a reasonable time frame, while 500 would expedite the process further.

Carrying Capacity (K): Sampled from a uniform distribution between 220 and 10,000. The lower boundary reflects the estimated 180–220 houses identified through magnetic survey, assuming the settlement may have reached its peak. The upper boundary is set higher to accommodate the area's economic and environmental potential, as indicated by studies such as those by Ksenija Borojević and Nerissa Russell (Russell 1993; Borojević 2006).

Growth Rate (r): Drawn from a uniform distribution between 0 and 0.06. This range is based on Porčić, Nikolić 2021, who observed that Late Neolithic populations often experienced relatively high growth rates compared to earlier periods.

Settlement Duration (T): Sampled from a uniform distribution between 29 and 440 years, based on the 95 % confidence interval of the radiocarbon model developed in this study.

House Lifespan (L): Sampled from a normal distribution with a mean of 35 years and a standard deviation of 5. This reflects the estimated use-life of Neolithic wattle-and-daub houses, which typically lasted between 20 and 50 years (Porčić, Nikolić 2021).

Household Size (S): Sampled from a range of 4 to 9 individuals per house. This is based on two sources: (1) studies suggesting 4–5 people per household (Diachenko, Zubrow 2015, 8), and (2) ethnographic estimates of 1 person per 6–10 m². With house sizes at Opovo ranging from 34.9 to 55.7 m² (median: 44 m²), this supports a plausible household size range of approximately 3.5 to 9.2 people.

1.2. Model Constraints

Rapid Abandonment Model: The number of accumulated houses must fall between 180 and 440, based on the magnetic survey, which identified 180–220 houses. The upper limit is doubled to account for potential underestimation due to unburnt or stratigraphically hidden houses. The number of houses at the start of the settlement must exceed 50, reflecting that settlement area I – enclosed by ditch s and dated to the early phase – includes 96 reconstructed houses. It is assumed that a substantial portion of these were present from the beginning.

Gradual Abandonment Model (additional constraints): The maximum population must be no more than 10 individuals below the carrying capacity. This ensures that the settlement reached near-capacity, creating conditions for a population decline due to environmental, economic, or social limitations.

The final population must be between 1 and 9 people, representing the maximum size of a single household. This filters out simulations where the settlement appears to end suddenly from a high population level – effectively resembling rapid abandonment rather than gradual decline. The simulations were conducted in R; the code is included in Appendix 2-2.¹

1.3. Population Modelling – Results

In addition to the findings already discussed in the main article, the following sections present the simulation result plots (Figs. 1–9) and the corresponding results tables (Tabs. 1–2).

Parameter	Median	Minimum	Maximum	1 st Quartile	3 rd Quartile
Initial Population	216	100	447	158	283
Max. Population	481	214	3679	346	711
Growth rate	0.04	0.00	0.06	0.03	0.05
Settlement duration	210	81	440	166	273

Tab. 1. Results of the simulations of the rapid abandonment model. Out of 1 million simulations, 4989 matched the constraints.

Parameter	Median	Minimum	Maximum	1 st Quartile	3 rd Quartile
Initial Population	226	100	448	167	293
Max. Population	449	211	1526	349	581
Growth rate	0.04	0.00	0.06	0.03	0.05
Negative growth rate	-0.07	-0.10	-0.02	-0.08	-0.05
Settlement duration	323	134	440	269	376

Tab. 2. Results of the simulations of the gradual abandonment model. Out of 1 million simulations, 8676 matched the constraints.

¹ Improvements and extended commenting were established using language models (ChatGPT; OpenAI 2024). This helped produce a streamlined version with a better simulation speed.

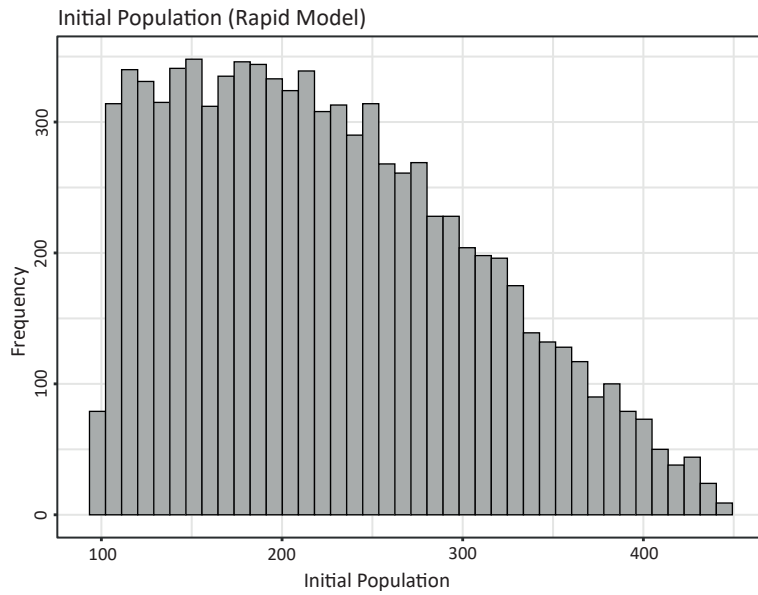


Fig. 1. Distribution of the initial population of the 4989 valid simulations of the rapid abandonment model.

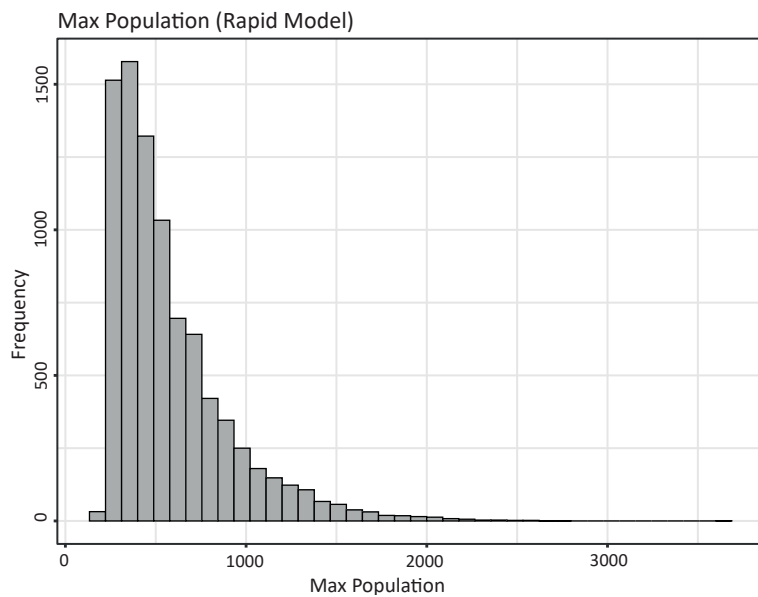


Fig. 2. Distribution of the maximum population of the 4989 valid simulations of the rapid abandonment model.

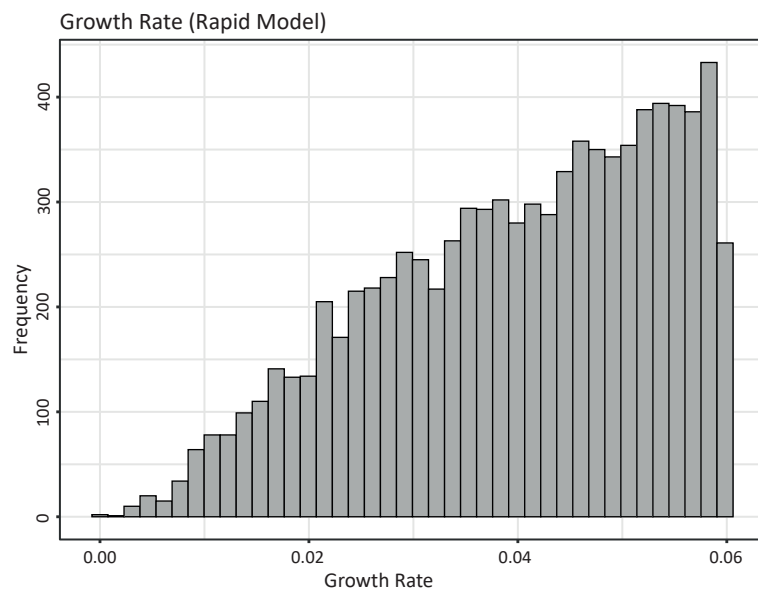


Fig. 3. Distribution of the growth rate of the 4989 valid simulations of the rapid abandonment model.

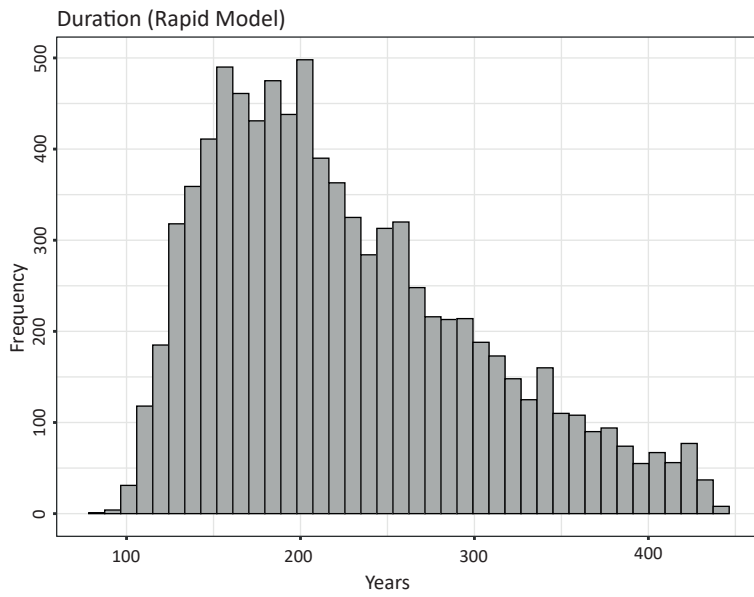


Fig. 4. Distribution of the settlement duration of the 4989 valid simulations of the rapid abandonment model.

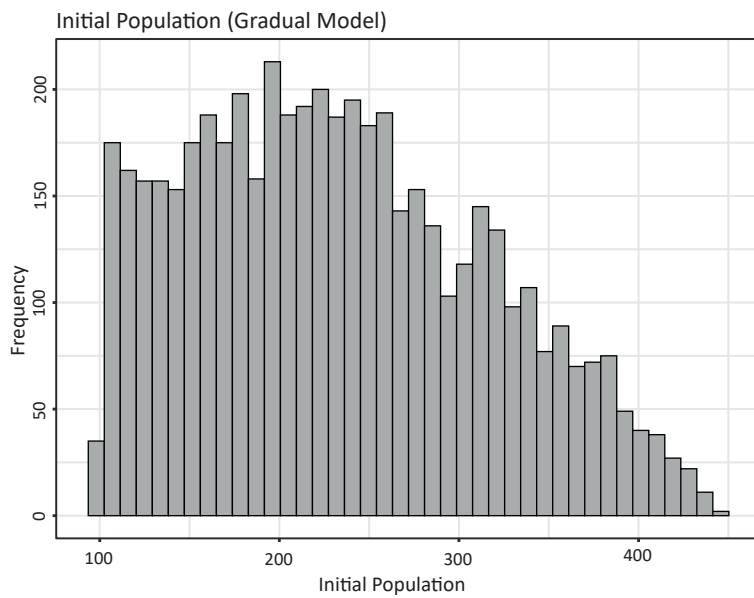


Fig. 5. Distribution of the initial population of the 8676 valid simulations of the gradual abandonment model.

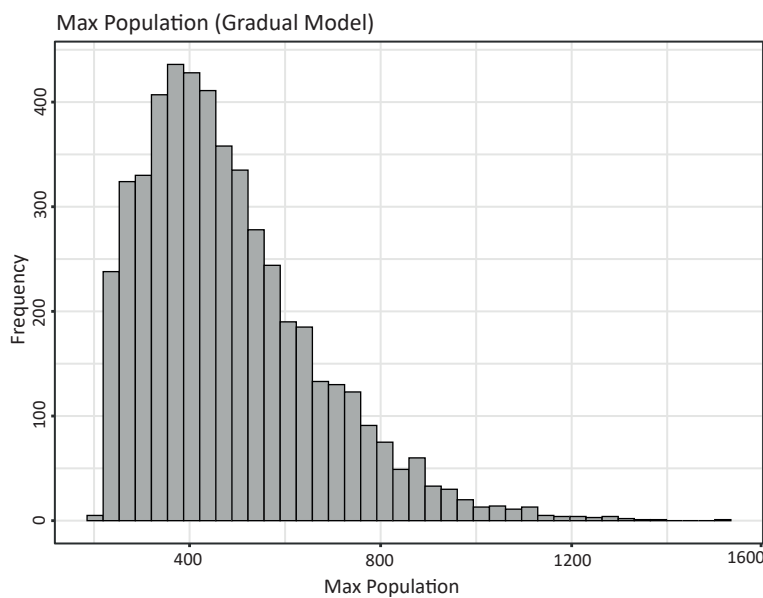


Fig. 6. Distribution of the maximum population of the 8676 valid simulations of the gradual abandonment model.

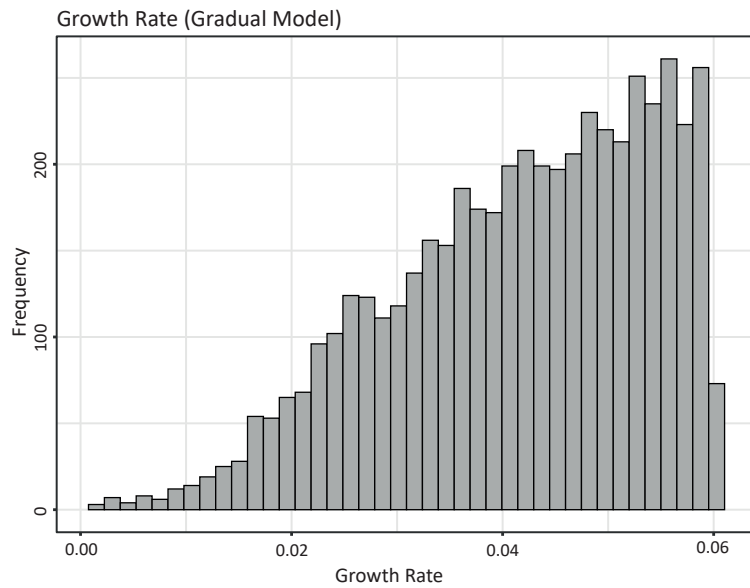


Fig. 7. Distribution of the growth rate of the 8676 valid simulations of the gradual abandonment model.

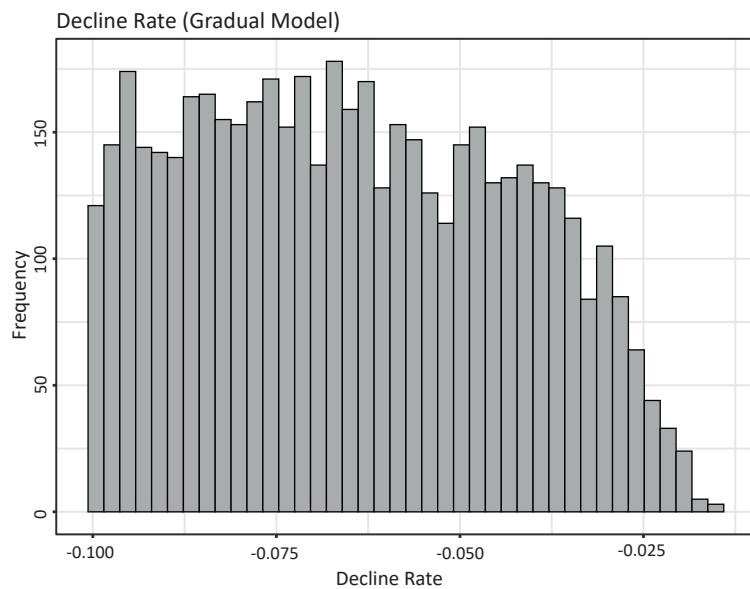


Fig. 8. Distribution of the negative growth rate of the 8676 valid simulations of the gradual abandonment model.

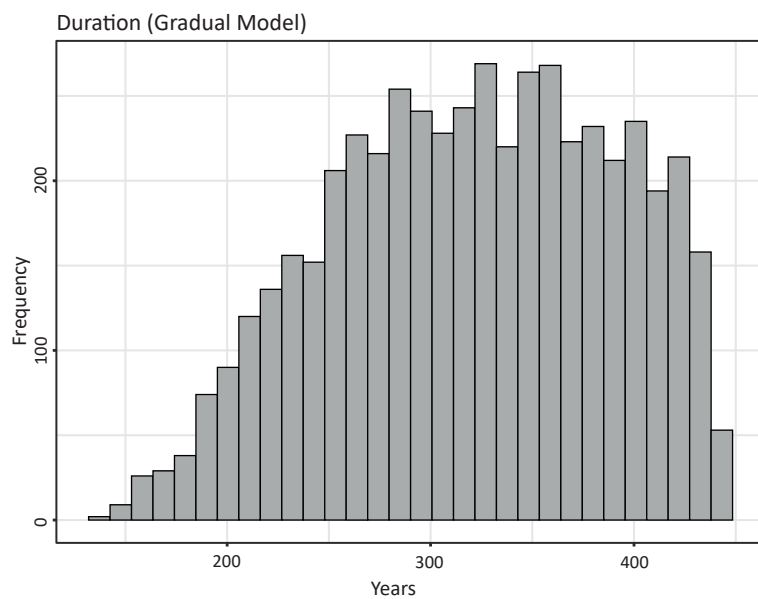


Fig. 9. Distribution of the settlement duration of the 8676 valid simulations of the gradual abandonment model.

2. Gini Index – House Size

The Gini index, or Gini coefficient, is a measure of the inequality in a distribution, or in other terms, a measure of concentration within a sample (Kamps, Krämer 2018a). The method was developed by the Italian Corrado Gini (Gini 1912) and is considered one of the most common measures of income and wealth inequality.

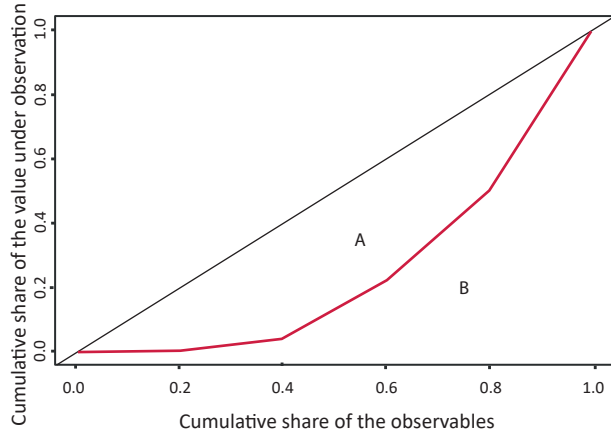


Fig. 10. Lorenz curve (red) and line of equality (black).

The Gini index is calculated using a Lorenz curve (Fig. 10). A Lorenz curve shows on the x-axis the cumulative share of the observables of a distribution, ordered from the lowest to the highest value. On the y-axis, the cumulative share of the value under observation within a group is plotted (Kohn, Öztürk 2017; Kamps, Krämer 2018b). With reference to income distribution, a Lorenz curve (Fig. 10, red line) shows how much of the income is earned by a certain part of a population.

The Gini index is determined from a Lorenz curve (Fig. 10, red line) and the straight line of an equal distribution – a hypothetical Lorenz curve for a perfectly equal distribution, a so called line-of-equality (Fig. 10, black line). The area between the two curves (Fig. 8, Area A) corresponds to the Gini index (Kamps, Krämer 2018a). So, if a variable is more evenly distributed within a sample, the line-of-equality and the Lorenz curve are relatively close to each other, and the area between them

is small. If the variable is more concentrated, the area becomes larger. The Gini index takes values between 0 and 1, where 0 indicates a total equal distribution and 1 indicates total unequal distribution (Kerig et al. 2022). This derivation of the Gini index using the Lorenz curve (G) is expressed by the following formula, where A is the area under the line-of-equality and B is the area under the Lorenz curve:

$$G = \frac{A - B}{A}$$

2.1. Gini Index Variation – House Size

Due to the absence of chronological information for individual house features visible in the magnetic image, it is difficult to determine which houses were in use at the same time during the settlement's existence. Consequently, calculating a single Gini index for the entire set of houses may lead to inconclusive results. To address this issue, a Monte Carlo simulation was applied to explore possible combinations of houses that could have been in use during different occupation phases.

The first step involves determining an adequate number of simulation runs. This is guided by Monte Carlo error estimation (Koehler, Brown, Haneuse 2009), illustrated in figures 11 and 12, which suggested that approximately 155 runs would be sufficient. To ensure reliable results, the number of runs was set to 500.

In each simulation run, a random selection of between 10 and 100 house sizes was drawn from the complete dataset of house sizes in Opovo (see Tab. 3). This reflects the assumption that the number of contemporaneous houses at the Opovo site could have varied within this range. A Gini index was then calculated for each sample, and the result stored. From the 500 calculated Gini indices, summary statistics were derived. These include the median, the first and third quartiles, the minimum, and the maximum values. The results are presented in Table 4 and illustrated in Figure 13; the R code can be found in Appendix 2-3.²

² Improvements and extended commenting were established using language models (ChatGPT; OpenAI 2024).

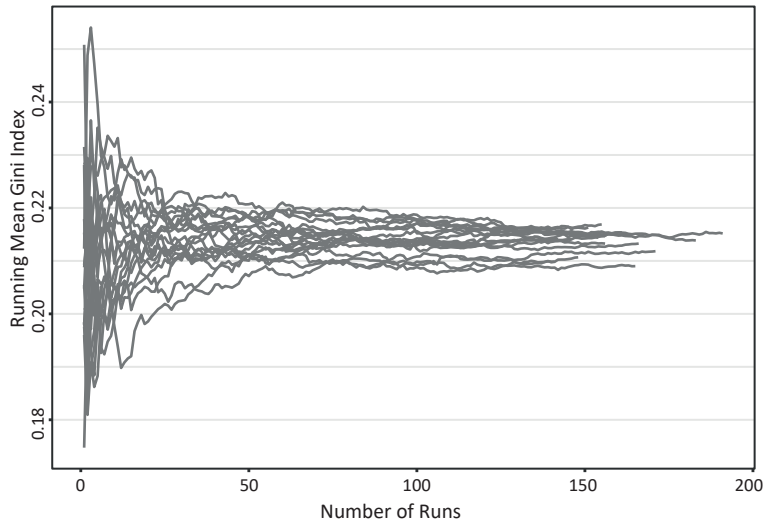


Fig. 11. A sample of 20 runs of the Monte Carlo error estimate to assess the necessary number of simulation runs for the Gini index simulations.

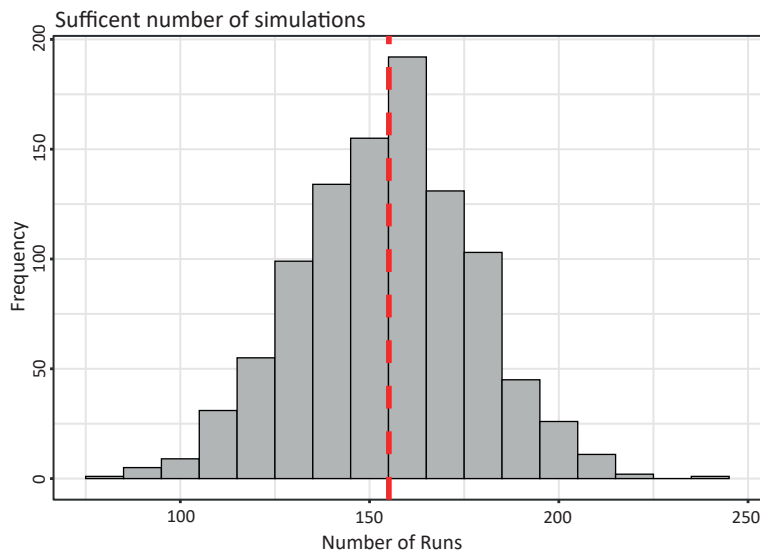


Fig. 12. Summary of the sufficient number of simulations based on the Monte Carlo error estimation. The red dashed line indicates the mean number of sufficient simulations (155).

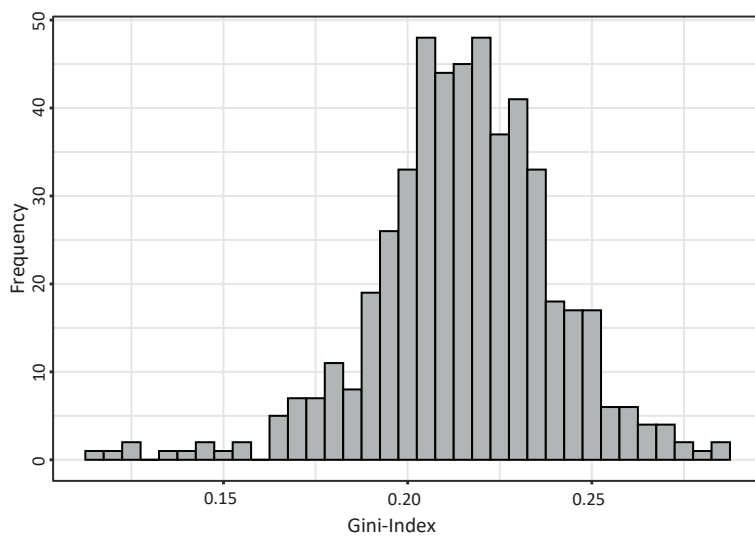


Fig. 13. Distribution of the results of the Gini index simulations.

Width (m)	Length (m)	Angle (°)	Area (m²)	Radiocarbon sample
2.78	5.6	42.86	15.57	
2.79	4.97	41.59	13.87	
3.01	6.25	42.84	18.81	
3.07	7.74	43.48	23.76	
3.09	6.23	53.53	19.25	
3.36	6.54	24.93	21.97	
3.39	5.57	29.28	18.88	
3.42	7.38	45	25.24	
3.51	6.1	54.46	21.41	
3.52	6.14	38.02	21.61	
3.54	6.16	51.84	21.81	
3.59	7.16	31	25.7	
3.64	6.94	16.37	25.26	
3.66	7.49	27.73	27.41	
3.71	6.61	56.63	24.52	
3.75	9.79	45	36.71	
3.77	7.35	54.66	27.71	
3.81	7.17	42.31	27.32	
3.83	8.47	97.91	32.44	
3.84	7.42	136.49	28.49	
3.87	8.02	45.87	31.04	
3.91	7.66	37.27	29.95	
3.92	5.45	20.73	21.36	
3.93	8.59	148.67	33.76	
3.93	8.88	42.05	34.9	
3.94	5.64	32.62	22.22	
3.96	5.76	26.47	22.81	
4.07	9.57	55.01	38.95	
4.07	6.24	18.12	25.4	
4.08	8.32	17.42	33.95	
4.09	8.47	18.25	34.64	
4.09	6.77	1.06	27.69	
4.1	4.81	29.2	19.72	
4.12	8.15	38.61	33.58	
4.12	7.26	109.5	29.91	
4.15	8.86	39.67	36.77	
4.16	9.28	129.47	38.6	
4.16	7.27	38.18	30.24	
4.16	10.58	57.22	44.01	
4.17	6.25	20.67	26.06	
4.18	11.06	41.9	46.23	
4.19	8.55	39.63	35.82	
4.2	10.46	138.37	43.93	

Width (m)	Length (m)	Angle (°)	Area (m²)	Radiocarbon sample
4.21	7.67	33	32.29	
4.23	8.17	46.18	34.56	
4.24	7.33	28.16	31.08	
4.26	8.64	37.5	36.81	
4.28	5.75	129.4	24.61	
4.29	8.39	159.08	35.99	
4.3	5.34	0.46	22.96	
4.31	6.59	179.08	28.4	
4.31	8.9	27.86	38.36	
4.33	7.73	58.37	33.47	
4.38	9.81	176.92	42.97	
4.38	7.48	178.79	32.76	
4.39	8.2	51.61	36	
4.4	8.09	36.51	35.6	
4.41	8.29	52.77	36.56	
4.42	7.97	52.88	35.23	
4.43	10.36	179.46	45.89	
4.44	9.02	16.67	40.05	
4.44	5.33	128.85	23.67	
4.45	10.32	40.24	45.92	
4.49	9.43	52.81	42.34	
4.5	6.96	16.37	31.32	
4.5	7.34	170.43	33.03	
4.5	9.04	56.39	40.68	
4.51	9.95	44.55	44.87	
4.51	10.43	41.83	47.04	
4.51	6.7	25.8	30.22	
4.55	12.93	46.21	58.83	
4.57	10.13	56.69	46.29	
4.65	9.09	54.46	42.27	
4.67	12.2	40.13	56.97	
4.68	13.59	56.44	63.6	
4.69	7.84	45	36.77	
4.7	8.01	40.71	37.65	KIA-57414
4.7	7.23	42.81	33.98	
4.71	9.04	47.62	42.58	
4.73	15.25	43.79	72.13	
4.74	7.38	44.76	34.98	
4.74	5.24	138.44	24.84	
4.75	8.95	42.14	42.51	
4.75	10.44	42.69	49.59	
4.75	7.78	23.86	36.96	
4.79	9.6	177.42	45.98	

Width (m)	Length (m)	Angle (°)	Area (m ²)	Radiocarbon sample
4.8	7.84	27.62	37.63	KIA-57402
4.8	8.25	38.33	39.6	KIA-57398
4.84	8.88	48.26	42.98	
4.85	8.13	48.52	39.43	
4.85	11.14	111.35	54.03	
4.86	8.88	37.66	43.16	
4.86	7.77	61.78	37.76	
4.91	7.57	28.71	37.17	
4.91	7.45	43.52	36.58	
4.92	7.39	41.56	36.36	
4.94	7.68	45	37.94	
4.95	7.11	53.13	35.19	
4.95	6.42	54.82	31.78	
4.96	7.65	21.86	37.94	
4.98	10.56	40.82	52.59	
4.99	8.22	46.08	41.02	
4.99	10.69	43	53.34	
5	8.55	19.63	42.75	
5.02	8	25.22	40.16	
5.03	7.15	11.73	35.96	
5.03	9.89	51	49.75	
5.03	12.74	41.27	64.08	
5.05	9.93	40.24	50.15	
5.06	10.97	54.1	55.51	
5.07	10.74	58.88	54.45	
5.07	11.33	47.85	57.44	
5.07	13	8.53	65.91	
5.08	8.06	34.57	40.94	
5.08	9.09	46.49	46.18	
5.08	7.77	55.62	39.47	
5.09	10.48	57.11	53.34	
5.09	10.4	19.65	52.94	
5.14	8.68	34.48	44.62	
5.14	8.8	42.57	45.23	
5.15	7.9	48.24	40.69	
5.16	8.52	58.78	43.96	
5.18	7.95	28.56	41.18	
5.18	6.6	33.64	34.19	
5.18	8.53	27.57	44.19	
5.19	10.23	42.18	53.09	
5.21	10.43	31.26	54.34	
5.21	8.99	25.79	46.84	
5.22	7.23	44.41	37.74	

Width (m)	Length (m)	Angle (°)	Area (m ²)	Radiocarbon sample
5.22	8.63	51.08	45.05	
5.25	10.03	26.85	52.66	
5.27	13.49	47.72	71.09	
5.28	13.08	12.53	69.06	
5.29	8.13	136.59	43.01	
5.32	9.25	27.47	49.21	
5.32	10.58	63.37	56.29	
5.34	10.21	34.08	54.52	
5.35	9.37	49.32	50.13	
5.37	8.42	46.01	45.22	
5.37	11.56	31.48	62.08	
5.38	10.35	58.71	55.68	
5.38	6.74	30.65	36.26	
5.38	11.41	30.86	61.39	
5.38	14.95	43.14	80.43	
5.39	10.25	17.96	55.25	
5.39	7.16	3.93	38.59	
5.4	11.62	116.81	62.75	
5.4	7.51	15.04	40.55	
5.41	8.03	37.29	43.44	
5.42	9.57	3.56	51.87	
5.43	9.75	32.14	52.94	
5.43	9.82	33.27	53.32	
5.44	9.21	35.48	50.1	
5.44	8.12	42.04	44.17	KIA-57411; KIA-57412
5.45	8.92	56.02	48.61	
5.48	8.52	33.85	46.69	
5.48	10.04	28.18	55.02	
5.48	5.9	26.19	32.33	
5.55	13.31	17.57	73.87	
5.55	8.31	13.85	46.12	
5.55	8.6	24.16	47.73	
5.56	7.36	34.37	40.92	KIA-57406
5.57	8.12	37.78	45.23	
5.59	7.08	44.4	39.58	
5.59	8.68	27.5	48.52	KIA-57397
5.59	11.72	50.07	65.51	
5.61	11.15	22.2	62.55	
5.63	12.53	37.63	70.54	
5.65	10.06	46.29	56.84	
5.65	7.09	3.93	40.06	

Width (m)	Length (m)	Angle (°)	Area (m ²)	Radiocarbon sample
5.72	9.41	35.89	53.83	KIA-57394; KIA-57403
5.73	15.43	44.77	88.41	
5.74	10.5	43.17	60.27	
5.75	9.3	28.57	53.48	
5.77	7.35	143.47	42.41	
5.79	11.26	45.91	65.2	
5.8	11.86	35.35	68.79	
5.82	8.45	16.5	49.18	
5.83	9.82	125.72	57.25	
5.85	11.12	19.8	65.05	
5.85	12.01	40.52	70.26	
5.86	11.31	37.15	66.28	
5.86	10.14	138.28	59.42	
5.86	7.96	41.72	46.65	
5.87	7.17	51.75	42.09	
5.9	11.58	43.26	68.32	
5.9	15	40.88	88.5	KIA-57413; KIA-57529
5.92	8.26	1.48	48.9	
6	8.94	36.63	53.64	
6.02	8.62	36.07	51.89	
6.06	13.61	41.33	82.48	
6.08	9.36	45.9	56.91	KIA-57405
6.08	9.43	20.29	57.33	

Width (m)	Length (m)	Angle (°)	Area (m ²)	Radiocarbon sample
6.2	10.79	21.3	66.9	
6.22	13.49	45.36	83.91	
6.22	14.94	45.71	92.93	
6.28	16.05	39.2	100.79	
6.29	11.17	58.11	70.26	
6.31	7.8	126.48	49.22	
6.37	15.27	46.97	97.27	
6.39	8.45	52.39	54	
6.41	17.38	47.35	111.41	
6.42	16.31	44.94	104.71	
6.45	13.08	28.97	84.37	
6.47	9.54	40.79	61.72	
6.54	10.64	43.01	69.59	
6.54	7.04	16.19	46.04	
6.56	8.62	67.24	56.55	
6.56	11.06	49.47	72.55	
6.68	10.2	28.24	68.14	KIA-57404
6.74	13.75	60.34	92.68	
7.18	9.25	138.23	66.42	
7.34	16.83	58.93	123.53	
7.55	13.88	18.37	104.79	
7.82	14.19	178.66	110.97	
7.87	15.12	45.46	118.99	
8.3	10.96	36.3	90.97	

Tab. 3. House measures derived from the magnetic image of Opovo Ugar-Bajbuk. Here the minimal number of houses (180; most agreed on) are listed.

Min.	1 st Quartile	Median	Mean	3 rd Quartile	Max.
0.12	0.2	0.22	0.22	0.23	0.3

Tab. 4. Summary statistics of the 500 Monte Carlo simulations for potential Gini indices.

3. Ditch Volume

The volume of the ditches was calculated using two different scenarios, as the exact shape of the ditches is unknown due to the lack of extensive excavation data. Ditch measurements have been derived from drillings and the magnetic imaging (Tab. 5). In the first scenario, the ditches are assumed to have a rectangular shape, and the volume is calculated using the formula for a rectangular cuboid:

$$V = length * height * width$$

In the second scenario, the ditches are considered to have a triangular or V-shape, and the following volume formula is applied:

$$V = \frac{length * height * width}{2}$$

To estimate the labour required for digging, a rate of 1 cubic metre per person per day (8 hours) was used. This value is based on a review of labour costs for ditch digging conducted by Vinci, Vanzani 2025.

Ditch	Length (m)	Width (m)
a	1,100	5–10
b	990	5–11.5
c	560	4–8
d	260	3–4
e	230	3–6

Tab. 5. Length and width of the five ditches based on the magnetic image (see Fig. 3 of the main article).

4. Excavation Trench

Figure 14 illustrates the layout and specific location of the excavation trench dug during the 2024 field season. The trench, positioned based on prior survey data, measured approximately 16 m in length and 2 m in width. For the purpose of systematic excavation and precise documentation, the trench was subdivided into a grid of 2×2 m quadrants.

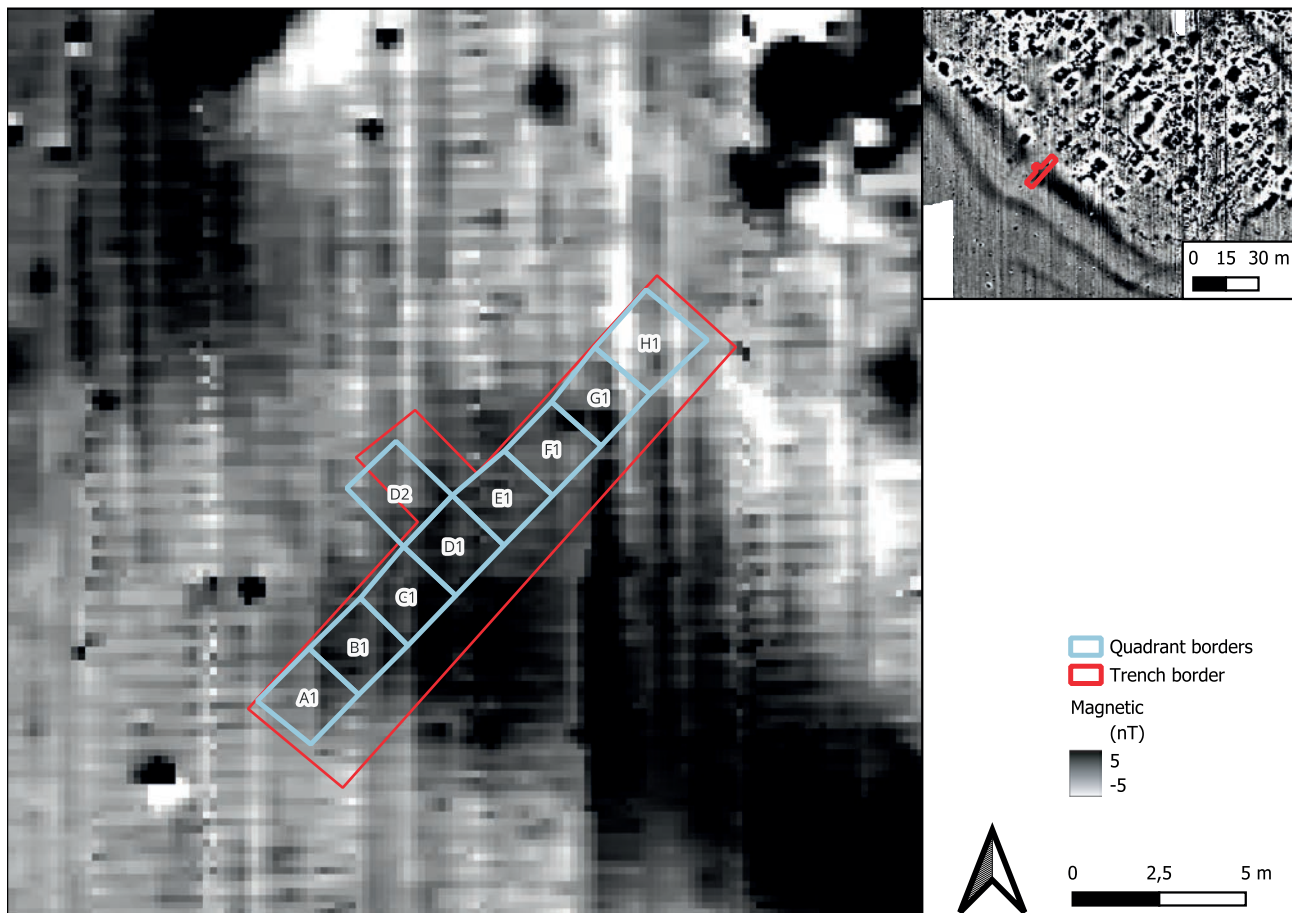


Fig. 14. Excavation trench of the 2024 excavation campaign.

5. Identification and Interpretation of Geomagnetic Anomalies

The magnetic survey results were interpreted with regard to house features and digitized by three team members. The final dataset used for analysis and figures was derived from these digitizations through discussion and comparison. Figures 15D and 16 show a high degree of overlap among the initial interpretations, and the general spatial density and distribution of houses was recognized similarly by all team members. Regarding the interpretation of rectangular anomalies with a raster value of

5–100 nT as houses, there are several examples from archaeological literature which support the interpretation as burnt buildings (Crnobrnja, Simić, Janković 2009; Hofmann et al. 2019; Perić, Miletić 2019; Corradini et al. 2025).

Vector- and raster-based approaches were applied to quantify overlap. Vector comparisons identified overlapping features, while rasterization allowed pixel-wise assessment of agreement. Across the study area, 56.2 % of pixels correspond to houses identified by all three interpreters, 27.6 % by two, and 16.2 % by one, indicating a high level of consistency in the spatial patterns. This analysis is not fully flexible to the fact that it is nearly impossible to achieve a pixel-perfect match for each identified house polygon; a certain fuzziness is therefore present, which can be attributed to small mismatches between polygons, while the same structures have been recognized. Although the identification of 180–220 houses is inherently subjective, the high level of consistency across interpretations indicates robust recognition of the main spatial patterns and house sizes used in further analyses.

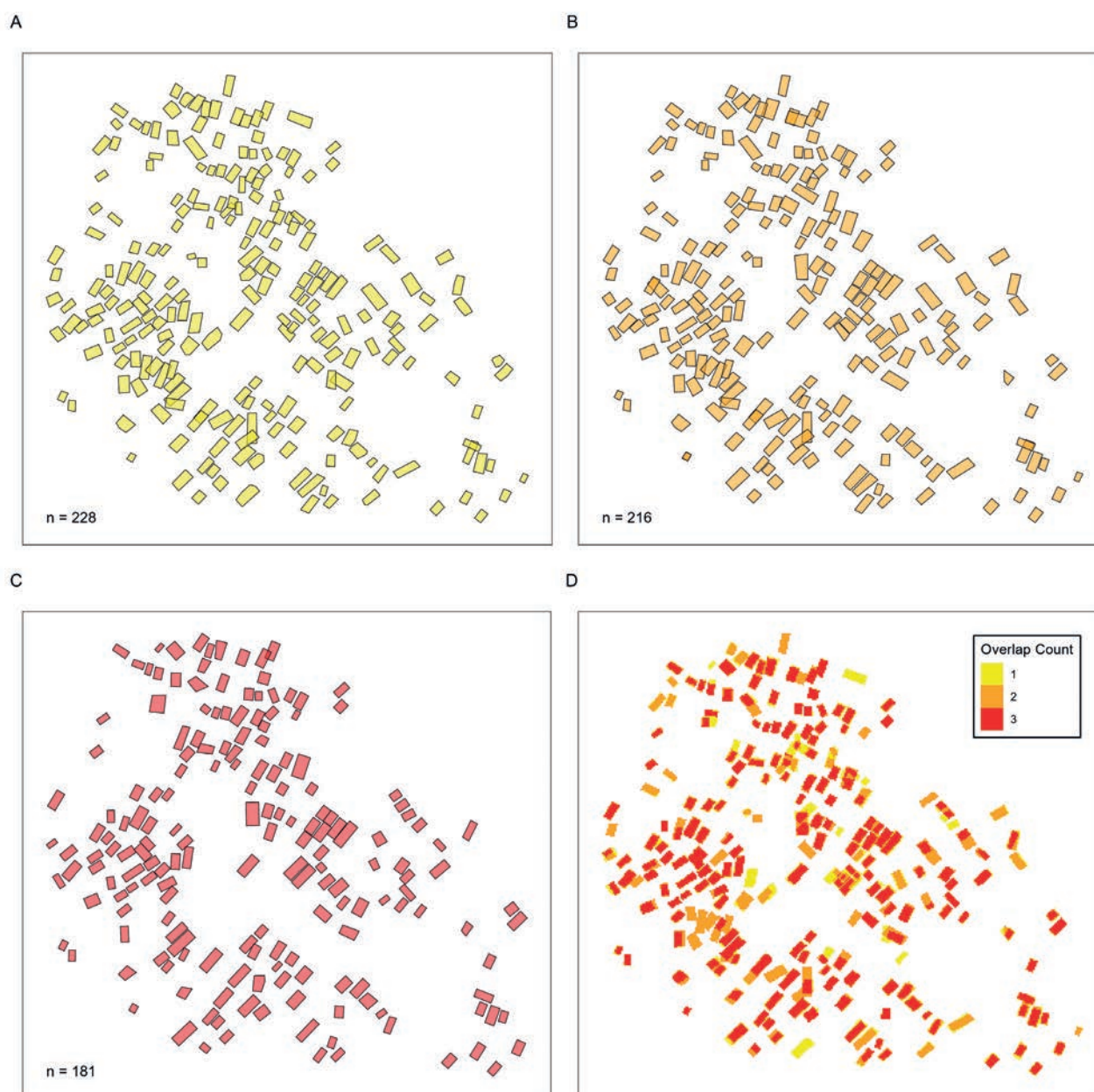


Fig. 15. House interpretations from the magnetic survey by interpreter 1 (A), 2 (B), and 3 (C). – D. Rasterized overlap showing areas identified by multiple interpreters: red = all three, orange = two, yellow = one.

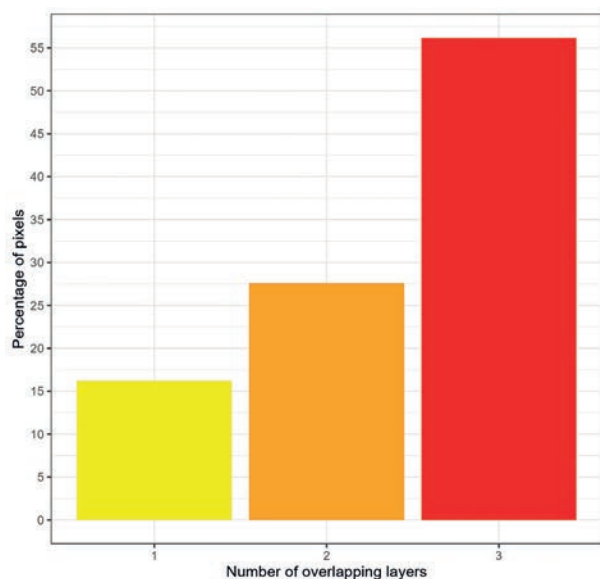


Fig. 16. Percentage of pixels corresponding to 1, 2, or 3 overlapping interpretations in the rasterized overlap map to illustrate the relative frequency of agreement among the digitizations.

6. Radiocarbon Model – Detailed Model Information

Figure 17 and Table 6 present the schematic structure of the radiocarbon model for Opovo. The stratigraphic information obtained from the drilling campaign could not be directly correlated with the specific building horizons documented in the original excavation records. Therefore, data from the drilling contexts and the earlier excavations have been integrated as parallel sequences within the Opovo I settlement phase. Samples from drilling contexts were ordered according to their stratigraphic depth.

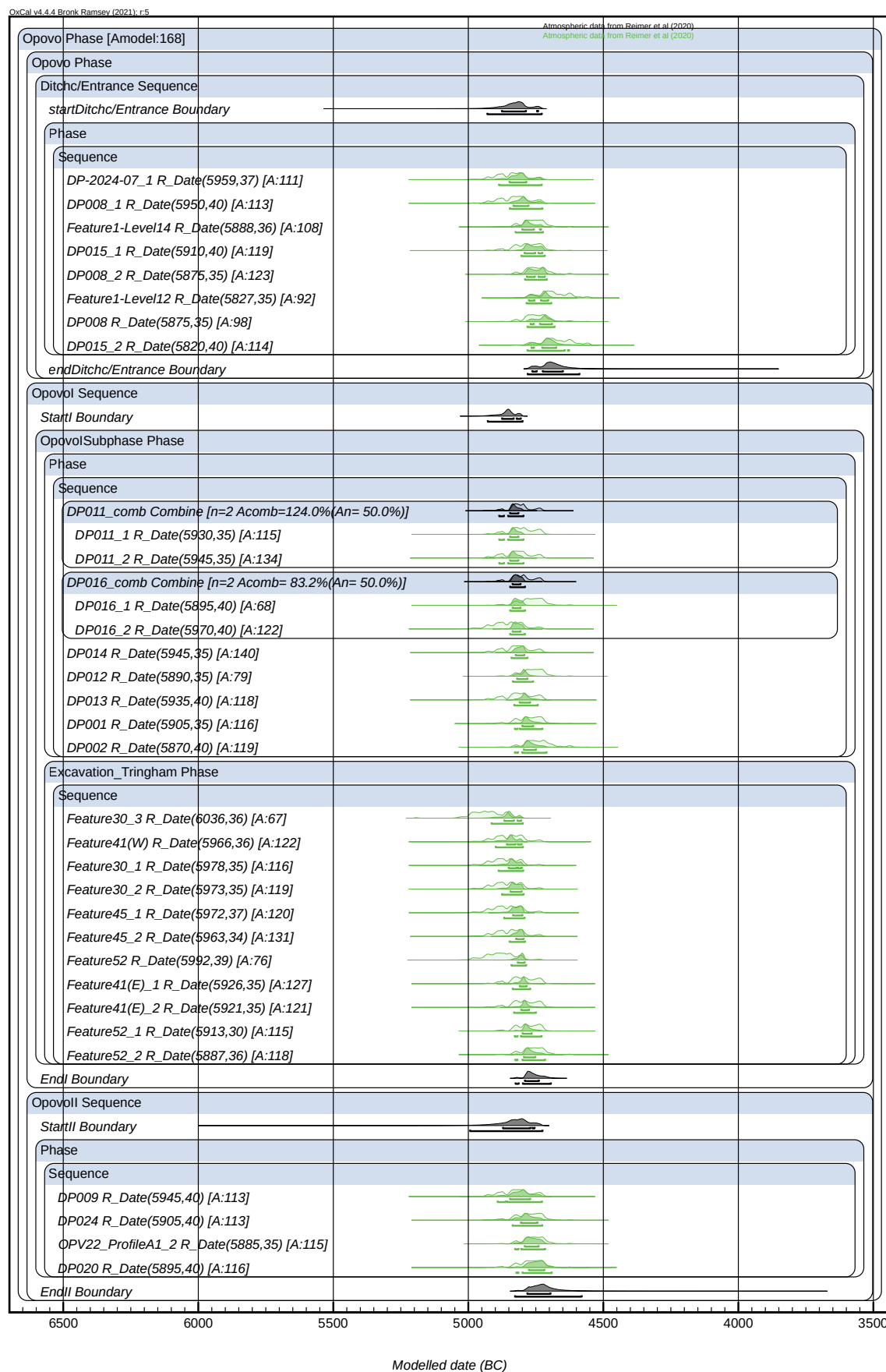
Seven radiocarbon determinations were excluded from the model as statistical outliers on the basis of poor agreement indices. These comprise one early measurement from the original excavations (Tringham et al. 1992) for which the sample preparation protocols are insufficiently documented. Two additional dates from feature 41 (Whittle et al. 2016; CAMS-4411 and CAMS-4413) were excluded, because this feature was attributed to both building horizon 2 and building horizon 3 in the excavation documentation, rendering its precise stratigraphic assignment ambiguous. Four recently obtained dates were likewise excluded as statistical outliers, potentially indicating the intrusion of residual or redeposited material resulting from post-depositional disturbance during drilling operations or earlier ground disturbance activities. Even when outlier modelling with increased tolerance was applied, these samples yielded an unsatisfactory model fit.

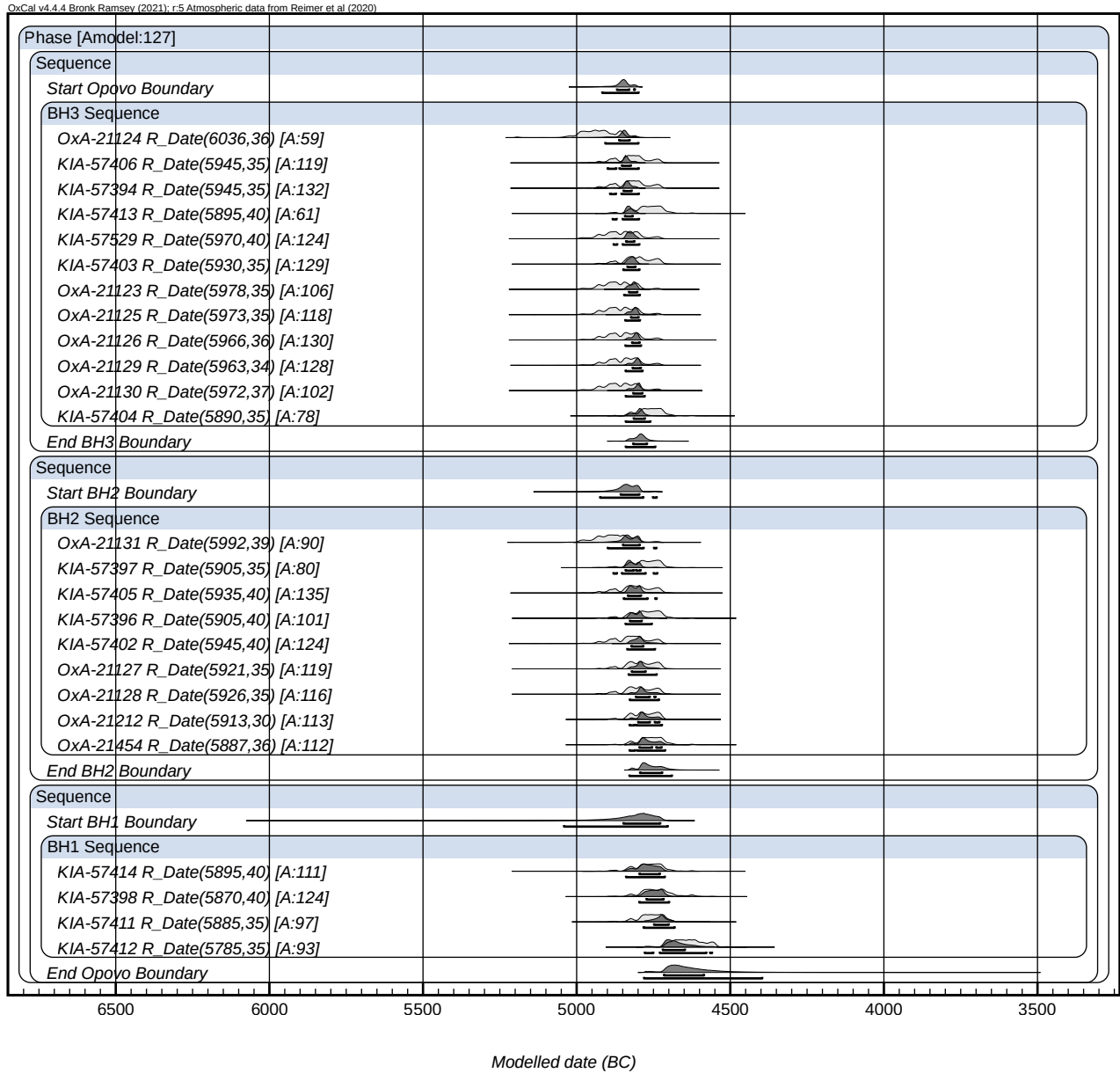
As discussed in the main article, distinguishing between in situ deposits and material affected by post-depositional processes remains challenging when working exclusively with drilling cores, where visual assessment of stratigraphic integrity and finer contextual information is limited.

In the model presented here, two spatial areas have been defined: Opovo I and Opovo II. Opovo I represents the initial settlement nucleus, while Opovo II marks a subsequent spatial expansion. The dates from the enclosure ditch have been positioned at the beginning of the occupational sequence, as alternative placements yielded lower agreement indices. Within each defined area, namely the ditch, Opovo I, and Opovo II, dates are modelled as sequences ordered by sample depth. Since absolute depth information was not available for the earlier dates derived from the excavations of Ruth Tringham, these determinations have been incorporated as a phase within Opovo I and ordered according to their respective building horizons. The OxCal code for this model is included in Appendix 2-1.

Several alternative model configurations were tested. These included: (1) a model based solely on the sample depth and building horizon stratigraphy, without consideration of the horizontal spatial position, and (2) models positioning the enclosure ditch dates at different points in the settlement's occupational sequence. The model presented here yielded the highest overall agreement index ($A_{\text{model}} = 168$; all individual agreement values $A > 60\%$) and is therefore considered the most robust representation of the site's chronological framework.

For the purpose of verification, one alternative model warrants brief discussion. In this configuration, all radiocarbon dates from the drillings were assigned to the three building horizons exclusively on the basis of depth, without regard to their horizontal position within the settlement (Fig. 18). The enclosure ditch was excluded from this model, as the ditch depth could not be meaningfully correlated with the building horizon sequence. This alternative model also produced an acceptable

Fig. 17. ^{14}C model of two proposed settlement areas of Opovo (for the areas, see Fig. 3 of the main article).

Fig. 18. Alternative ¹⁴C model based on stratigraphic depth.

Name	Modelled (BC/AD)				Indices Amodel 168.3 Aoverall 172	
	from_68_3	to_68_3	from_95_4	to_95_4	Acomb	Agreements
IntCal20 Curve						
Opovo Phase						
Ditch c/Entrance Sequence						
Start Ditch c/Entrance Boundary	-4876	-4742	-4930	-4729		
Phase						
Sequence						
DP-2024-07_1 R_Date(5959,37)	-4848	-4786	-4887	-4729		110.5
DP008_1 R_Date(5950,40)	-4833	-4778	-4847	-4726		113

Name	Modelled (BC/AD)				Indices Amodel 168.3 Aoverall 172	
	from_68_3	to_68_3	from_95_4	to_95_4	Acomb	Agreements
Feature1-Level14 R_Date(5888,36)	-4801	-4731	-4826	-4724		107.6
DP015_1 R_Date(5910,40)	-4792	-4727	-4804	-4717		119.3
DP008_2 R_Date(5875,35)	-4784	-4717	-4791	-4710		122.6
Feature1-Level12 R_Date(5827,35)	-4777	-4705	-4785	-4693		91.5
DP008 R_Date(5875,35)	-4770	-4691	-4782	-4681		98.1
DP015_2 R_Date(5820,40)	-4767	-4675	-4782	-4627		113.5
Ditch c/Entrance Interval	28	193	0	302		
End Ditch c/Entrance Boundary	-4764	-4650	-4781	-4589		
Opovo I Sequence						
Start I Boundary	-4876	-4806	-4929	-4800		
Opovo I Subphase Phase						
Phase						
Sequence						
DP011_comb Combine	-4846	-4815	-4886	-4796	124	
DP011_1 R_Date(5930,35)	-4846	-4815	-4886	-4796		115.2
DP011_2 R_Date(5945,35)	-4846	-4815	-4886	-4796		133.9
DP016_comb Combine	-4837	-4807	-4846	-4791	83.2	
DP016_1 R_Date(5895,40)	-4837	-4807	-4846	-4791		68.4
DP016_2 R_Date(5970,40)	-4837	-4807	-4846	-4791		121.9
DP014 R_Date(5945,35)	-4825	-4793	-4841	-4781		139.6
DP012 R_Date(5890,35)	-4820	-4782	-4836	-4761		78.7
DP013 R_Date(5935,40)	-4811	-4772	-4831	-4743		117.9
DP001 R_Date(5905,35)	-4801	-4760	-4828	-4726		115.8
DP002 R_Date(5870,40)	-4795	-4750	-4828	-4711		118.7
Excavation_Tringham Phase						
Sequence						
Feature30_3 R_Date(6036,36)	-4867	-4805	-4915	-4799		66.7
Feature41(W) R_Date(5966,36)	-4858	-4803	-4899	-4798		121.6
Feature30_1 R_Date(5978,35)	-4851	-4803	-4889	-4797		115.8
Feature30_2 R_Date(5973,35)	-4845	-4803	-4876	-4796		118.7
Feature45_1 R_Date(5972,37)	-4835	-4800	-4868	-4792		119.8
Feature45_2 R_Date(5963,34)	-4824	-4796	-4848	-4791		130.7
Feature52 R_Date(5992,39)	-4818	-4792	-4841	-4786		76
Feature41(E)_1 R_Date(5926,35)	-4810	-4785	-4836	-4771		126.8
Feature41(E)_2 R_Date(5921,35)	-4805	-4776	-4831	-4750		120.7
Feature52_1 R_Date(5913,30)	-4800	-4766	-4829	-4729		115
Feature52_2 R_Date(5887,36)	-4795	-4752	-4827	-4716		118.1
Duration I Interval	18	137	3	216		
EndI Boundary	-4791	-4739	-4826	-4695		
Opovo II Sequence						
Start II Boundary	-4872	-4755	-4994	-4726		

Name	Modelled (BC/AD)				Indices Amodel 168.3 Aoverall 172	
	from_68_3	to_68_3	from_95_4	to_95_4	Acomb	Agreements
Phase						
Sequence						
DP009 R_Date(5945,40)	-4846	-4771	-4892	-4728		112.7
DP024 R_Date(5905,40)	-4806	-4744	-4837	-4727		113.2
OPV22_ProfileA1_2 R_Date(5885,35)	-4792	-4740	-4827	-4716		114.9
DP020 R_Date(5895,40)	-4776	-4719	-4823	-4692		116.1
Duration II Interval	0	142	0	381		
End II Boundary	-4782	-4696	-4828	-4581		
Duration Opovo Span	124	265	72	446		

Tab. 6. Detailed model results from OxCal of the model used in this study. The OxCal code is included in Appendix 2-1.

agreement index (Amodel = 127), though considerably lower than that of the preferred model. While it is not unexpected that a depth-based sequence generally produces a reasonable model fit, this result also implies the possibility that the entire settlement area was occupied from the outset rather than expanding outward from a central nucleus. Nevertheless, the interpretation of settlement development presented in this study follows the model with the highest agreement index, as it provides the strongest statistical support for the proposed chronological framework.

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