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Funerary Practices Among Central European First Farmers in the Light of New Radiocarbon Dates: The Case of Southern Moravia/Western Slovakia

Alba Masclans[1] · Peter Tóth[2] · Zdeněk Tvrdý[3] · Derek Hamilton[4] · Penny Bickle[5] · Marta Díaz-Zorita Bonilla[6,7] · Berta Morell-Rovira[8]

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Abstract
This paper examines the temporal dynamics of Linearbandkeramik (LBK) mortuary practices in south-eastern Czechia and western Slovakia, focusing on the emergence and development of funerary traditions. New radiocarbon dating of Moravian sites, including *Vedrovice* (with the large cemetery *Široká u lesa*, the settlement graves at *Sídliště,* and the small cluster of burials at *Za dvorem*), *Brno-Starý/Nový Lískovec*, *Těšetice-Kyjovice-Sutny*, as well as the Slovakian cemeteries of *Nitra-Horné Krškany* and *Nitra-Mlynárce* are presented and modelled. Our findings reveal that LBK mortuary practices were largely contemporaneous, beginning with the establishment of cemeteries, closely followed by settlement graves, and culminating in secondary deposition of bones and the transition to later Neolithic mortuary practices. The chronological framework aligns with existing models, indicating continuous LBK funerary practices in the timespan 5315–5035 cal BC, which underscores the influence of cultural exchange and migration from the Balkan–Anatolian area. Additionally, we identified temporal trends among individuals' lifeways and mortuary treatments, as well as significant patterns concerning the foundational burials of non-adults in settlement graves. This revised chronology provides a more reliable basis for future interpretative work based on accurate chronological attributions.

Keywords *Linearbandkeramik culture* · Radiocarbon dating · Funerary contexts · Early Neolithic · Bayesian modelling · Central Europe

Alba Masclans and Berta Morell-Rovira have contributed equally to this work.

Extended author information available on the last page of the article

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Introduction: An Overview of Chronological Trends in LBK Funerary Practices

The funerary practices of the *Linearbandkeramik* culture (LBK: c.5500–4900 cal BC) have been in the spotlight for decades thanks to the exceptional interpretative possibilities. This record has become the basis for a rich and detailed literature on social inferences involving the development of social hierarchies (Jeunesse, 1997; Van der Velde, 1979), mobility and dietary patterns (Bentley & Knipper, 2005), gender relationships (Augereau, 2022; Bickle, 2020; Masclans et al., 2021a), and kinship (Childebayeva et al., 2022; Gelabert et al., 2025).

LBK burials appear in at least five different contexts: settlement graves, cemeteries, small clusters of graves, mass murder sites, and multiple burials at enclosures (Hofmann & Orschiedt, 2015). These funerary practices generally involve primary inhumations, but cremation and secondary treatment of the body have also been found. In addition, isolated human bones recovered from domestic spaces and the fill of cemetery graves suggest the existence of further, less visible rites (Whittle et al., 2013).

The temporal attributions of various funerary practices have presented significant challenges for researchers investigating the LBK funerary record, primarily due to the persistent issue of a limited number of typologically identifiable graves. As a result, chronologies have traditionally been constructed based on general impressions of pottery styles and the assumption that different types of burials may or may not have coexisted. One key phase relevant to understanding these chronological challenges is the 'Flomborn period' (approximately between 5300 and 5000 cal BC). The term derives from the archaeological site of Flomborn (south-west Germany), and the phase is characterised by notable changes in material culture, including pottery styles with more complex linear decoration, as well as shifts in settlement patterns and subsistence strategies.

In Western LBK research, the term *Flombornisation* refers to the process by which the cultural traits associated with the Flomborn period—such as distinctive pottery styles, changes in settlement organisation, and evolving subsistence strategies—spread throughout the LBK sphere. Although this concept originates in the western LBK, it also refers to a broader social reorganisation believed to have occurred around 5300 cal BC, after the initial migration phase. This process reflects not just the spread of stylistic traits but also broader cultural transformations, including the emergence of new social and funerary practices. For instance, cemeteries are believed to have emerged around the Flomborn period, approximately 5300 cal BC, 200 years after the first settlement grave, with the Vedrovice cemetery marking the first appearance. Settlement burials are thought to have persisted throughout the duration of the LBK (Bickle & Whittle, 2013; Jeunesse, 1997).

However, recent research on the speed of the spread (Jakucs et al., 2016) challenged this view by proposing that the spread of the formative LBK took place later and was quicker, compressing the time for *flombornisation* and the development of cemeteries at 5300 cal BC. Following this line, assumptions about the temporal dynamics of the different funerary practices across Central Europe have been recently challenged by new radiocarbon data and statistical Bayesian analysis of LBK funerary contexts

from the south-western German area (Morell et al., 2025). The new results indicate that Early Neolithic cemeteries did not expand westwards from Vedrovice and thus do not follow an east–west progression from eastern to western Central Europe following the original expansion of the LBK, but appeared more simultaneously than previously considered. Additionally, the results demonstrated a high degree of temporal simultaneity between the different types of funerary contexts, including settlement burials, cemeteries and, the Herxheim enclosure.

These new results call into question the rates of change and the identification of potential synchronicities traditionally regarded as sequential based on pottery typological changes, a situation that it is not new as the application of large series of absolute dates often does not produce results in accordance with the existing ideas on the sequence of defined Neolithic typological groups (Hertelendi et al., 1995; Oross & Siklósi, 2012; Yerkes et al., 2009).

The new chronological trends also challenge sociological inferences and interpretative proposals based on previous temporal assumptions. For example, the interpretation that inherited hierarchies develop in the LBK's late phases (Jeunesse, 1997) is based on the assumption that there is an increase in the number of higher status burials through time. Likewise, the model suggesting that cemeteries were part of the broader flomborn regionalisation starting around 5300 cal BC—alongside changes in ceramic styles, potentially indicating a reorientation of networks from the first spread of the culture (Cladders et al., 2003)—also requires reconsideration. The updated evidence suggests that these developments may have occurred simultaneously rather than as sequential phases driven by cultural diffusion.

The observed chronological imprecision presents significant challenges to the robust testing of hypotheses derived from the analysis of the funerary record. This inaccuracy affects our critical understanding of whether differences within these communities, such as those found in the diet, mobility, and the distribution of grave goods, are contemporary implying social differentiation or represent change over time (Bickle & Whittle, 2013; Masclans et al., 2020, 2021b). For example, throughout the LBK lifeways project, Bickle and Whittle and their collaborators (2013) found differences suggesting individuals were sourcing their food from areas of different depths of canopy cover, but could not assess whether these were contemporary choices indicating dietary preference or due to progressive deforestation through time.

The regions of southern Moravia (Czechia) and western Slovakia offer a unique setting to refine LBK mortuary chronologies, test the contemporaneity of different burial practices, and reassess broader social interpretations of the Early Neolithic. This area contains some of the earliest Early Neolithic cemeteries, with radiocarbon evidence dating to c. 5300–5200 cal BC. It has been generally acknowledged that LBK cemeteries emerged relatively late compared to settlement graves, starting in the timespan 5300–5200 cal BC in Slovakia, coinciding with the *Notenkopf* phase (Pavúk, 2024). Radiocarbon dating programs established over the past decade have suggested that this timeframe represents the *terminus ante quem* for the spread of Neolithic cemeteries into Western Europe (Griffiths, 2013; Pettitt & Hedges, 2008; Stadler, 2015; Zvelebil & Pettitt, 2013).

Southern Moravia and western Slovakia display a wide range of funerary practices, including primary inhumations in settlement contexts, cemeteries, grave clusters, and

ditch structures, along with secondary bone treatments. Settlement graves—found both in isolation and near houses, often in lateral pits or other working areas—were dug into purpose-made pits or domestic features (Orschiedt, 1998; Veit, 1993). This kind of funerary tradition is found throughout the LBK area, from Hungary to the Paris Basin, and it has traditionally been considered the earliest burial practice within the LBK and persisted throughout the horizon's duration.

Single or double inhumation in large cemeteries represents the largest percentage of burials known from the LBK (Jeunesse, 1997). Similarly, single or double inhumation in small clusters of graves within settlements is common within the LBK contexts (Jeunesse, 1997). They usually appear associated with longhouses, but apart from the dwellings' lateral pits, though in some cases the burial is in the loam pit. Finally, isolated human bones found either in domestic spaces or within the graves' fill in cemeteries have also been identified, indicating secondary treatment of the bodies was also likely widely practised in the LBK.

Because the LBK funerary record in this region is both extensive and well-studied, it offers an excellent framework for testing hypotheses on rates of change and possible synchronicities in burial traditions during the first farmers' migrations. To date, 107 funerary sites containing 587 burials have been identified in southern Moravia and western Slovakia (Table 1). In this study, we present 37 new radiocarbon determinations from 37 LBK individuals. Combined with previously dated inhumations, this dataset comprises 161 radiocarbon-dated burials—27% of the total record. Such coverage allows for more robust Bayesian modelling, refining the chronology of burials and integrating them into ceramic sequences and broader cultural developments.

With this new dataset, together with the existing corpus of radiocarbon dates, our study aims to refine LBK funerary chronologies in this region by addressing three key aspects: (1) the internal chronology of individual sites; (2) the temporal trends in demographics, lifeways, and the distribution of grave goods; and, (3) the regional dynamics of funerary practices across south-eastern Moravia and western Slovakia.

Materials: The South-Eastern Czechia/Western Slovakia Funerary Contexts

Radiocarbon Dates

A total of 43 new human bone samples were selected, corresponding to 43 individuals found in 42 different burials: 3 from *Těšetice-Kyjovice-Sutny* (Znojmo District), 14 from *Vedrovice* (including 5 from *Sídliště* and 9 from *Za dvorem*) (Znojmo Dis-

Table 1 LBK burial count in the Moravia and western Slovakia area

	Cemetery/ Cluster sites	Cemetery/ Cluster burials	Settlement sites	Settlement burials	Isolated sites	Isolated burials
Moravia	6	208	48	105	15	17
Slovakia	6	98	23	151	8	8

trict), 1 more from *Brno-Starý Lískovec/Nový Lískovec* (Brno District), 3 from *Nitra-Mlynárce* and 22 from the cemetery of *Nitra-Horné Krškany* (Nitra District) (SI-1, Table 1) (Fig. 1). Five samples failed during laboratory procedures (see SI-1, Table 1) and one more was discarded because it did not belong to the LBK (see SI-2). Consequently, the models were performed with a total of 266 radiocarbon dates, of which 37 are new determinations presented here, while the remainder correspond to previously published dates from the same sites (see SI-1, Table 2) as well as other funerary and domestic contexts in Moravia and western Slovakia (see SI-1, Table 4).

The Main Characteristics of the Selected Sites

Our sample selection includes sites displaying settlement graves, cemeteries, and grave clusters. The LBK site of *Vedrovice* (Znojmo District) is located in southern Moravia at the base of the Bohemian Massif, between the rivers Dyje (south) and Jihlava (north). *Vedrovice* contains two sites: *Za dvorem* and *Široká u lesa,* which include a settlement area displaying burials (*Široká u lesa-Sídliště*), and the cemetery (*Pohřebiště I*).

At *Za dvorem* ditches as well as a rondel dated to the Late Neolithic were identified, with 5 burials in settlement pits (1/85, 3/86, 11/97, 12/96, 13/97) and 9 graves (2/85, 5/88, 6/88, 7/88, 8/88, 9/88, 10/89, 14/97) belonging to the small cemetery/grave cluster (*Pohřebiště II*) dated to the LBK (Fig. 2). At least 9 more graves that

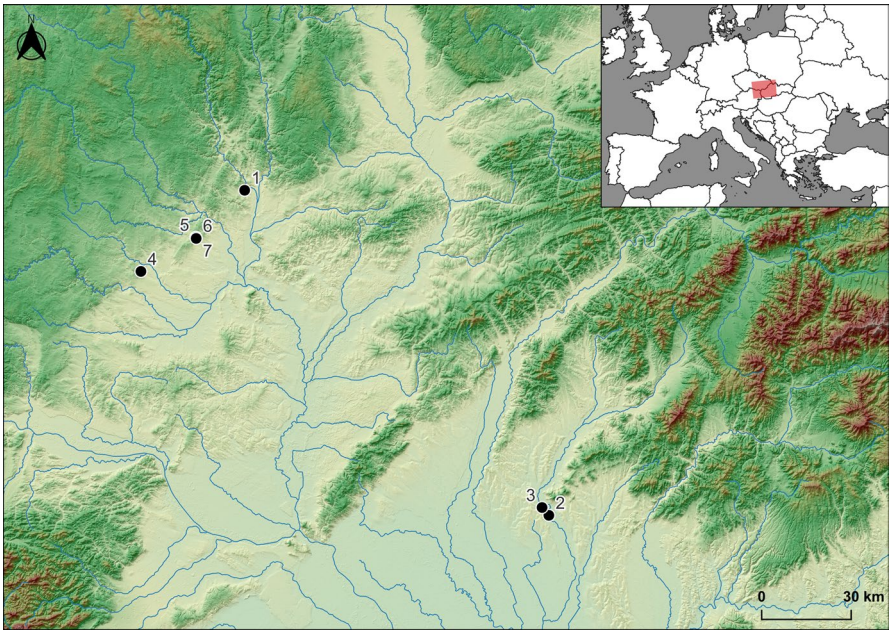

Fig. 1 Map displaying the sites included in the analysis: 1. Brno-Starý/Nový Lískovec, 2. Nitra-Horné Krškany, Priemyselná ulica, 3. Nitra-Mlynárce, železničná stanica, 4. Těšetice-Kyjovice-Sutny, 5. Vedrovice-Široká u lesa, pohřebiště, 6. Vedrovice-Široká u lesa, sídliště, 7. Vedrovice-Za dvorem. Map source: raster data from CIAT-CSI SRTM, vector data from Natural Earth Data

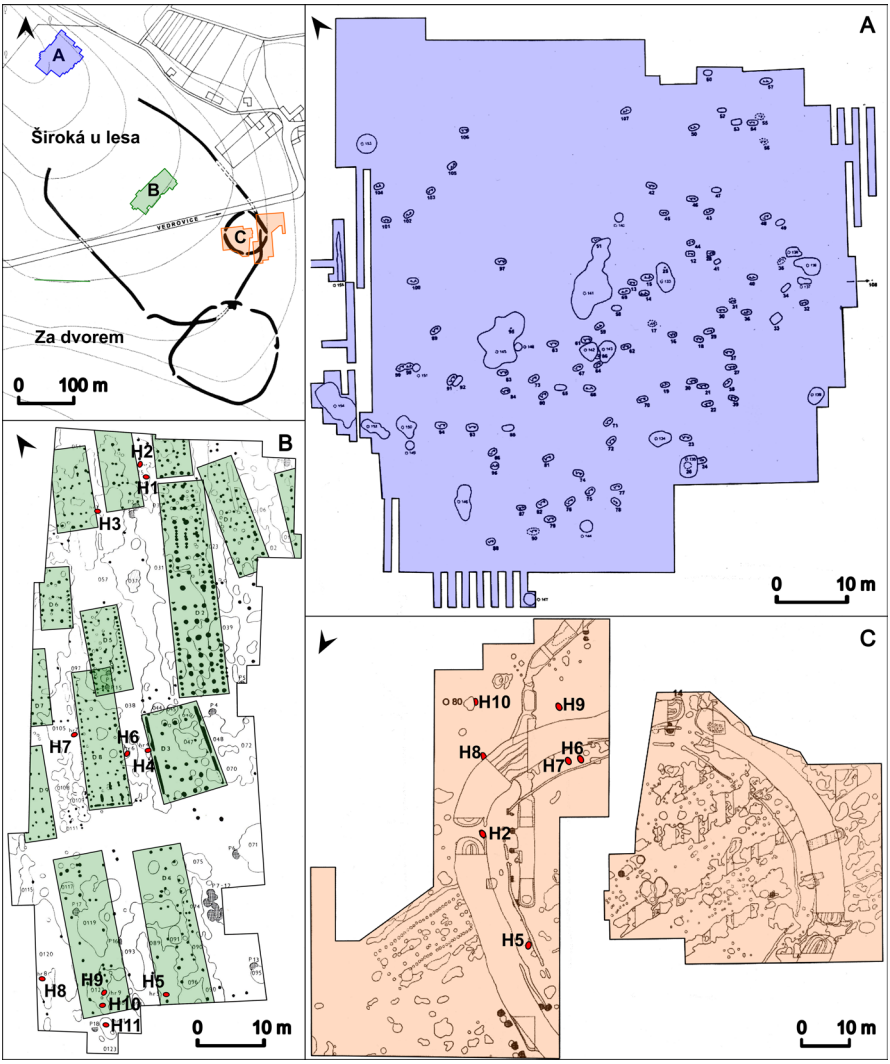

Fig. 2 Vedrovice general plan and sectors including the settlement (*Sídliště*), the grave cluster (*Za Dvorem*), and the cemetery (*Široká u lesa*). **A** Široká u lesa, pohřebiště I (cemetery I); **B** Široká u lesa, sídliště (settlement); **C** Za dvorem, pohřebiště II (cemetery II).
Adapted from Podborský (2002)

probably belonged to this cemetery were excavated in 1910–1911 in *Vinklerova cihelna* (Vinkler´s brickyard) nearby, but the skeletons were not collected. In order to follow the nomenclature present in the bibliography, we will call *Vedrovice-Široká u lesa* the cemetery, and *Vedrovice-Sídliště* the settlement graves.

According to the grave descriptions, 97 preserved burials have been identified at *Široká u lesa*, and at least 12 more graves from 19th-century excavations were identified during modern works (Podborský, 2002). However, the anthropological remains from the 19th-century excavations are not known, and only some of the associated

archaeological materials are available. The only evidence we have comes from the records of the excavations carried out between the 1960s and 1980s, which revealed empty burial structures. For our analysis, we focused exclusively on burials at *Široká u lesa* with well-preserved contexts, totalling 85. Additionally, we included 11 burials from *Sídliště* (Dočkalová & Čižmář, 2007, 2008; Ondruš, 1972; Smrčka et al., 2005), and 13 from *Za dvorem* (Berkovec et al., 2004; Dočkalová & Čižmář, 2007, 2008; Podborský, 2002).

Based on the contextual information found in Podborský (2002), we excluded 13 burials from our analysis due to preservation issues, resulting in a total of 86 individuals distributed across 84 graves. Burial 9/74 from *Sídliště* was also excluded from the analysis after being radiocarbon dated by our project (see SI-1, Table 1) because its radiocarbon date proved to be much more recent than the rest of the burials (4193 BP). In total, the Vedrovice grave assemblage comprises 109 individuals (SI-1, Table 3). The chronological attribution of the *Vedrovice* cemetery (*Široká u lesa*) is presently supported by radiocarbon dating of 42% of the grave chronologically distributed between 5315–5224 cal BC and 5215–5110 cal BC (*95.4%*, all probability ranges in this work will be at *95.4%* unless otherwise stated) (Masclans et al., 2021b; Pettitt & Hedges, 2008). Finally, 4 out of 10 graves from *Sídliště* had been previously radiocarbon dated before our study (Trampota & Pajdla, 2022) while *Za dvorem* had never been radiocarbon dated.

Brno-Starý/Nový Lískovec (Brno District) is an enclosed LBK multi-phase settlement located on the Bohunice plateau, on the southern outskirts of Brno (Berkovec et al., 2004; Přichystal, 2008). According to the grave descriptions, there are a total of 12 settlement graves (Dočkalová & Čižmář, 2007, 2008) distributed between the LBK dwellings (SI-1, Table 3, Fig. 3), and a total of 7 out of 12 have been radiocarbon dated (Vostrovská et al., 2021).

The multi-phase site of *Těšetice-Kyjovice-Sutny* (Znojmo District) is located at the junction of the Bohemian Massif and the Carpathian area. The site includes an LBK settlement area with approximately 100 houses detected by geomagnetic survey, out of which 17 longhouses were excavated (Milo, 2013; Tóth et al., 2020; Vostrovská, 2018), along with a small grave cluster located in the north-east part of the settlement consisting of 9 graves. Additionally, 4 isolated burials were found among the Neolithic dwellings (Fig. 4) (SI-1, Table 3) (Dočkalová, 2006; Dočkalová & Čižmář, 2007, 2008). From this number, a total of 9 graves were radiocarbon dated and calibrated to between 5266–5103 cal BC and 5216–5048 cal BC (with 68.2% probability; Vostrovská, 2018).

The Slovakian cemetery of *Nitra-Horné Krškany, Priemyselná ulica* (henceforth *Nitra-Horné Krškany*) is situated in western Slovakia on the border of the Carpathian Mountains and the Danube Plain, where 74 burials and 8 piles of cremated bones have been identified (Fig. 5). A total of 67 burial structures and 70 individuals were included in this study according to Pavúk's database (1972) and after excluding unreliable graves (SI-1, Table 3). Before our study, only 14% of the graves from *Nitra-Horné Krškany* had been dated (12 out of 76 burials, Griffiths, 2013), providing a chronological distribution between 5367–5219 cal BC and 5221–5029 cal BC (Masclans et al., 2021b).

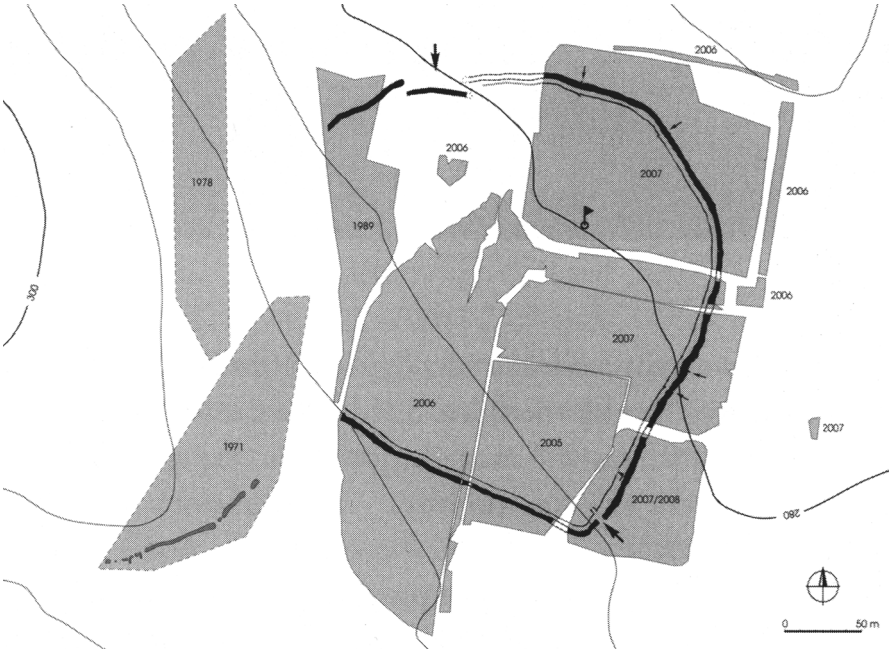

Fig. 3 Brno-Starý/Nový Lískovec plan according to Přichystal (2008), obr. 3

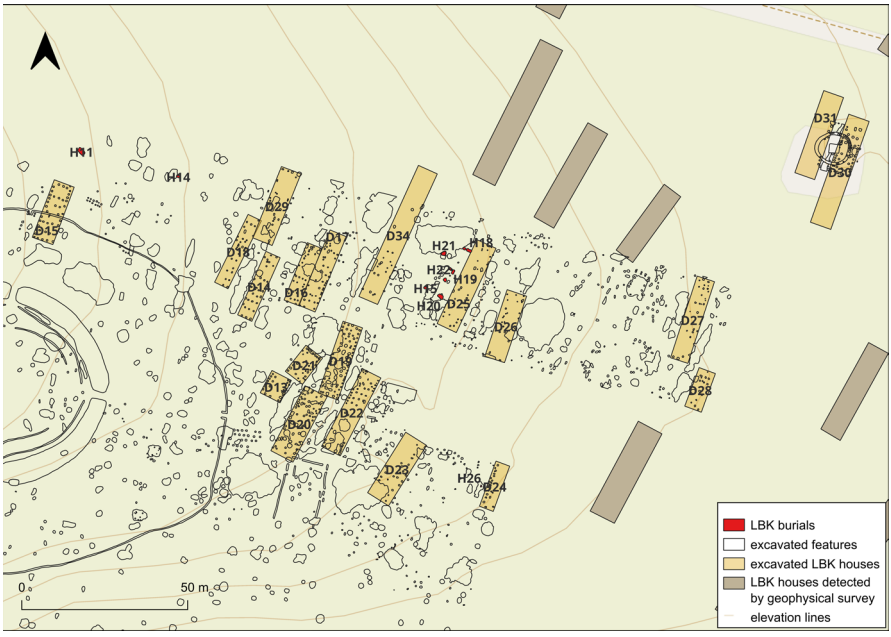

Fig. 4 *Těšetice-Kyjovice*—Sutny plan showing the spatial disposition of the buried individuals. Map source: Openstreetmap, Masaryk University, Vostrovská (2018)

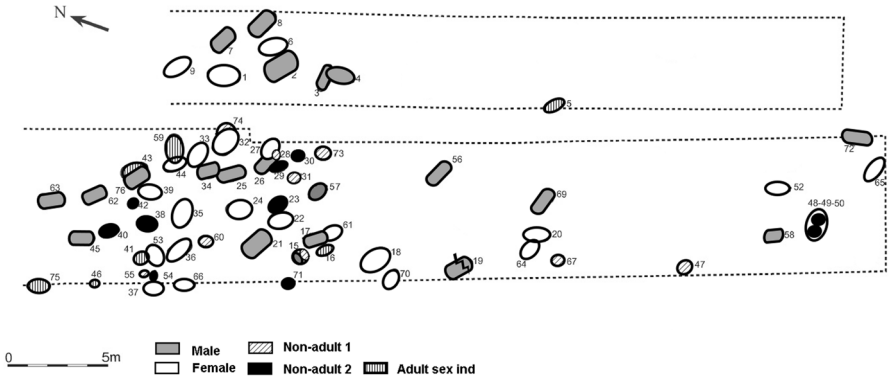

Fig. 5 *Nitra-Horné Krškany, Priemyselná ulica* plan showing the individuals' spatial organisation. Plan made by the authors, based on Pávuk's (1972) grave disposition and Tvrdý's (2016) sex determination

Finally, a small cluster of 9 graves was found at *Nitra-Mlynárce, železničná stanica* (henceforth *Nitra-Mlynárce*), 5 km from the cemetery at *Nitra-Horné Krškany*, Priemyselná ulica (Farkaš, 2002), containing the remains of 10 individuals (Fig. 6). According to the excavator (Plesl, 1952), the original number of graves could have been up to 20, but the context of their discovery is unclear according to the documentation. Human skeletal material from the site is deposited in Bratislava and Brno with unclear description. The anthropological analysis of the remains curated in the Moravian Museum in Brno identified the presence of 5 adults, 3 juveniles (15–19 years old), and 5–6 non-adults, totalling a minimum number of 13 individuals (SI-1, Table 3). Furthermore, some of the burials may belong to other periods, since the site has never been completely dated.

Demographic, Lifeway, and Grave-Goods Distribution Trends of the Selected Sites

The selected sites provide several striking demographic features (Table 2, more details at SI-1, Table 3). In the first place, female-sexed skeletons outnumber males at both *Nitra-Horné Krškany* and *Široká u lesa* cemeteries and the grave cluster *Za dvorem*. In contrast, males are dominant at the settlement graves of *Sídliště* and *Brno-Starý/Nový Lískovec*. At *Těšetice-Kyjovice-Sutny*, there are two males belonging to the small grave cluster and one male subjected to secondary treatment, whereas there are two females buried in isolated graves and one more was found among the grave cluster but displaying non-standard features, as the grave pit was filled in gradually, unlike the rest of the burials. The evidence for this non-standard burial comes from the weathering observed in the grave pit, suggesting that it was gradually infilled, in contrast to the other burials.

The other significant feature is the fact that non-adults are under-represented at both *Nitra* and *Široká u lesa* cemeteries, considering the infant mortality rate in the Neolithic is likely to have been about 40–50% (Rinne, 2001) (Table 1, more details at SI-1, Table 3). In contrast, adults and non-adults are more evenly distributed at sites such as *Brno-Starý/Nový Lískovec* (6 adults, 5 non-adults), *Za dvorem* (4 non-adults, 9 adults), *Těšetice-Kyjovice-Sutny* (6 non-adults, 6 adults) or are even dominant at

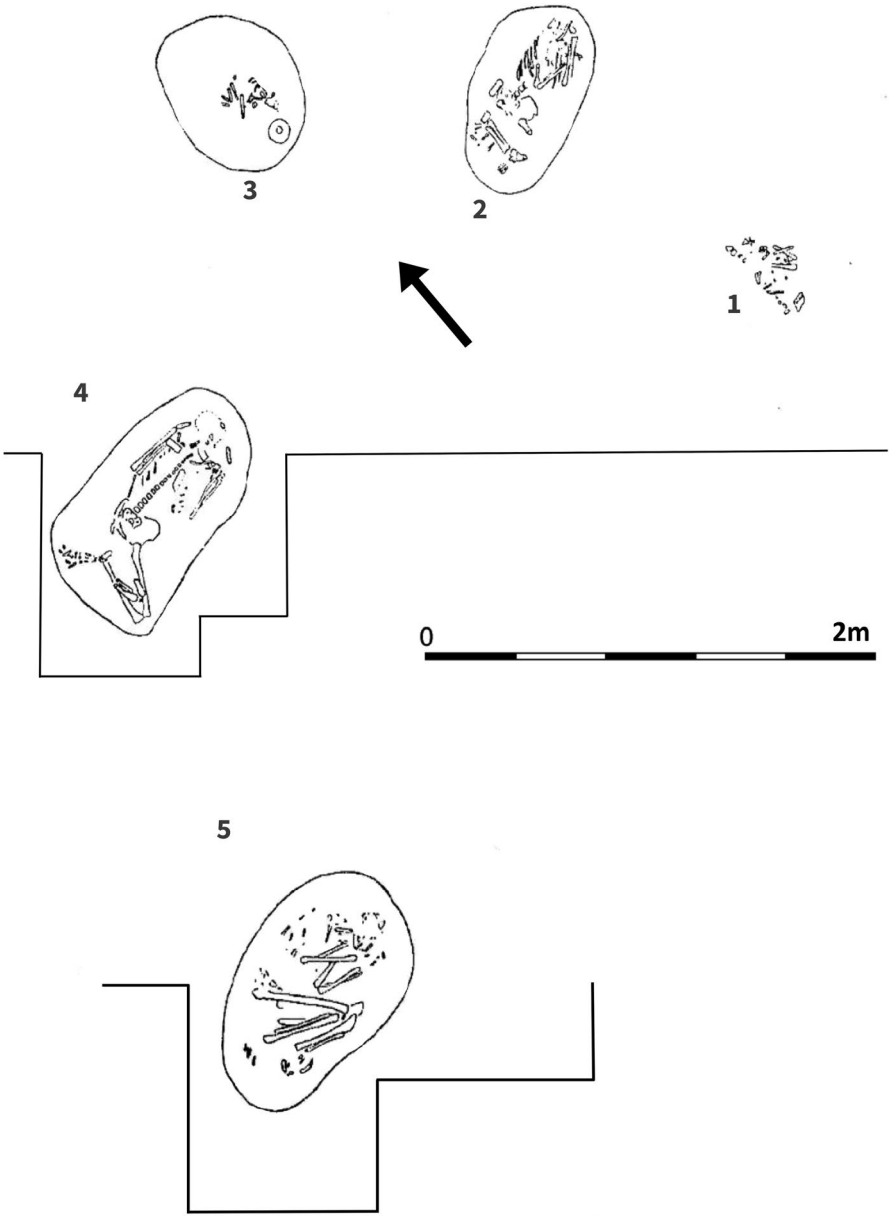

Fig. 6 *Nitra-Mlynárce, železničná stanica* plan showing the individuals' spatial organisation (modified after Plesl, 1952)

Sídliště (8 non-adults, 2 adults). Interestingly, the cases where the non-adult population is well represented are those where females do not outnumber males.

Recent strontium isotope ($^{87}Sr/^{86}Sr$) analysis performed on the same sites (Morell-Rovira et al., 2024) found that age and especially sex played a key role in the mobility patterns of the LBK Moravian and Slovakian communities. Adult females were more

Table 2 Eastern Moravia/western Slovakia sampled individuals' age and sex distribution by site

Site	Perinatal	NA 1	NA 2	JUV	YA	AM	AA	A IND
Široká u lesa	2	3	12	3F, 1 M, 4 IND	12F, 11 M, 1 IND	14F, 5 M	7F, 2 M	5F, 2 M, 2 IND
Sídliště	1	3	4			2 M		
Za dvorem		3	1	3F	1F, 2 M	1F	2F	
Těšetice-Kyjovice-Sutny		1	5	2 M	2F, 1 M	1F		
Brno-Starý/Nový Lískovec	1	3	1	2 M	1 M	2 M	1 M	1 IND
Nitra-Horné Krškany		8	10	3F, 2 M, 4 IND	8F, 2 M, 1 IND	8F, 10 M	7F, 5 M	1F, 2 IND
Nitra-Mlynárce		2–3	3–4	3 IND		2 M, 2F		1 IND

Age and sex ranges according to White et al. (2011) and Schaefer et al. (2009) criteria: Perinatal (birth to 3 months), Non-adult 1 (up to 3 years), Non-adult 2 (3–12 years), Juvenile (12–20 years), Young adult (20–35 years), Adult mature (35–50 years), Senile (+50 years)

NA = non-adult. JUV = juvenile. YA = young adult. AM = adult mature. AA = Advanced age. A IND = adult age indeterminate. F = female. M = male. IND = indeterminate

mobile than males, regardless of the funerary rites, indicating a heterogeneous patchwork of mobility patterns and challenging patrilocality, which to date is the current favoured explanation for female mobility within the LBK, as the only explanation for this phenomenon.

The diet of the studied sites, based on $\delta^{15}N$ variations, has also been addressed separately (Masclans et al., 2021a; Whittle et al., 2013). These studies indicate statistically significant differences between male and female individuals at Vedrovice cemetery (Masclans et al., 2020; Zvelebil & Pettitt, 2013). However, with the exception of the work by Jarošová and Tvrdý (2017) on dental microwear and carbon and nitrogen isotopic analysis in the cemeteries of *Vedrovice-Široká u lesa* and *Nitra-Horné Krškany*, no comparative analysis between sites has been conducted. The limited number of radiocarbon dates available has made it challenging to carry out a robust cross-site comparison, as it remains difficult to determine whether dietary variations among individuals are due to changes over time, differences in social status, or site-specific variations.

Concerning the funerary rituals and body treatment, primary inhumations generally involve oval pits dug directly in the ground, where the bodies are often placed in a flexed position on their left side. Body position is generally more variable among settlement graves than in cemeteries, with right-flexed, supine, prone and, more irregular positions also documented. Specifically, while 85% of cemetery burials are left-flexed, this position is found in 58% of settlement burials and 92% of small grave clusters (SI-1, Table 3). This is a pattern found for the LBK area as a whole (Hedges et al., 2013). Orientation variations are also more diverse at settlement burials than in cemeteries. Thus overall, the archaeological record shows that individuals buried in cemeteries were more normative compared to those buried in other contexts (Hofmann, 2009).

Similarly, presence/absence of grave goods tends to differ between settlement graves and cemetery burials, with a higher frequency of furnished graves among cemeteries (65%) and small clusters of graves (70%), compared to settlement graves where only 48% are furnished. The distribution of grave goods among cemetery graves has been addressed from several perspectives, consistently highlighting their correlation with age and gender (Augereau, 2022; Bickle, 2020; Masclans et al., 2021a, 2021b). Indeed, multivariate analysis shows a strong correlation between biological sex, grave goods assemblages, diet and mobility, particularly evident in the case of *Vedrovice-Široká u Lesa* (Masclans et al., 2021a, 2021b).

However, all these observed trends need to be re-examined to determine if they can be attributed to chronological factors. In other words, it is essential to test whether time can explain the varying distributions of age, sex, body disposition, and grave goods. Current interpretations of these phenomena often assume implicitly that diet and mobility patterns remain static and persist throughout the entire duration of the cemetery. This overlooks the chronological nuances necessary to explore changes over time within the cemetery population.

Methods

Methods

Details of both sampling criteria and methods can be consulted at SI-2. For specifics on chemical pre-treatment, target preparation, and AMS measurement, refer to Bronk Ramsey et al. (2004) and Brock et al. (2010). Collagen yields for carbon and nitrogen are provided in SI-1, Table 1. Isotopic values of $\delta^{13}C$ and $\delta^{15}N$ on human and animal bones indicate a predominantly terrestrial and homogeneous diet of these communities based on the consumption of C_3 plants and limited protein intake (see SI-2) (Katzenberg & Krouse, 1989; Schoeninger & DeNiro, 1984).

Due to the absence of archaeological data enabling the modelling of detailed site chronologies, such as stratigraphic relationships or kinship information, a single-bounded phase Bayesian model was used to provide an understanding of the overall chronology of the burial activities (see Hamilton & Kenney, 2015 for further discussion of this most basic model type). This was conducted using the OxCal v.4.4 software (Bronk Ramsey, 2001, 2009) and the IntCal20 calibration curve (Reimer et al., 2020). The use of pottery seriation to group the radiocarbon results was discarded for two reasons. First, only a small number of the vessels deposited as grave goods displayed chronological-diagnostic decorations, as also observed at sites such as Aiterhofen (Hofmann et al., 2013) and Schwetzingen (Gerling, 2012). Second, establishing correlations between archaeological materials and ^{14}C dates at a regional scale lies beyond the scope of this paper. Typo-chronological seriation in the area remains sporadic and has only been correlated with radiocarbon evidence in isolated cases (Trampota & Květina, 2020). For this reason, ceramic seriation was not employed as a prior in our Bayesian models. Nevertheless, in the Discussion we compare the radiocarbon results with existing ceramic typochronologies in order to evaluate the extent to which the independent absolute chronology converges with—or departs from—traditional typological sequences.

Finally, to check if the variability found in funerary practices, mobility or diet, on which LBK social models rest, represents change over time or rather contemporary differences, several single-bounded phase Bayesian models were performed. When the models suggested chronological trends among the categories, the events were integrated into an 'order' parameter. This process involved using priors from earlier models, which were then incorporated into the 'order' parameter, replacing existing dates.

Simulating Radiocarbon Data and Chronologies

LBK radiocarbon dates must be interpreted in the context of their placement on the calibration curve (*c.* 5300–5000 cal BC), where a notable wiggle occurs around 5300–5200 cal BC, followed by a plateau, extending 5200–5000 cal BC. The overall shape of the plateau curve shape, highlighted by Weninger (2020), can produce strongly bi-modal posterior distributions.

As the modelled radiocarbon dates appear to group between the wiggle and the plateau there appeared the possibility that they could be a result of, or at least very

strongly affected by, the shape of the curve, and not a reflection of the actual chronology of the dated activity.

For this reason, we conducted 20 simulation models (*R_Simulate*) structured identically to our data-based models and using the same number of radiocarbon dates from each analysed site. These dates were uniformly distributed between the approximate midpoints of the 95% probability ranges established in our initial models, following the procedures proposed by Meadows et al. (2020). This approach allowed us to assess the potential distortions caused by the calibration curve and adjust our interpretations accordingly. By comparing the simulation outcomes with the actual data-based models, we can evaluate the extent to which the wiggle and plateau in the calibration curve might influence our results (see SI-3 for the full results).

Site-Specific Results

Brno-Starý Lískovec/Nový Lískovec

At *Brno-Starý/Nový Lískovec* the single-bounded phase Bayesian model suggests that all the dated individuals belong to a continuous phase lasting 25–360 years: *5530–5225/5270–4865* cal BC (*Amodel. 93* and *Aoverall 92.1*) (Fig. 7). The results

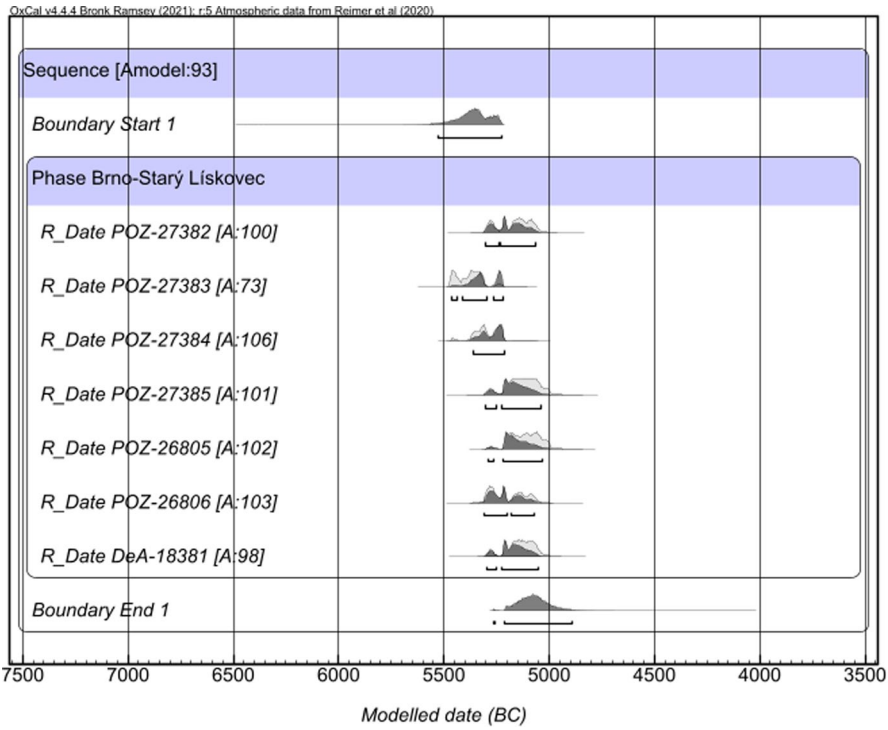

Fig. 7 Single-bounded phase Bayesian modelling of the available radiocarbon dates of *Brno-Starý/Nový Lískovec*

align with the 20 simulations performed (SI-3.1), with the start and end intervals in most cases falling within the site's probability intervals.

To test if adult and non-adult burials belong to different chronological distributions, a single-bounded phase model followed by an order parameter was implemented. The results indicate that the burials of non-adult individuals (graves 801 and 802) are significantly earlier (*5475–5460/5235–5215 cal BC*) than those of adults (*5340–5070/5210–4940 cal BC*, SI-4.1, Table 1). The non-adult burials were not only significantly older than the rest, but they also presented different characteristics. For example, they were the only ones containing *Lithoglyphus* shells and stone beads among their grave goods, and they were located in areas not directly associated with dwellings.

Těšetice-Kyjovice-Sutny

At *Těšetice-Kyjovice-Sutny*, the single-bounded phase model suggests a chronological distribution between *5245–5080/5165–5010 cal BC* (*Amodel. 105.2* and *Aoverall. 105.9*) with a span of use of *0–135 years* (Fig. 8). The timeline proposed by the model

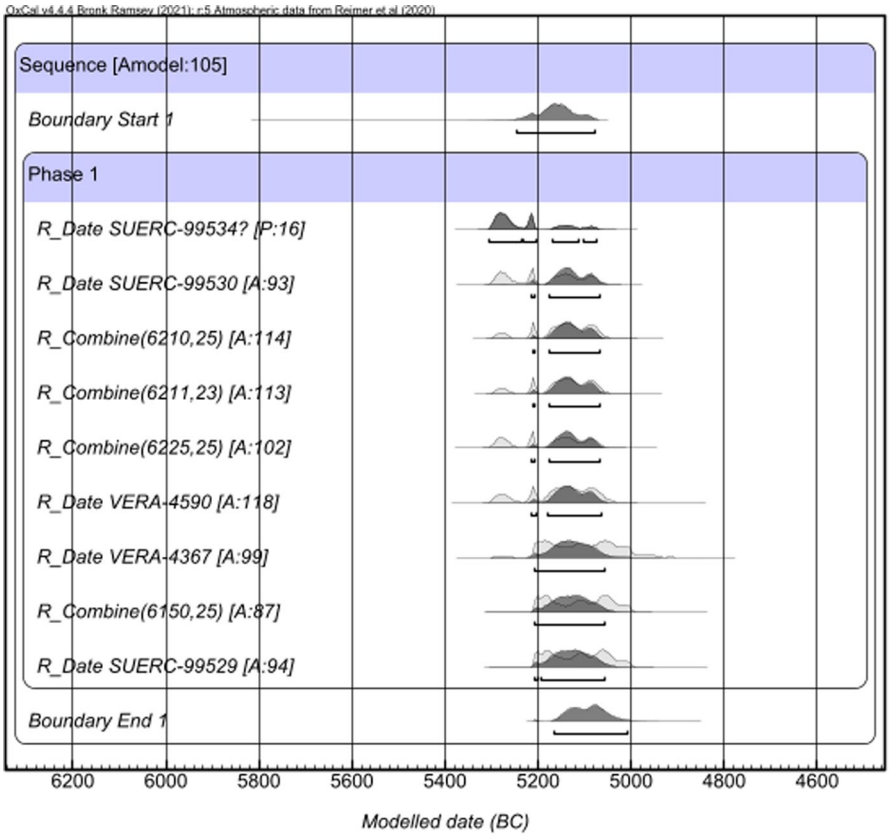

Fig. 8 Single-bounded phase Bayesian modelling of the available radiocarbon dates from *Těšetice-Kyjovice—Sutny*

aligns with the simulations conducted, displaying very similar posterior probabilities for the start and end of burial activity and the overall span (SI-3.2).

The burial 23/92, corresponding to a non-adult individual from to the grave cluster, is older than the other graves of the site (A = 39.7%). This follows the pattern observed at *Brno-Starý/Nový Lískovec*, where non-adults were buried in the early stages of funerary occupation.

To test whether the graves from the small grave cluster and the isolated graves belong to different chronological distributions, a single-bounded phase model followed by an order parameter was accomplished. The data indicate a first occasional funerary occupation of the site where a child was buried (*5302–5072 cal BC*, grave 23/92). This was followed by a second occupation, during which the grave cluster was formed around the first non-adult individual's grave (*5290–5125 cal BC*) (SI-4.1, Table 2). Finally, in the third phase, the last burial within the grave cluster was performed, and two additional graves (11/86 and 26/2006) were made, scattered among the buildings (5210–5070 cal BC).

Vedrovice

In the case of *Vedrovice*'s funerary practices (including *Široká u lesa* cemetery, *Za dvorem* cluster, and *Sídliště*'s settlement graves), there was a continuous occupation lasting between *5325–5265/5165–5045 cal BC*, with a span of *113–260 years* (*Amodel 102.8 and Aoverall 99.1*).

Single-bounded phase Bayesian modelling suggested that the oldest and shortest occupation was represented by the small cluster of burials at *Za dvorem* (Fig. 9), dating between *5375–5130/5285–5000 cal BC* with a span of *0–220 years* (*Amodel 101.4 and Aoverall 101.4*, and good convergence according to the C values). This was followed by the cemetery of *Široká u lesa,* dated between *5330–5270/5200–5040 cal BC* with a span of *85–250* (*Amodel 121.7 and Aoverall 12*), and the settlement burials of *Sídliště*, distributed between *5280–5065/5190–4920 cal BC*, with a span of *0–215 (Amodel 78.6 and Aoverall 75.6*) (Figs. 9, 10, and 11). For simulation results supporting the proposed chronology, see SI-3.3, SI-3.4 and, SI-3.5.

A single phase followed by an order model was performed to test the presence of different chronological distributions among Vedrovice-*Široká u lesa* individuals depending on the sex, age, mobility, diet, body orientation, grave goods distribution, including their presence/absence, as well as the presence of arrow points, *Spondylus* items, and stone adzes. According to our data, there were only temporal-based discontinuities in the case of the individuals' age and mobility patterns distribution, as well as in the presence/absence of projectile points (SI-4.1-Tables 3–17).

The presence of more mobile individuals started a bit earlier (*5460–5135 cal BC*, 90% probability) than the less mobile (*5310–5210 cal BC*), and lasted longer (*5290–4955 cal BC*, 80% probability) according to the 'order' parameter model. The model also indicates a 95% probability that senile and juvenile burials lasted longer (*5210–4830 cal BC* and *5200–4900 cal BC,* respectively) than both the burials of young adults (*5295–5090 cal BC*, 95% probability) and mature adults (*5295–5100 cal BC*, 94% probability). Finally, graves containing projectile points appear to start earlier (*5435–5210 cal BC*) than the ones without them (*5330–5210 cal BC*). This result

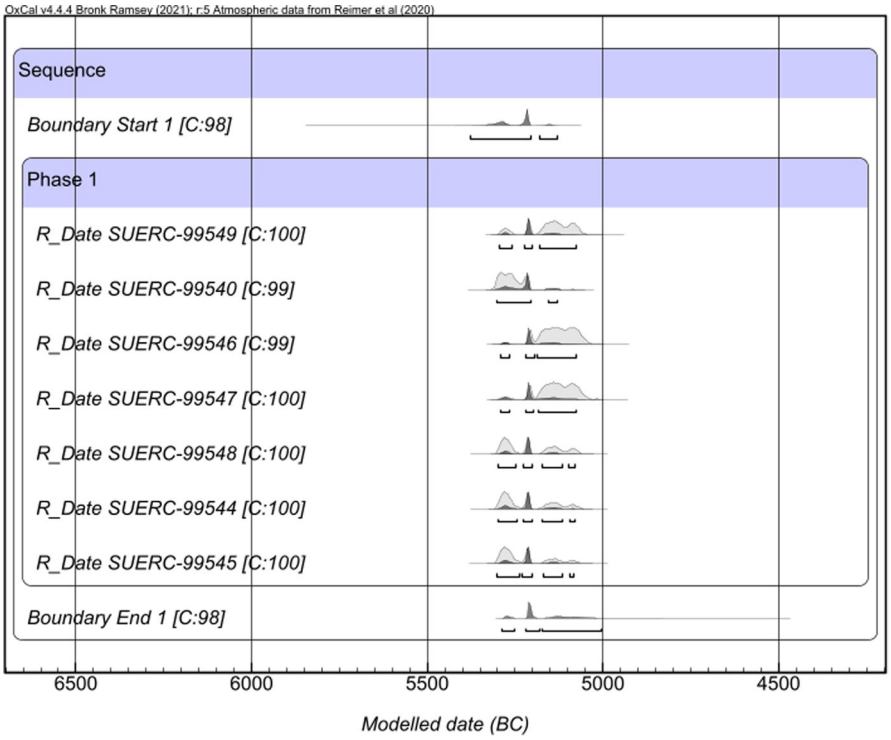

Fig. 9 Single-bounded phase Bayesian model of the available radiocarbon dates from *Vedrovice-Za dvorem*

coincides with the 'order' parameter model, which suggested that there is a 78% probability that the earliest graves of the cemetery contained projectiles.

Nitra-Horné Krškany, Priemyselná ulica and Nitra-Mlynárce

The chronology of the cemetery of *Nitra-Horné Krškany,* is defined in a *single contiguous phase* (*Amodel 97.9 and Aoverall 90.9*) between *5330–5230/5040–4935* cal BC with a span of *200–350* (Fig. 12), a temporal distribution also supported by the simulations (SI-3.6).

Once again, the single-bounded phase model followed by an order parameter was performed to test the presence of different chronological distributions based on sex, age, mobility, diet, body orientation, and the distribution of the grave goods, including their presence/absence, as well as the presence of *Spondylus* items and stone adzes. According to our data, temporal-based discontinuities were observed in individuals' diet patterns, the presence and absence of grave goods in general, and the presence and absence of *Spondylus* items in particular (SI-4.1-Tables 17–31).

Specifically, unfurnished graves started earlier (*5460–5220 cal BC*) than those with grave goods (*5325–5110 cal BC*). This result aligns with the 'order' parameter model, which suggested a 94% probability that the earliest graves in the cemetery were unfurnished. Similarly, graves containing *Spondylus* items ceased to be present

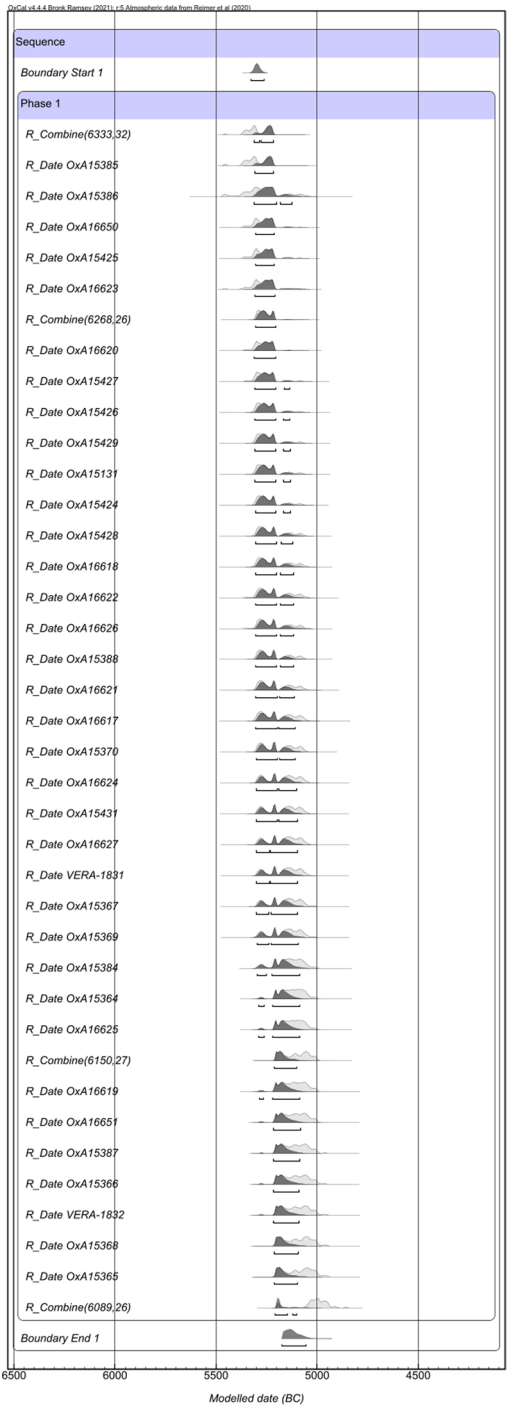

Fig. 10 Single-bounded phase Bayesian model of the available radiocarbon dates from *Vedrovice-Široká u lesa*

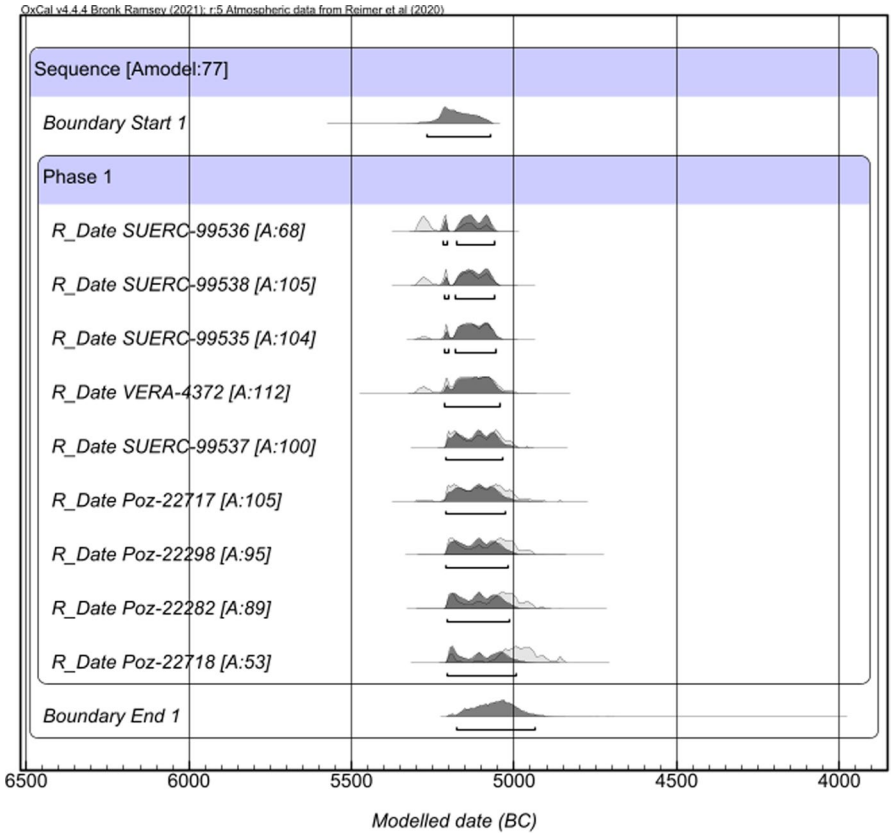

Fig. 11 One phase Bayesian model of the available radiocarbon dates from *Vedrovice-Sídliště*

earlier than those without them (in the timespan *5290–5030 cal BC*, 98% probability according to order parameter). Finally, individuals displaying higher δ^{15}N values (see SI-4.2 for statistics) started slightly earlier (*5335–5220 cal BC*, 90% probability) than those with lower values (*5320–5070 cal BC*).

As there were only three available dates at Nitra-*Mlynárce* it was not possible to perform a Bayesian Model with empirical consistency. According to χ^2 test, graves 4/52 and 9/52 could be contemporary, dating to the timespan *5290–5065 cal BC* (*Acomb. 119.2*). In addition, a third date places another grave (17,893) more recently, in the span *5205–4845 cal BC*, suggesting that the use of the site extended into later times.

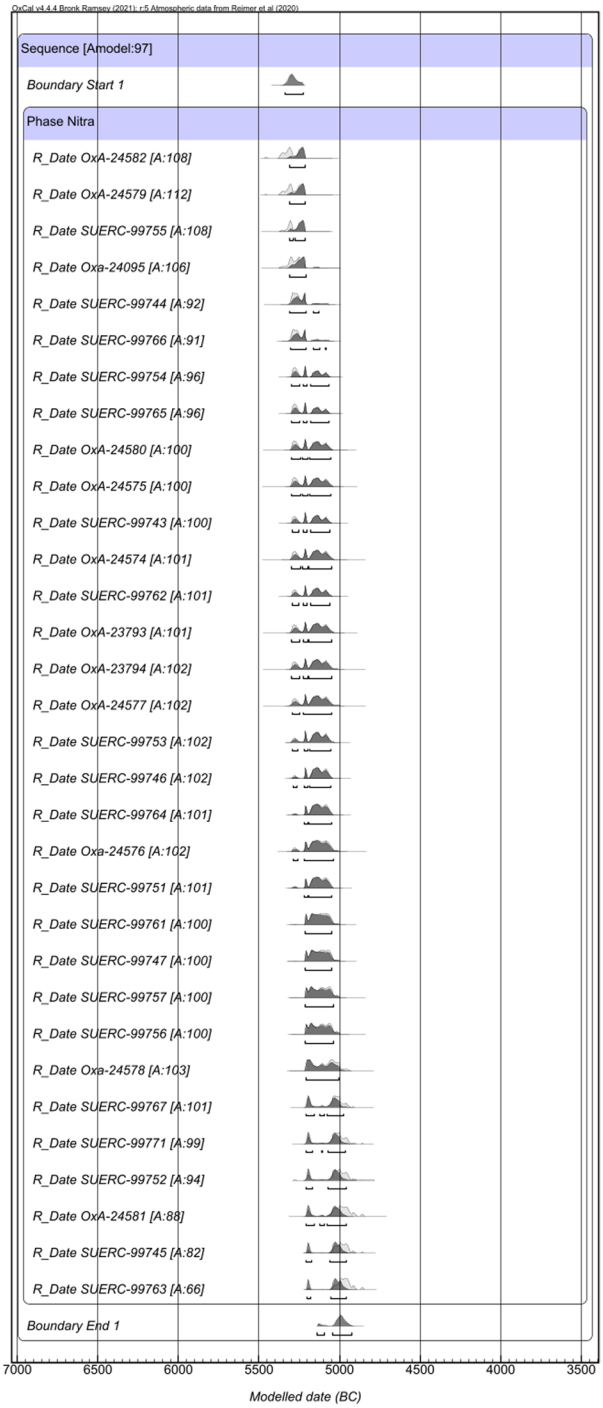

Fig. 12 Single-bounded phase Bayesian modelling of the available radiocarbon dates from the cemetery of *Nitra-Horné Krškany*

Regional Results

Chronological Distribution of the Dated Sites

To address the variability in the burial practice of south-eastern Czechia/western Slovakia, the results from the sampled contexts were compared with a total of 45 available radiocarbon dates from 9 different LBK funerary sites: Jelšovce (Görsdorf, 1995), Mašovice-Pšeničné (Dočkalová & Čižmář, 2008), Olomouc-Nemilany (Kalábek & Pankowská, 2012), Nová Ves-Kopaniny (Trampota & Pajdla, 2022), Seloutky-U planičky (Trampota & Pajdla, 2022), Slatinky-Močílky (Trampota & Pajdla, 2022), Velatice-Velatický Široký (unpublished site), Vráble-Veľké Lehemby (Müller-Scheeßel et al., 2021) and Žádovice-Dolní újezd (Unpublished site) (Fig. 13) (SI-1, Table 2).

According to the single-bounded phase model, the temporal distribution of all LBK-associated funerary practices or burial events in south-eastern Czechia/western Slovakia was continuous in time within the same chronological phase between *5315–5270/5035–4985 cal BC*, with a span of *245–315* (*Amodel* 99.5 and *Aoverall*. 82.3). However, outliers have been identified at both the beginning and, notably, the end of the sequence. The first outlier corresponds to the non-adult individual from

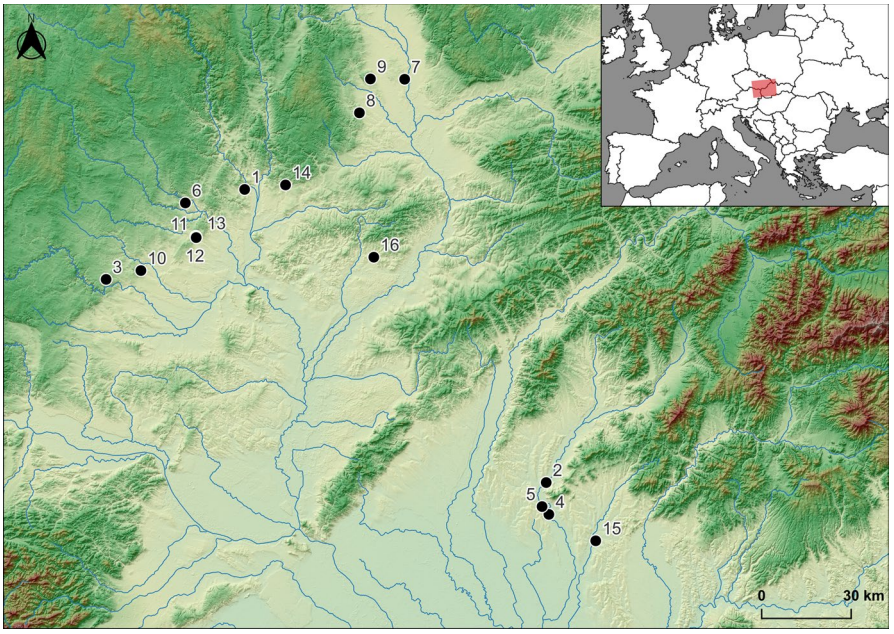

Fig. 13 Map of all the sites containing radiocarbon dates from funerary contexts. 1. Brno-Starý/Nový Lískovec, 2. Jelšovce-JRD, 3. Mašovice-Pšeničné, 4. Nitra-Horné Krškany, Priemyselná ulica, 5. Nitra-Mlynárce, železničná stanica, 6. Nová Ves-Kopaniny, 7. Olomouc-Nemilany 4, 8. Seloutky—U planičky, 9. Slatinky- Močílky, 10. Těšetice-Kyjovice-Sutny, 11. Vedrovice-Široká u lesa, pohřebiště, 12. Vedrovice-Široká u lesa, sídliště, 13. Vedrovice-Za dvorem, 14. Velatice-Velatický široký, 15. Vráble-Veľké Lehemby, 16. Žádovice-Dolní újezd. Map source: raster data from CIAT-CSI SRTM, vector data from Natural Earth Data

Brno-Starý/Nový Lískovec grave 801 (*5475–5235 cal BC*), which has been previously identified as being significantly older than the adult male burials at the site, as well as containing distinct grave goods.

The outliers at the end of the sequence belong to Vráble. Six of them were also omitted from Müller-Scheeßel et al. (2021) models since they were incompatible with the proposed relative chronology of the site and/or they came from disarticulated bones that could be intrusive. However, our model also considered several burials from this site that are relatively more recent than the dates analysed for all the LBK funerary contexts examined in this article. Specifically, these include the burials G2-S21, G7-S21, and G1-S14, which are located near houses and along the ditch structure (Müller-Scheeßel et al., 2021), involving both primary and secondary inhumations.

According to the 'order' model (Table 3, see also SI-4.3, Table 1), the earliest funerary site in the area is *Brno-Starý/Nový Lískovec*, primarily due to the presence of older non-adult individuals considered as outliers (*see above*). Otherwise, the first mortuary practices would simultaneously date to *Vedrovice-Široká u lesa* and *Nitra-*

Table 3 Chronology of the analysed sites estimated by One Contiguous Phase Model, including *Brno-Starý Lískovec/Nový Lískovec, Těšetice-Kyjovice, Nitra-Horné Krškany, Vedrovice-Za Dvorem, Vedrovice-Široká u Lesa* and *Vedrovice-Sídliště*

Site	Chronological interval	Span (years)	Agreement indices
Brno-Starý Lískovec/Nový Lískovec	*5530–5225/5270–4865 cal BC*	*25–360*	*Amodel 93.3 Aoverall 92.2*
Vedrovice-Široká u Lesa	*5330–5270/5200–5040 cal BC*	*84–250*	*Amodel 121.7 Aoverall 121*
Nitra-Horné Krškany	*5340–5240/5035–4930 cal BC*	*220–365*	*Amodel 99.2 Aoverall 96.4*
Vedrovice-Za Dvorem	*5375–5130/5285–5000 cal BC*	*0–220*	*Amodel 101.4 Aoverall 100*
Žádovice	*5375–5045 cal BC*	–	
Vedrovice-Sídliště	*5280–5065/5190–4920 cal BC*	*0–205*	*Amodel 78.6 Aoverall 75.6*
Vráble	*5280–5090/4780–4630 cal BC*	*320–530*	*Amodel 108.5 Aoverall 112.1*
Těšetice-Kyjovice-Sutny	*5295–5080/5210–5020 cal BC*	*0–150*	*Amodel 80.3 Aoverall 79.1*
Nitra-Mlynárce	*5290–5065 cal BC*	–	*Acomb 119.5*
Mašovice-Pšeničné	*5290–5010 cal BC*	–	
Seloutky-U planičky	*5210–5045 cal BC*	–	
Slatinky-Močílky	*5305–4850 cal BC*	–	
Velatice-Velatický Široký	*5300–5030 cal BC*	–	
Jelšovce	*4995–4730 cal BC*	–	
Nová Ves-Kopaniny	*5300–5045 cal BC*	–	
Olomouc-Nemilany 4 Lidická ulice / Kožušanská ul	*5210–4940 cal BC*	–	

Due to the limited number of samples, the chronology estimation for the sites of Nitra-Mlynárce has been conducted using the χ^2 test, while for the sites of Mašovice-Pšeničné, Seloutky-U planičky. Slatinky-Močílky, Velatice-Velatický Široký and Žádovice have been estimated through their two-sigma calibration. A visualisation can be consulted at SI-5.1 and SI.5.2

Horné Krškany, Priemyselná ulica. Afterwards, the activity begins at the *Vedrovice-Za dvorem* grave cluster and the double burial of *Žádovice*, followed by *Vráble* and the settlement graves of *Vedrovice-Sídliště*, which started contemporaneously. *Těšetice-Kyjovice-Sutny* is the last site with several burial individuals to start, followed by the isolated graves of *Mašovice-Pšeničné*, *Seloutky-U planičky*, Jelšovce, *Slatinky-Močílky (grave 1), Nitra-Mlynárce, Velatice-Velatický Široký, Nová Ves-Kopaniny, and Olomouc-Nemilany 4.*

The LBK funerary activity ends first at *Vedrovice-Široká u lesa*, followed by *Brno-Starý/Nový Lískovec*, Vedrovice-Za *dvorem, Těšetice-Kyjovice-Sutny, Vedrovice-Sídliště* and *Nitra-Horné Krškany*. Finally, *Vráble* is the last context in use, with radiocarbon dates closer to the Lengyel pottery culture than the LBK, especially the ones that fell out of the single-bounded phase model (*see above*). In this sense, even though these dates have been linked to later LBK funerary practices (Müller-Scheeßel et al., 2021), they could also be interpreted as a first example of the Lengyel culture mortuary evidence (see Discussion below).

These results have to be interpreted in the light of the overrepresentation of dates from cemetery contexts compared with isolated graves in settlement contexts. This situation could have been influenced by sampling or preservation biases, or differences in the intensities of burial practices, which may affect the chronological framework and interpretations of the temporality of the different funerary contexts.

Regional Funerary Practices

According to the results of the single-bounded phase model, the start of cemeteries and settlement graves was very similar, almost contemporaneous. However, the order parameter suggests an 81% probability, based on the available dates, that the start of cemeteries is slightly older (SI-4.3). This is due to the initial chronological distribution of settlement graves extending to more recent dates compared to the starting boundaries of cemeteries. Finally, the grave clusters and Vráble's Ditch burials began simultaneously.

Grave clusters are the first mortuary practice to be abandoned, though this could be the result of their having the fewest dates, which may be an effect of the sample. Cemeteries end before both settlement graves and Vráble's Ditch burials, with settlement graves ending before activities at the Ditch (Table 4).

If we focus solely on dates from our sampled sites, a nuanced picture of funerary practices emerges. Cemeteries appear as the earliest established funerary practice, closely followed by settlement graves associated with houses.

Later on, grave clusters and isolated graves start, followed by the secondary treatment of bodies (Table 5, order model at SI-4.3, Table 2). The end of the funerary rites of the LBK before the SBK/Lengyel horizon begins with the grave clusters, followed by cemeteries and settlement graves. Interestingly, the period of settlement grave use seems to extend slightly beyond that of cemeteries, although the order parameter model does not highlight this difference as significant.

Table 4 Chronology of the different mortuary practices estimated by one contiguous phase model including all the dates available from the area

	Chronological interval	Span (years)	Agreement indices
Cemeteries	*5320–5270/ 5140–5050 cal BC*	*145–255*	*Amodel 124.4* *Aoverall 122.6*
Grave clusters	*5225–5085/5215–5070 cal BC*	*0–74*	*Amodel 151* *Aoverall 128.2*
Settlement graves (including Vráble)	*5325–5220/5090–4925 cal BC*	*140–350*	*Amodel 98.1* *Aoverall 91.4*
Settlement graves (excluding Vráble)	*5335–5130/5160–4990 cal BC*	*0–255*	*Amodel 102.1* *Aoverall 96.8*
Ditch	*5245–5105/4790–4710 cal BC*	*320–465*	*Amodel 94.5* *Aoverall 94.7*

A visualisation can be consulted at SI-5.3

Table 5 Chronology of the different mortuary practices estimated by One Contiguous Phase Model including only the sampled sites analysed in the paper

	Chronological interval	Span (years)	Agreement indices
Cemeteries	*5320–5270/ 5140–5050 cal BC*	*145–255*	*Amodel 124.4* *Aoverall 122.6*
Grave clusters	*5225–5085/5215–5070 cal BC*	*0–74*	*Amodel 151* *Aoverall 128.2*
Settlement isolated	*5230–5050/5200–4940 cal BC*	*0–155*	*Amodel 119.2* *Aoverall 117.9*
Settlement near houses	*5360–5135/5210–4985 cal BC*	*0–265*	*Amodel 98.9* *Aoverall 97.3*
Secondary treatment	*5290–5060 cal BC*	–	*Acomb 119.1*

Table 6 Three Overlapping Phases Bayesian Model of the available radiocarbon dates of Moravian LBK settlements (Amodel 290.8 and Aoverall 258)

Moravian LBK settlements	Chronological interval	Span (years)
Phase 1	*5380–5310/5300–5210 cal BC*	*10–145*
Phase 2	*5190–5080/5155–5050 cal BC*	*0–115*
Phase 3	*5065–5000/5040–4965 cal BC*	*0–70*

Regional Chronological Trends Between Settlement and Funerary Contexts

To compare the chronology of the funerary practices with the temporality of the settlements in the area, we selected the available published radiocarbon dates from domestic contexts displaying standard deviations below or equal to ± 40 (SI-1, Table 4). According to the models, the LBK domestic contexts of SE Moravia were chronologically distributed across three overlapping phases: the first from *5380–5310* and *5300–5210* cal BC, the second from *5190–5080* and *5155–5050* and the third from *5065–5000* and *5040–4965* cal BC (*Amodel 290.8 and Aoverall 258*, Table 6 and Fig. 14).

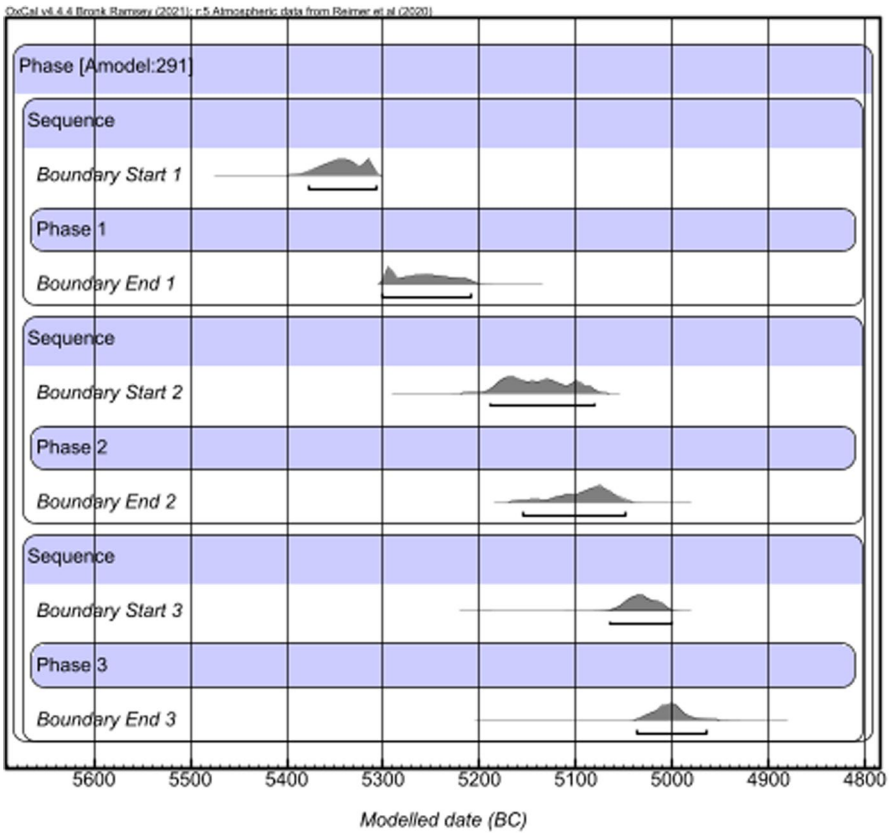

Fig. 14 Three overlapping phases Bayesian model of the available radiocarbon dates of Moravian LBK settlements (*Amodel 290.8 and Aoverall 258*)

This evidence indicates that the end of the first regional LBK phase in settlements coincided with the emergence of cemeteries and burials associated with house structures. The beginning of the second settlement phase aligned with the onset of grave clusters and isolated settlement graves. Finally, the end of both cemeteries and grave clusters ended alongside the second settlement phase, while the end of settlement graves coincides with the last moments of phase 3.

Discussion

Mortuary Practices and Temporal Dynamics in South-Eastern Czechia/Western Slovakia

The Beginning of the LBK Funerary Traditions

The first LBK settlers in our study region built their dwellings and began burying their dead shortly afterwards, with children being the first to be interred, as observed

at *Těšetice-Kyjovice-Sutny* and *Brno-Starý/Nový Lískovec*. Almost contemporaneously with these initial settlements, cemeteries began to be established, followed closely by settlement graves associated with houses. Later on, grave clusters and isolated graves at settlements started, with secondary treatment of the bodies being the last practice to emerge. The temporal distribution of all LBK-associated funerary practices appeared to be continuous in time between 5315–5270/5035–4985 cal BC.

The rapid implementation of various funerary practices almost simultaneously across the region aligns with the interpretations proposed by Jakucs et al. (2016), who emphasised the dynamics and interactive nature of LBK communities, particularly between the earliest/formative LBK (*älteste* LBK) and the older LBK (*ältere* LBK). While estimates for the formative phase in Transdanubia and eastern Austria place the start of the LBK around 5500 cal BC, those for the start of the earliest LBK in the study region are significantly later than previously thought, placing the LBK expansion not earlier than the 54th century.

Our chronological models for Moravia and western Slovakia place the beginning of the LBK in this region around 5380–5310 cal BC, bringing together settlements and visible funerary practices, aligning with Jakucs and colleagues' (2016) proposed expansion date from Hungary. This supports the idea of a later onset of the LBK initial migration and that it took place within just a few generations. This raises important questions regarding the growth rate of the developed LBK and the social mechanisms that allowed such rapid expansion.

The results also raise questions about the nature of this first migration process into Moravia and western Slovakia. On the basis of current understanding the LBK forms out of the Starčevo–Körös–Criș culture in Transdanubia (Bánffy & Oross, 2010; Jakucs et al., 2016; Marton & Oross, 2012; Oross, 2010), with the role of indigenous communities in this first formation still debated (Lenneis, 2007; Pavlů & Zápotocká, 2007; Pavúk, 2024). In subsequent expansions of the fully formed LBK from its regions of origin in Transdanubia, communities may have also met with hunter-gatherers, as hypothesised by Zvelebil and Pettitt (2013) as possibly explaining the diversity they found in lifeways at the Vedrovice cemetery. Further genome-wide data may yet shed light on this (e.g. Nikitin et al., 2019).

Among these debates about LBK origins, there are currently unresolved issues regarding the origins of funerary practices, such as the emergence of cemeteries and cremation practices. Although the number of Early Neolithic cemeteries in southwest Europe is notably sparse, the concept of interring the dead in designated areas was not unprecedented during the 6th millennium, including in regions like the Iron Gates, where both Mesolithic inhumation cemeteries and cremation practices have been documented (Boroneanț & Bonsall, 2012). However, it is important not to hastily attribute the origins of these funerary practices solely to pre-LBK community practices, as alternative explanations may exist. For example, Hofmann and Bickle (in press) have recently suggested that cemeteries might have served as a means of fostering community cohesion during periods of significant fragmentation and mobility between settlements and regions. This may also be suggested by the burial practices found in the formative regions for the LBK, where people remained relatively less mobile, and cemeteries are not documented. Recent studies further emphasise that several LBK sites extended into relatively late phases. Lipid residue analyses

from Central Germany document LBK pottery use until c. 4775 BC (Breu et al., 2024), while multi-proxy isotopic studies of cattle husbandry reveal prolonged activity and local adaptations in forested environments (Gillis et al., 2025). Both cases correspond well with our chronological models and reinforce the view that funerary innovations and social transformations were not synchronous across the LBK, but rather embedded in regionally diverse and long-lasting trajectories.

While the origin of settlement graves seems to be linked to Starčevo–Körös–Criș culture in Transdanubia, other funerary rites, such as cremations or the use of cemeteries, however, remain unclear. Examining what cultural practices were retained or modified during this migration process is crucial in future interpretative endeavours, as well as considering the possible Mesolithic heritage for some LBK burial practices (Lenneis, 2007).

In this respect, recent palaeogenomic research has provided key evidence for the degree of interaction between incoming LBK farmers and indigenous hunter-gatherers. Genome-wide data from more than 250 individuals from sites including Nitra-Horné Krškany, Polgár-Ferenci-hát, and Asparn-Schletz show clear but regionally variable admixture with western hunter-gatherer ancestry—on average ~ 11% in eastern LBK/ALPC contexts versus ~ 4–5% in western LBK—indicating differential processes of incorporation of local Mesolithic groups (Gelabert et al., 2025). These results highlight that cultural and biological interactions went hand in hand, and that some funerary practices within the LBK may have roots in these complex local dynamics.

Traditional interpretative models have also viewed LBK cemeteries as a means for expressing the prestige and social distinction of elders (Pavúk, 1972). With increasing settlement density, migration may have become a less viable option, causing elders to lose their authority as they could no longer sponsor migration events for social control. According to these interpretations, new ways of expressing prestige and social distinction had to be developed, and various avenues were tried out, including larger and architecturally more complex buildings and the deposition of wealth as grave goods in newly established cemeteries (Hofmann et al., 2016).

However, our results suggest that cemeteries were not simply static markers of settled life but reflected the dynamism and interconnectedness of LBK communities. The traditional models, which attribute the emergence of cemeteries primarily to demographic pressures and reduced mobility, may oversimplify the complex interactions and rapid cultural exchanges of the LBK horizon, especially given the diversity of kinship groups using cemeteries indicated by low rates of familial relationships (Childebayeva et al., 2022; Gelabert et al., 2025). Instead, cemeteries should be viewed as dynamic sites reflecting the ongoing adaptation and fluid social landscapes of these communities. This perspective challenges the notion of rigid cultural boundaries and reveals a complex early Neolithic reality characterised by continuous exchange and adaptation.

The End of the LBK Funerary Traditions

Cemeteries and grave clusters end before both settlement graves and *Vráble*'s ditch (5140–5050 cal BC and 5215–5070 cal BC respectively). Furthermore, settlement

graves (5160–4990 cal BC) ended before *Vráble*'s funerary evidence in the ditch (4790–4710 cal BC).

Vráble is the latest context in use, with radiocarbon dates closer to Lengyel pottery culture than LBK, especially those that fell outside of the single-bounded model (*see above*). Although these dates have been considered a representation of later LBK funerary practices (Müller-Scheeßel et al., 2021), they could also be interpreted as early evidence of the transition to Lengyel culture. This idea is reinforced by the fact that the latest pottery in *Vráble* can be considered early ceramic forms of the succeeding Lengyel Culture (Cheben et al., 2020), as well as by the abundance of dispersed Lengyel culture settlements in the surrounding areas (Gabulová, 2015). The research at Vráble remains in progress, suggesting that the site's historical narrative is not yet fully established, and additional data is anticipated to provide a more comprehensive understanding of the processes.

As the chronological characterisation of Lengyel culture funerary practices is still a work in progress (Regenye et al., 2020), this is a challenging topic to address on the basis of our results. However, it is considered that the first Lengyel culture graves in Transdanubia started around *5070–4830 cal BC* (*68%* probability) and became fully established by probably *4960–4810 cal BC* (*68%* probability) (Regenye et al., 2020). Although those dates belong to cemetery graves in Hungary and not the Slovakian-Moravian burials, which are scarce and generally related to unusual, partial or multiple inhumations, they reinforce the idea that part of *Vrable*'s funerary practices could be seen more as the beginning of something new rather than the end of something old.

Correlating Radiocarbon with Pottery Seriations

The use of absolute dating to validate relative chronologies is a well-established methodology that has yielded significant insights into chronological sequences. In a recent study, Trampota and Květina (2020) analysed Moravian LBK radiocarbon dates by modelling them into the three established pottery groups (I, II, and III; see Fig. 15). Their models revealed that these groups do not represent successive chronological stages but rather exhibit partial overlap. This observation extends to more specific pottery subgroups (Ia, Ib, IIa, IIb, and III; see Fig. 14). The earliest LBK Ia group appears to have begun contemporaneously with the LBK Ib group, which persisted for a considerably longer period than LBK Ia. Additionally, the LBK IIa and LBK IIb pottery groups emerged concurrently, with no significant temporal differentiation between them.

In the same line Furholt et al. (2020) used a chronological model based on 138 radiocarbon dates from *Vráble* (23 of the 313 houses in the settlement) to establish the settlement's timeline. When crossing their data with typochronology, they discovered a lot of overlap between Younger LBK and Želiezovce pottery groups.

It is possible that while the sequence of pottery typological changes may be accurate at some times, the proposed rates of change and the identification of potential synchronicities might be incorrect. Trampota and Květina (2020) verified that Moravian LBK pottery styles were not always sequential, but frequently overlap. They

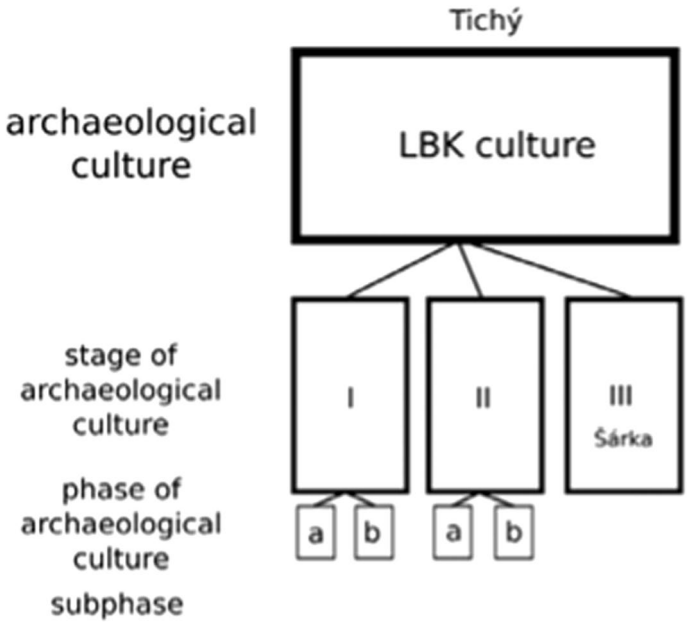

Fig. 15 The traditional concept of chronology based on Neolithic archaeological cultures and their subdivision in Moravia [modified after Trampota & Květina (2020), based on Tichý (1962)]

Table 7 Moravian decorated pottery is associated with a chronological phase and the radiocarbon dates of the burial to which the pottery belonged

Pottery phase	Pottery phase	LabCode	^{14}C date	SD	Cal BC
Ib Čižmář 2002	Early LBK	OxA16628	6125	37	5210–4950
Ib1 Čižmář 2002	Early LBK	OxA15367	6219	35	5300–5050
Ib Čižmář 2002	Early LBK	OxA15429	6268	37	5320–-5070
Ib1 Čižmář 2002	Early LBK	OxA16617	6240	45	5310–5055
Ib1 Čižmář 2002	Early LBK	OxA16621	6244	40	5310–5060
Ib1 Čižmář 2002	Early LBK	OxA16622	6250	40	5310–5065
Ib1 Čižmář 2002	Early LBK	OxA15131	6266	36	5320–5075
Ib1 Čižmář 2002	Early LBK	OxA16650	6299	35	5360–5210
Ib1 Čižmář 2002	Early LBK	OxA15385	6332	37	5375–5215
Ib2 Čižmář 2002	Early LBK	OxA15425	6298	34	5360–5210
IIa Čižmář 2002	Middle LBK	OxA15433	6069	36	5205–4845
IIa Čižmář 2002	Middle LBK	OxA15365	6141	34	5210–4990
IIa Čižmář 2002	Middle LBK	OxA15384	6199	37	5300–5035

also established that factors other than the progress of time were the cause of pottery change.

Pottery typology alone cannot provide a detailed retrospective of the duration of each pottery type, and this is where Bayesian modelling of radiocarbon dates can offer valuable assistance. In our case, we have collected those burials from Moravia containing pottery displaying decorations that could inform on chronological matters according to Čižmář (2002) classification (Table 7).

The single-bounded phase Bayesian model (Fig. 16) has demonstrated that all radiocarbon dates associated with different pottery are continuously distributed between *5345–5210/5225–5055* cal BC with a span of *0–225 (Amodel 117.7* and *Aoverall 117.5*), with the exception of OXA15433, which corresponds to pottery type Ib according to Čižmář (2002) and the model considered it an outlier (A = 34.2%). Furthermore, Chi-squared testing (Ward & Wilson, 1978) has revealed a significant statistical similarity among the radiocarbon dates associated with different pottery types (Fig. 17). This supports the idea that the various pottery types overlap temporally, indicating that the observed differences are not necessarily due to distinct time periods. Consequently, based on the available radiocarbon data, we cannot confirm

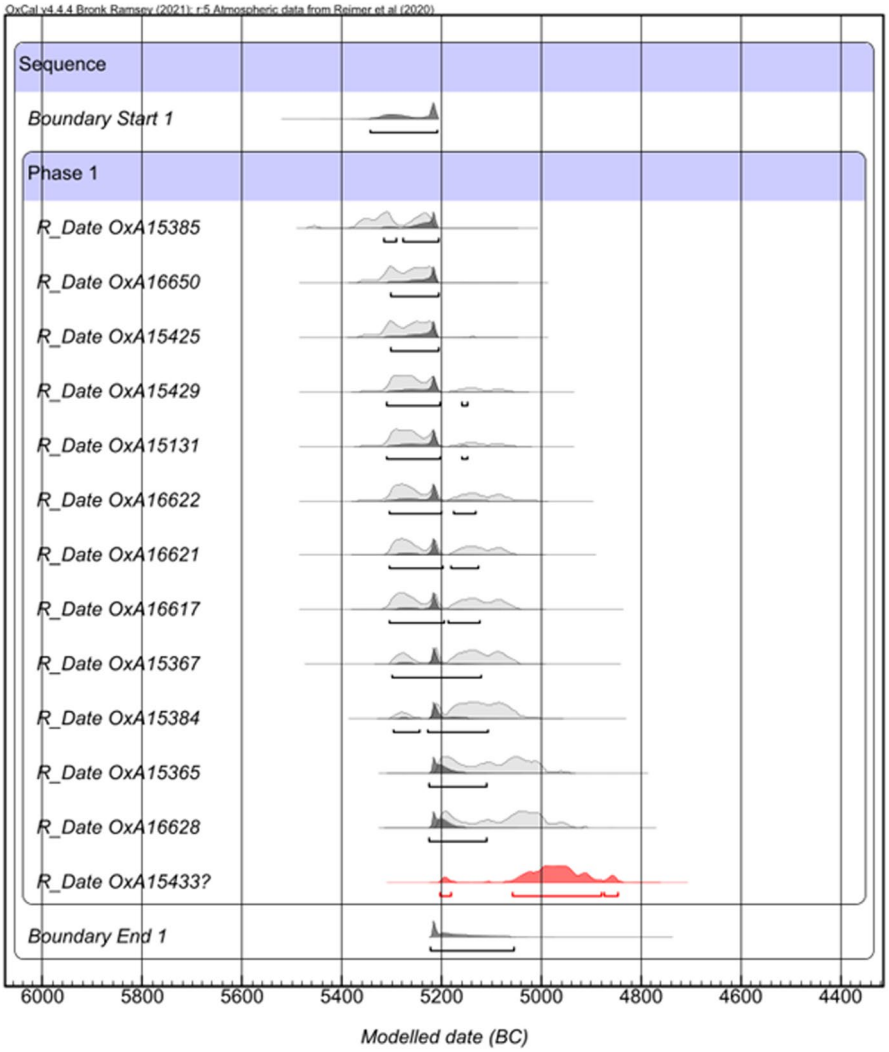

Fig. 16 Single-bounded phase of the radiocarbon dates associated to typology (*Amodel 105.5* and *Aoverall 91.2*)

Pottery Phase	Pottery phase	Lab Code	Radiocarbon date	SD
Ib1 Čižmář 2002	Early LBK	OxA15385	6332	37
Ib1 Čižmář 2002	Early LBK	OxA16650	6299	35
Ib2 Čižmář 2002	Early LBK	OxA15425	6298	34
Ib Čižmář 2002	Early LBK	OxA15429	6268	37
Ib1 Čižmář 2002	Early LBK	OxA15131	6266	36
Ib1 Čižmář 2002	Early LBK	OxA16622	6250	40
Ib1 Čižmář 2002	Early LBK	OxA16621	6244	40
Ib1 Čižmář 2002	Early LBK	OxA16617	6240	45
Ib1 Čižmář 2002	Early LBK	OxA15367	6219	35
IIa Čižmář 2002	Middle LBK	OxA15384	6199	37
IIa Čižmář 2002	Middle LBK	OxA15365	6141	34
Ib Čižmář 2002	Early LBK	OxA16628	6125	37
IIa Čižmář 2002	Middle LBK	OxA15433	6069	36

Fig. 17 Different groups of radiocarbon dates associated with each pottery type determined to be statistically similar by the Chi-square test

that typology serves as a reliable basis for chronological determinations; therefore, it cannot be confidently used as a prior for the Bayesian modelling of the radiocarbon dates.

The Internal Chronology of the Sites: Lifeways, and Demographic and Grave Goods Distributions

One of the most important findings of this research is the evidence that, for the most part, all the different forms of funerary practice were in use at the same time. This is significant because it indicates that the different patterns observed within cemeteries, grave clusters, and settlement burials belong to the same chronological phase. Consequently, it can be stated that there was a highly diverse mortuary treatment of the deceased within these communities, based on social codes that determined different burial locations according to sex, age, and possibly other social categories. Therefore, all the lifeways and mortuary practices (including dietary and mobility patterns, body position and orientation and, the presence and distribution of grave goods) should be considered as part of the same phase of activity. This resulting chronology allows us to interpret the observed variability of the funerary record as representative of the same population.

However, our study has also identified certain patterns related to time. Notably, at both *Těšetice-Kyjovice* and *Brno-Starý/Nový Lískovec,* the burials of non-adult individuals are significantly earlier than those of adults. This data opens new avenues for interpretation, suggesting that non-adult individuals could be associated with an earlier occupation phase, potentially linked to the foundation of the settlements. Interestingly, this pattern has only been identified in settlements and not in other types of funerary contexts, indicating a possible relationship between the burials of non-adult individuals and the beginnings of this funerary practice during the LBK.

The presence of foundational burials is not unheard of through the LBK. A significant instance is a male burial uncovered at the base of an early Neolithic settlement site at Schwanfeld, Germany. This burial, located within one of the settlement's loam pits, has been classified as a foundational burial (Gronenborn, 1999). However, further research is needed to determine the extent and consistency of this practice across the LBK region, and to explore the potential social implications and interpretations associated with it.

Another interesting aspect of these foundational burials is that the earliest burial at *Brno-Starý Lískovec/Nový Lískovec* (burial 801, 5475–5235 cal BC) is among the few in the region to include shell ornaments as grave goods. This chimes with Lenneis's (2007) proposal that shells have been associated with the latest Mesolithic burial traditions (Lenneis, 2007). This finding provides new scope for interpretations related to population movements and interactions with the Mesolithic traditions.

In the case of the cemeteries, where intra-site comparisons were possible due to the higher number of inhumations and radiocarbon dates, several temporality patterns have been identified. However, these patterns do not present any kind of regularity between *Vedrovice-Široká u lesa* and *Nitra-Horné Krškany*. For example, at *Vedrovice-Široká u lesa* the presence of more mobile females started earlier and lasted longer than that of the non-mobile ones, indicating that the associated practices with this mobility were stable during the entire use of the cemetery. Additionally, these data suggest that the first and last settlers were predominantly females moving around short distances (see Morell-Rovira et al., 2024). Age also appears as a relevant factor, as there were more senile and juvenile individuals among the final burials. Finally, graves containing projectile points appeared earlier than the ones without them, suggesting that this grave good pattern is more closely associated with the early phases of the cemetery.

In the case of *Nitra-Horné Krškany, Priemyselná ulica*, unfurnished graves started earlier than the ones containing grave goods, and graves displaying *Spondylus* items disappeared earlier. Finally, individuals with higher amounts of δ^{15}N values (normally corresponding to males) began to be present slightly earlier than those with lower values. This suggests a change in the dietary patterns or protein consumption sources among certain individuals within the community during the occupation of the cemetery. A more detailed approach to the reasons for these patterns, such as manuring systems and animal diet, should be undertaken to interpret this variability.

Conclusions

The results of this study challenge the traditional notion that LBK settlement graves preceded the establishment of cemeteries across the whole of its distribution. Our findings reveal that systematic burial practices at cemeteries began around the same time as the first LBK settlements in Moravia and western Slovakia. Burial areas near dwellings were also used shortly thereafter.

The rapid adoption of funerary practices across the LBK region supports Jakucs and colleagues' (2016) view of dynamic, interactive LBK communities, particularly between the earliest and older LBK phases. While the Formative LBK in Transdanubia and eastern Austria is estimated to start around 5500 cal BC, the earliest LBK in the region under study actually began later, around the 54th century BC. Our own chronological models for Moravia and western Slovakia suggest that the beginning of the LBK settlement started around 5380–5310 cal BC, followed closely by the first cemeteries between 5320–5270 cal BC, aligning with Jakucs and colleagues' (2016) expansion timeline from Hungary.

Our results also align with recent radiocarbon analyses of south-western LBK funerary contexts, which suggest that various mortuary rites began to be practised more or less simultaneously, including the cemetery of Schwetzingen (*5240–5215 cal BC*), settlement graves (*5260–5055 cal BC*) and the burial enclosures at Herxheim (*5240–5215 cal BC*), with the mass burial at Talheim as the final event, all within the same continuous radiocarbon phase (Morell-Rovira et al., 2025).

This indicates a later, rapid expansion of the LBK, raising questions about the growth rate and social mechanisms of this migration. The swift spread of the LBK horizon in the 53rd century cal BC, perhaps beginning from around 5450 cal BC, highlights the adaptability of these populations. The swift dissemination of their pottery and longhouses across Central Europe indicates a high degree of interaction and fluidity in cultural development that needs to be further investigated. Alongside this, the role of indigenous communities in this first formation also remains to be established.

These findings also offer an alternative to Jeunesse's (1997) model, which suggests increased social hierarchy and inheritance patterns evidenced by more elaborate graves at the end of the LBK period. In contrast to this, we have seen that the earliest LBK funerary practices exhibit a high degree of standardisation in terms of grave goods disposition, body orientation, and position. This standardisation seems to wane towards the end of the LBK period, maybe indicating some kind of social disaggregation or relaxation of social norms or the mechanisms to sustain them, supporting Frirdich's (1994) suggestion that long-standing kinship relations break down at the end of the LBK, reducing rigid adherence (perhaps even including monitoring or restrictions), to social norms, as the younger generations were freer to make their own choices.

Of particular interest is the emergence of secondary body treatment practices towards the end of the LBK. These practices might reflect a change at the end of the LBK occupation. Future research should aim to radiocarbon-date these practices more precisely and interpret them in light of *Vráble*'s last funerary practices and the onset of the Lengyel culture's mortuary treatments.

These discrepancies prompt a re-evaluation of the notion that social hierarchies gradually intensified over time, peaking at the end of the LBK period and leading to an escalation of violence, as evidenced by the emergence of mass burials. Considering the regional diversity in funerary practices towards the end of the LBK it is difficult to compose general explanations for the whole LBK area. The eastern and western LBK cultures diverged significantly, with the east exhibiting continuity post-LBK and the west experiencing a gap or depopulation (e.g. Denaire et al., 2017). For example, at sites such as Eythra, Saxony (Frirdich et al., 2015), or Hrdlovka, Bohemia (Vondrovský et al., 2016), it has been proposed that the LBK settlement transitioned directly into a Middle Neolithic settlement. Moreover, mass burial sites indicating violence are predominantly found in the west, with Asparn being a notable exception in the east. Therefore, it can be argued that there is little evidence for the intensification of burial practices at the end of the LBK period; instead, there is greater diversity, indicating a much more complex scenario, perhaps with regionally specific responses to change.

In summary, this research underscores the complexity and diversity of LBK mortuary practices. The findings suggest that LBK communities employed a wide range of burial customs simultaneously, which were influenced by various factors such as sex, age, and possibly other social categorisations. This complexity indicates that LBK social structures were likely intricate and multifaceted. The variations in funerary practices over time, including the shift towards less standardised burials and the introduction of secondary treatments, imply that these communities experienced significant social and cultural changes. Understanding these practices requires a nuanced interpretation that considers the interplay of social norms, cultural traditions, and possibly economic or environmental factors. Such interpretations can enhance our understanding of the social organisation, beliefs and adaptive strategies of early LBK farming communities.

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Author Contributions Alba Masclans: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Writing original draft. Peter Tóth: Resources; Writing review & editing. Zdeněk Tvrdý: Resources; Writing review & editing. Derek Hamilton: Methodology; Writing review & editing. Penny Bickle: Writing review & editing. Marta Díaz-Zorita Bonilla: Methodology; Writing review & editing. Berta Morell-Rovira: Conceptualization; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Writing original draft.

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Declarations

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Authors and Affiliations

Alba Masclans[1] · Peter Tóth[2] · Zdeněk Tvrdý[3] · Derek Hamilton[4] · Penny Bickle[5] · Marta Díaz-Zorita Bonilla[6,7] · Berta Morell-Rovira[8]

✉ Berta Morell-Rovira
bertamorell@imf.csic.es

[1] Independent Researcher, Girona, Spain

[2] Department of Archaeology and Museology, Masaryk University, Brno, Czech Republic

[3] Moravian Museum, Anthropos Institute, Brno, Czech Republic

[4] University of Glasgow, SUERC – Centre for the Isotope Sciences, Glasgow, UK

[5] Department of Archaeology, University of York, York, UK

[6] Department of Prehistory and Archaeology, University of Granada, Granada, Spain

[7] Institut für Ur- und Frühgeschichte und Archäologie des Mittelalters, University of Tübingen, Tübingen, Germany

[8] Department of Archaeology and Anthropology, Institució Milà i Fontanals – Consejo Superior de Investigaciones Científicas, Barcelona, Spain