RESEARCH ARTICLE – VÝZKUMNÝ ČLÁNEK

Reassessing the LBK/post-LBK transition at the northwestern edge of Central Europe: Crossing boundaries with a lithic perspective

Přehodnocení LBK/post-LBK přechodu na severozápadním okraji střední Evropy: Překračování hranic z perspektivy štípané industrie

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In this paper, we reevaluate the transition from the Linearbandkeramik (LBK) to the various post-LBK groups along the north-western edge of Central Europe, focusing on settlement clusters in the Rhineland (Germany), Dutch Limburg (Netherlands), and Hesbaye (Belgium). Previous research was fragmented by modern political borders, obscuring the cultural and environmental continuity of the region during the Neolithic period. Adopting a supra-regional perspective, this study puts forward a new synthesis by combining harmonised material-culture analyses and network modelling of siliceous raw-material distribution. Our results indicate a period of possible instability marked by a notable decline in archaeologically recorded activity, yet continuities in technical knowledge suggest underlying structural stability. The modelled raw material networks reveal a structural shift within the circulation of siliceous raw materials between the LBK and the post-LBK. We believe that this collaborative effort will become the groundwork for a coherent, region-wide narrative of this pivotal transition in the European Neolithic.

Neolithic – Linearbandkeramik (LBK) – post-LBK – Northwestern Europe – cultural transition – network modelling

V tomto článku přehodnocujeme přechod od kultury s lineární keramikou (LBK) k různým post-LBK skupinám na severozápadním okraji střední Evropy, se zaměřením na sídelní klastry v Porýní (Německo), Limburgu (Nizozemsko) a Hesbaye (Belgie). Dosavadní výzkum byl roztříštěn moderními politickými hranicemi, které zastíraly kulturní a environmentální kontinuitu regionu v období neolitu. Tato studie přijímá nadregionální perspektivu a předkládá novou syntézu založenou na propojení harmonizovaných analýz materiální kultury a síťového modelování distribuce silicitových surovin. Naše výsledky naznačují období možné nestability, projevující se výrazným poklesem archeologicky doložených aktivit; kontinuita technických znalostí však zároveň poukazuje na hlubší strukturální stabilitu. Modelované sítě surovin ukazují strukturální proměnu v cirkulaci silicitových surovin mezi LBK a post-LBK obdobím. Domníváme se, že toto společné úsilí se stane základem pro ucelený, regionálně provázaný výklad tohoto zásadního přechodu v evropském neolitu.

neolit – kultura s lineární keramikou (LBK) – post-LBK – severozápadní Evropa – kulturní přechod – síťové modelování

Introduction

The post-Linearbandkeramik (post-LBK) transition in the early 5th millennium BC marks one of the most fundamental transformations in European prehistory, giving rise to many

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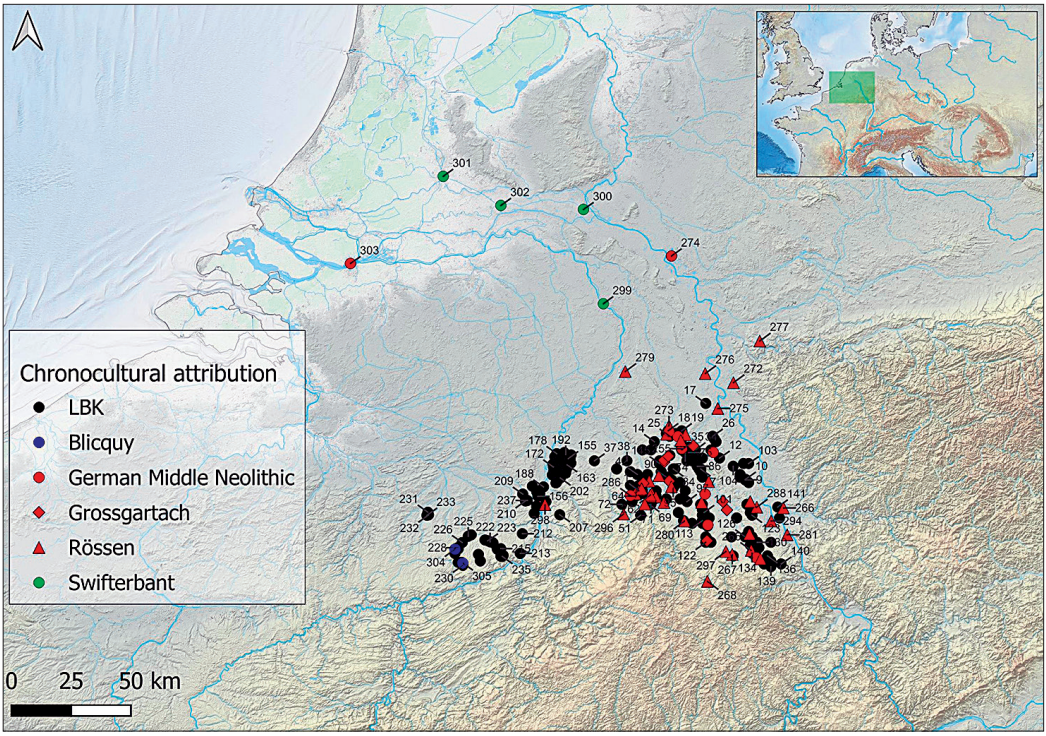


Fig. 1. Map of the study area showing the sites according to their chrono-cultural attribution. The site ID numbers correspond to the database presented in *Online Supplementary Material 1*, and *Online Supplementary Material 2* includes a detailed map of the study area, with all sites clearly labelled. Sites from Westphalia are not mapped or included in this study. German Middle Neolithic refers to sites with multiple post-LBK occupations (DEM: https://emodnet.ec.europa.eu).

of the social, economic, and cultural structures that would define the subsequent two millennia. Traditionally, these developments have been interpreted as the inevitable outcome of the collapse or fragmentation of LBK communities. This regionalisation phenomenon, sometimes perceived as resulting from declining mobility networks (e.g. *Furholt 2018*), has often been studied within the confines of modern national or disciplinary boundaries. However, recent research has challenged this narrative, revealing the transition as a highly heterogeneous process, variable in its tempo, causes, and timing (e.g. *Gleser – Hofmann 2019*; *Kroon et al. in press*). Rather than a linear progression from unity to regional diversity, the post-LBK period emerges as a complex, continent-wide phenomenon that demands investigation beyond the scale of individual regions or chrono-cultural frameworks.

To address this complexity, we adopt a supra-regional perspective across a geographically and environmentally coherent landscape (*Fig. 1*): the Jülich-Zülpicher Börde (including the Aldenhoven Plateau in North Rhine-Westphalia, Germany), Limburg (the Netherlands), and Hesbaye (Belgium). This area, characterised by open plateaus interspersed with small valleys and tributaries of the Meuse and Rhine, provided ideal conditions for early agricultural colonisation during the LBK (*Meijs 2002*; *Haesaerts et al. 2011*; *Schirmer 2016*). Yet, the region exhibits starkly divergent post-LBK trajectories: Belgium's

Blicquy/Villeneuve-Saint-Germain culture, the Rhineland's Grossgartach and Rössen communities, and the Dutch Limburg plateau's archaeological 'void'. These disparities reflect not only modern disciplinary silos, with German, Dutch, and Belgian scholars traditionally focusing on their respective areas, but also entrenched methodological and interpretative differences. Contacts between these different entities have long been postulated (e.g. *Spatz 1991*; *Constantin – Ilett 1998*), and their significance has been increasingly recognised in recent years (e.g. *Gehlen – Schön 2009a*; *Teetaert 2020*; *Denis 2020*; *2025*). It has therefore become essential to challenge these boundaries. Our supra-regional approach seeks to reconcile disparate research traditions, thereby revealing the broader coherence of the LBK/post-LBK transition and its underlying socio-economic dynamics. At the current stage of our research, we established a simplified sites database, which is not intended to be exhaustive but provides a preliminary overview. It will be progressively refined and expanded as the study advances.

Our analytical framework centres on lithic assemblages, offering a complementary perspective to parallel research in this volume (*Kroon et al. in press*) that examines settlement and temporal patterns. Through this integrated lens, we aim to illuminate the interplay between regional diversity and supra-regional connectivity during this pivotal transition.

State of the art on the LBK post-LBK transitions

In this section, we examine the various paradigms addressing the transition from the LBK to post-LBK phases across the regions under study (*Fig. 2*; *Online Supplementary Material 1*). This review deliberately retains the geopolitical boundaries that have traditionally structured research in this field to highlight how the question of this transition has been approached to date. As such, this state of the art does not assume uniform depth of analysis or identical research objects; rather, it reflects the specific expertise and institutional priorities of the different teams involved.

Jülich-Zülpicher Börde (Rhineland, Germany)

LBK

The conventional start date for LBK in the Rhineland is 5300 BC (*Lüning 2005*, 67–71). However, the initial appearance of LBK in this area might be slightly older: between the middle of the 55th century BC and the last decade of the 54th century BC (68.3% probability, see *Kroon et al. in press*). The earliest known settlement to date is the settlement of Niederkassel-Uckendorf, east of the Rhine River (*Heinen et al. 2004*; *Heinen 2005*; *2011*; *2015*; *Balkowski et al. 2016*). A recently published critical revision of the site stresses the lack of clear evidence for the earliest LBK. Instead, '*a more complex change from early LBK to Flomborn*' would take place (*Balkowski et al. 2016*, 84). This transition is characterised by, among other things, the presence of early LBK features resulting from a more traditional or old-fashioned way of producing pottery. Therefore, the authors envisage a colonisation of the Rhineland during the Flomborn phase, on the left and right banks of the Rhine (*Balkowski et al. 2016*, 84).

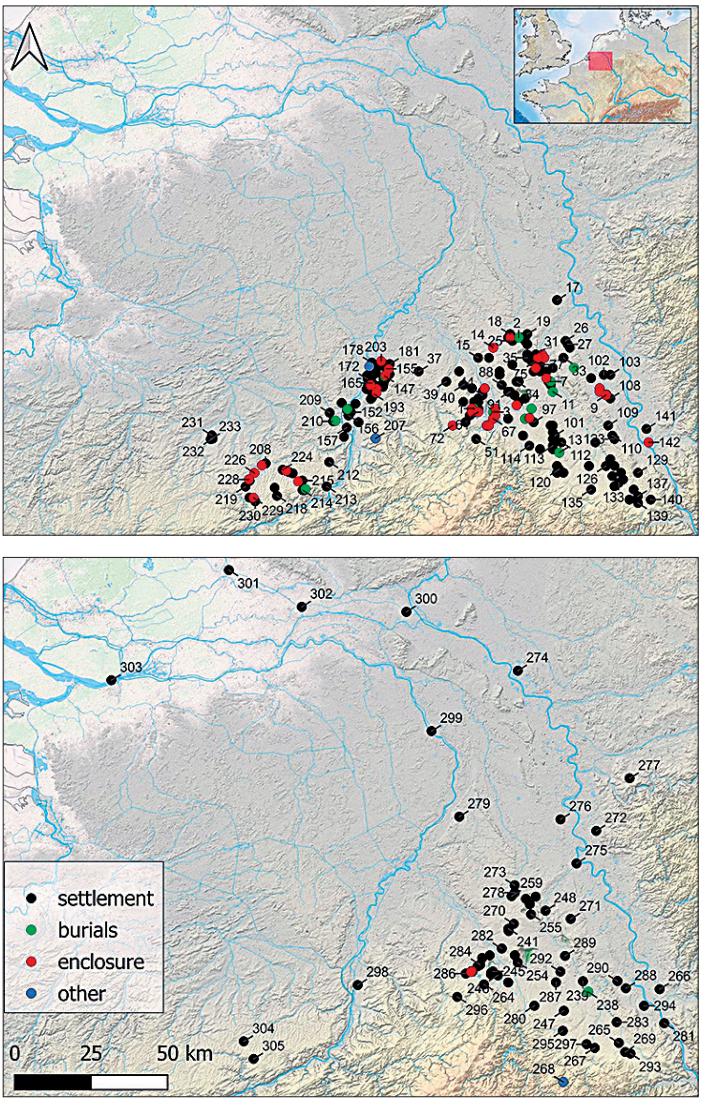


Fig. 2. Distributions of LBK (left) and post-LBK sites (right) in the study area. Sites are broadly classified as settlement, enclosure, or funerary contexts. Numbers correspond to the site IDs in *Online Supplementary Material 1* (DEM: https://emodnet.ec.europa.eu).

The initial colonisation of the landscape began with pioneer settlements consisting of 2 to 4 farms, each spaced roughly 2–3 km apart (*Zimmermann 2002*, 23). Subsequent developments are comparatively well understood, owing to the intensive, large-scale archaeological investigations conducted in the Rhenish lignite-mining district from the late 1970s onward (*Zimmermann 2002*, 18). This robust dataset not only enables detailed insights into settlement dynamics but also permits calculations of settlement and, ultimately, population densities using the so-called Hofplatzmodell.

The Hofplatzmodell is a methodological framework developed to reconstruct the temporal and spatial structure of LBK settlements (see *Zimmermann 2012* for a summary of the model and extensive discussion of critique). The model aims to determine which

houses were active simultaneously and how individual farmsteads developed through time. In the Rhineland, the Hofplatzmodell led to the distinction of 16 house generations (hereinafter HG I–XVI), which last 25 years on average, based on later calculations involving dendro-calibrated wiggle-matching. Note, however, that HG XVI has so far only been identified in the LBK settlements at Niederkassel-Mondorf and Frimmersdorf 141 (*Broich 2016*, 106–107, 109).

The total number of households per house generation shows that the population in the Rhineland was relatively low in the early phases of the LBK (*Kroon et al. in press*; *Fig. 2*). The current reconstruction for the Aldenhoven Plateau suggests a development from approximately 12 households at the beginning of the local LBK to approximately 70 simultaneous households in the last quarter of the 51st century BC (*Zimmermann et al. 2020*). The typical settlement structure until the Late LBK would consist of large settlements with 7 to 10 simultaneous houses, hamlets with 3 to 4 simultaneous houses and individual farms. The large settlements would have more extensive contact networks and appear to be specialised in specific crafts or features related to long-distance connections (*Zimmermann 2002*, 25). Larger settlements also show a consistency of place with occupation lasting 10 or more house generations (*Zimmermann 2002*, 35). From around 5050 BC, a rapid decline in the number of houses is evident within just three generations (*Zimmermann et al. 2020*). Only a few settlements in the broader region retain Hofplätze dating to HG XV (e.g. Frimmersdorf 141 and Kückhoven, both to the north of the plateau).

Enclosures are common at LBK settlements in the North Rhine area, but only seem to appear in the later LBK (HG XII, *Peters – Zimmermann 2017*, 45). We refer to *Kroon et al.* (*in press*) for a discussion of these structures.

LBK longhouses in the Rhineland have a rectangular ground plan, averaging about 20 m in length and 6.5 m in width. The interior is subdivided by transverse rows of three posts (a four-aisled structure) that carry the roof load. The longhouses often consist of three sections: a northwestern, a central, and a southeastern part. While the central section is always present, the other two sections may be absent (summarised in *Zimmermann et al. 2007*). The central section is considered the living area. Double posts identified in the southeastern sections are interpreted as evidence for an upper storey, which may have served as a storage space.

Generally, it has to be pointed out that our perspective on LBK burial rites in the area under research is hampered by the poor bone preservation in the decalcified loess soils. The scarcity of settlement burials, disarticulated remains, and Late LBK mass graves, compared to other European regions, may partly reflect poor preservation. The Cologne Lowlands feature nine burial sites, ranging from small clusters to large cemeteries (e.g. Jüchen-Holz with 20–30 burials, Niedermerz or Arnoldsweiler-Ellebach with 100–280 burials). These bi-ritual cemeteries (mostly flexed inhumations with fewer cremations) appear from the start of LBK occupation (ca. 5300 BC, HG I; *Morell-Rovira et al. 2025*) and persist until the end of the Early Neolithic (ca. 5000/4950 BC, HG XV; *Balkowski 2024*; *Peters 2024*).

The post-LBK period

Middle Neolithic (following the Southwest German Chronology) inhabitation of the Rhineland emerged only after a gap of approximately 100 years relative to the last LBK occupation (*Zimmermann et al. 2007*, 34), with the Middle Grossgartach phase (*Spatz 1996*;

Broich 2021, 6). *Zimmermann* (*2002*, 34) initially noted that Grossgartach settlements avoided earlier LBK sites, implying discontinuity. However, recent evidence (e.g. Hasselsweiler 1 and 2, Gymnich 'Im Grisfeld'; *Broich 2021*, Appendix 1) shows that some Grossgartach/Rössen sites do overlap with or adjoin LBK locations. This challenges the assumption of discontinuity in land-use selection during the transition (e.g. *Eisenhauer 1999*).

Overall, settlements were still primarily situated in fertile loess plains. However, from the Rössen phase onward, settled areas expanded into less fertile, sandier soils (*Broich 2021*, 90).

Well-documented post-LBK sites like Aldenhoven 1 suggest significantly larger settlements than during the LBK. *Broich* (*2021*, 92) estimates up to 366 inhabitants (versus 70–100 during the LBK), though earlier studies proposed 200 (*Zimmermann 2002*, 34). However, these figures remain uncertain due to the lack of datable Middle Neolithic features (*Suhrbier – Scharl 2023*). Settlements were also relocated every three to four generations, sometimes just 1 km away (*Zimmermann 2002*; *Zimmermann et al. 2007*, 40), and post-LBK settlement density was lower, with Grossgartach and Rössen sites more widely spaced than LBK ones (*Broich 2021*).

During the Early Middle Neolithic (GG), longhouses have a ship-shaped ground plan. From the Rössen phase onward, both ship-shaped and trapezoidal house plans occur (*Suhrbier – Scharl 2023*). In addition, Middle Neolithic house plans are on average larger than those of the LBK. Some Rössen house plans also exhibit an internal subdivision (*Broich 2021*, 69).

Only in recent years have post-LBK inhumation burials been confirmed in the German Rhineland. Two inhumation burials were documented at the site of Erftstadt-Lechenich (Rhein-Erft-Kreis), although it is unknown whether these belong to a settlement or a cemetery due to the small scale of the excavation (*Heinen 2011*, 72–73). The sizes of the burial pits hint at burials in a supine position. These burials were attributed to the beginning of the Grossgartach culture. Cemeteries of the subsequent Rössen culture are so far unknown from the German Rhineland and Limburg (*Louwe Kooijmans 2005*). The burials at Vettweiß-Müddersheim, which were previously thought to be Rössen, could recently be dated to the Bischheim culture (*Scharl et al. 2023*).

Transition

Viewed diachronically, the above considerations indicate a cyclical population trajectory, with a peak during the LBK, followed by a settlement gap and low population during Grossgartach, and then a subsequent rise during the Rössen period. Several explanations have been proposed for the abrupt end of the LBK in the Rhineland. Short-term climatic fluctuations, particularly dry periods, during which the wells documented at LBK sites were constructed, may have played a role (*Zimmermann et al. 2020*; *Broich 2021*). Internal conflicts toward the end of LBK are another possibility, given the emergence of enclosures. Finally, the breakdown of social networks has been suggested as a contributing factor (*Zimmermann et al. 2020*). However, there are traditions in the archaeological record of the Middle Neolithic that are rooted in the LBK (e.g. long-house architecture, shape or decoration of the pottery). They must have developed outside the Rhineland in areas with continuous development and have been reintroduced after the hiatus in occupation, for instance from Southwest Germany, where Grossgartach culture emerges.

The Netherlands

LBK

In the Netherlands, the begin of the LBK is conventionally said to occur after the Flomborn phase, around 5250 BC, following *Lanting and Van der Plicht* (*2002*). *Kroon et al.* (*in press*) propose a slightly later date, ca. 5170–5090 BC (68.3% probability). Settlements in the Graetheide plateau and the Maastricht area are found on both sides of the river Meuse and mainly located on the middle terraces. The LBK cluster is limited to a narrow corridor of approximately 25 km long and 6 km wide in South Limburg. The northern boundary of this settlement cluster lies just north of Sittard. In total, 70 settlements have been discovered, which usually consisted of two to six houses used simultaneously. The earliest settlements are Sittard, Geleen, Elsloo, and Maastricht, on either side of the Maas River. During the Flomborn phase, eight settlements were established. In the subsequent phases, this number increased to over 20 settlements. Most settlements were inhabited throughout the whole LBK, while some, like Geleen-Janskamperveld, show habitation gaps. The number of settlements grew towards the end of the LBK period. At its peak (Modderman ceramic phase 2c), approximately 30–40 settlements were inhabited simultaneously (about one settlement per 4 km²; *Van Wijk in preparation*).

Currently, more than 300 house structures are known from Dutch Limburg. Their orientation is mainly NW-SE/WNW-ESE, while a quarter of the houses are orientated towards the east or north. Type 1A houses are the rarest. These houses often lack the characteristic long pits and associated assemblages of finds. Additionally, they often show signs of fire, as if they had been deliberately burned down (*Van de Velde – Van Wijk 2014*; *Claßen – Schmidt 2019*). The type 1B house is the most common across the settlements. At some sites, such as Maastricht-Cannerberg, both type 1A and 1B are rarely found alongside, but most of the houses belong to types 2 and 3 (*Van Wijk 2016*). There is no shift in tradition regarding the distribution of houses over time, nor for the orientation or number of different house types. All were used until the end. The same goes for their orientation, size, width, and shape. Although some houses have a trapezoidal shape, or have two parallel rows of wall posts, they seem to be isolated occurrences. The only major shift is the alteration of the middle section where roof supporting posts in a Y-configuration gradually shift to a configuration where all the roof posts are aligned.

Three burial grounds are known, including the iconic Elsloo-Koolweg, which was discussed widely due to the numerous cremation burials (*Modderman 1970*; *Van de Velde 1979*; *Van Wijk – Amkreutz 2022*).

After the initial stages of the LBK occupation, a gradual infilling of the landscape with more settlements is observed, especially along rivulets. Additionally, LBK settlements started to appear in less favourable areas, such as the floodplains of the Meuse and high plateaus. This expansion of LBK settlements may suggest demographic stress or a process of familiarisation with the landscape and its resources.

Two trends are apparent during the later stages of the LBK in Dutch Limburg. Firstly, there is evidence for the construction of enclosures (Beek, Kelmond, and Born) towards the final LBK stages. Secondly, the raw material procurement for lithic tools of the LBK communities in Dutch Limburg shifts. Certain settlements increasingly relied on a single specific raw material source (e.g. Banholt or Valkenburg flint), while other settlements

appear to have functioned as regional hubs for flint production. A notable example of this development is the series of pits at Maastricht-Cannerberg. These pits were filled with hundreds of kilos of flint waste and discarded cores, suggesting mass production of flint artefacts and distribution of these artefacts to adjacent LBK communities (*Van Wijk 2016*). Taken together, these findings suggest that the LBK groups in the Dutch Limburg area may have expanded beyond their capacity after the initial settlement of the area. Settlements were then constrained by access to particular sources and task divisions, prompting efforts to establish new exchange networks (*Molthof – Baetsen 2022*). These processes may well have contributed to the demographic stress towards the end of the LBK.

The end of the LBK in Dutch Limburg is marked by a decline in the number of settlements, from 25 known sites during phase 2c to 19 in phase 2d (*Van Wijk in preparation*). By around 4900 BC, there appears to be no direct continuation of the LBK occupation. Instead, Limburg seems to have been entirely abandoned at the end of the LBK, for which a break-down of networks and social structure is suggested (*Amkreutz 2016*).

post-LBK

The post-LBK period in the southern Netherlands is still ill-understood due to a lack of excavated sites. Further north, in the central Rhine-Meuse Delta area, communities of hunter-gatherers, producing Swifterbant pottery (SWB hereafter), imported ceramics from both Blicquy and Grossgartach communities beyond the Limburg area. Earlier imports of southern flint, including an LBK arrowhead and a flint core, are attested at the SWB site of Hardinxveld-Polderweg, which lies to the north of, and thus outside, our study area (*Louwe Kooijmans 2022*). Additionally, Early Neolithic *Breitkeile* are frequently found in the area, with some fragments stemming from SWB sites (*Verhart 2012*). Although no post-LBK Neolithic sites are attested, these exchanges demonstrate that contacts between Neolithic groups (both LBK and post-LBK) and SWB communities were indeed well-established.

The earliest confirmed Neolithic settlement in the southern Netherlands during the post-LBK is the Rössen site of Maastricht-Randwijck, which dates around 4700 BC. This site yielded no house plans, but silo pits and finds indicate *Breitkeil* production. Further finds attributed to the Rössen culture are scarce to date and mostly include isolated *Breitkeile* fragments or sherds. Furthermore, German Middle Neolithic influences (Rössen or Bischheim mainly) are present in ceramics at some Swifterbant sites along rivers, such as Well-Aaijen on the Meuse. The SWB settlement at Angeren yielded Rössen-affiliated pottery alongside evidence for animal husbandry and milk processing during its earliest phase (5000–4500 BC). Only local flint was used at this site (*Van der Leije et al. in preparation*). Traces of grain have been discovered from subsequent settlement phases (4500–3400 BC), along with imported southern flint, which was used for making blades and adzes. Therefore, the post-LBK appears as an amalgamation of Neolithic elements, including aspects of farming communities, together with older traditions. This coexistence of traditions culminates at sites further west, such as Tiel (4400–3900 BC) in the central river area, where clear evidence exists for Bischheim-affiliated pottery and for house architecture in the Bischheim tradition (*Ten Anscher 2023*; *Scharl et al. 2025*).

Transition

Dutch Limburg appears to have been largely deserted by the end of the LBK. Yet, the overall picture of the transition from LBK to post-LBK remains unclear, preventing a definitive conclusion about the potential abandonment of this area. SWB communities in the Netherlands clearly adopt certain Neolithic elements (e.g. ceramic styles, animal husbandry), but these communities also retain practices from their hunter-gatherer background. Ancient DNA analysis of human remains from SWB sites demonstrates that the earliest Neolithic individuals outside the loess and upland sand-covered area are genetically highly heterogeneous. Some individuals in these communities descended entirely from local hunter-gatherer populations, whereas others have genomes evidencing admixtures between hunter-gatherer and early farming communities, but with an emphasis on hunter-gatherer aDNA (*Olalde et al. 2025*).

Hesbaye

LBK

This overview primarily focuses on the LBK settlement cluster in the eastern part of Middle Belgium, also referred to as the Hesbaye region. This settlement cluster represents the earliest LBK occupation within present-day Belgium. The LBK occupation would have begun around 5300 BC (*Hauzeur – Jadin 2025*), though more likely around 5150 BC (*Bosquet – Fock 2025*), as supported by the estimated date range of 5193–5087 BC (68.3% probability) proposed by *Kroon et al.* (*in press*).

The presence of LBK communities in Hesbaye was discovered in the late 19th century by Marcel De Puydt. For an extensive discussion, we refer to one of the author's doctoral dissertations, which remains the most recent comprehensive synthesis of the LBK historiography and inventories of Belgian sites (*Jadin 2003*). More than 200 sites are currently known from Hesbaye (*Hauzeur – Jadin 2025*), but only 30 of them have been thoroughly excavated to date (*Bosquet – Fock 2025*, 1–2). Furthermore, in most cases, excavations do not encompass the entire settlement site, except for Darion.

The LBK settlement dynamics in Hesbaye are ill-understood, but several recent publications have sought to address this issue. *Blouet et al.* (*2021*) have published a typo-chronology for the LBK of the Meuse area. They divide the Meuse chronology into six phases (ME1 to 6) and 14 stages (*Blouet et al. 2021*, 315, Tab. 3). *Bosquet and Fock* (*2025*, 4) highlighted key data limitations which need to be overcome to gain a deeper understanding of settlement dynamics. However, they reconstruct an initial pioneer phase of the LBK inhabitation during which settlers arrived from (potentially) Dutch Limburg (*Blouet et al. 2021*; *Bosquet – Fock 2025*). At the end of the Middle LBK phase (ME3a2), settlement activity in Hesbaye had expanded markedly, and it continued to grow during the Late LBK (ME3b), before undergoing a pronounced decline in the second half of the Late LBK (ME4b1–4b2). The Final to Terminal LBK transition (ME6a–6b) in Hesbaye reveals a concentration of LBK occupation in and around enclosed villages (*Bosquet – Fock 2025*, 6, 8; *Kroon et al. in press*). It was likely during the phase of settlement expansion that a surplus production of flint blades was established by specialist knappers in this area (*Allard 2007*). As mentioned for the Netherlands, this surplus of blades is structuring new exchange networks.

While the internal layout of LBK houses follows a standardised, long-lasting spatial organisation consisting of predominantly rectangular or slightly trapezoidal floor plans, divided into three functional areas, regional nuances distinguish local adaptations of this model (*Hauzeur – Jadin 2025*). The dominance of houses with rear foundation trenches for exterior wall posts represents a specificity of our studied area (*Hauzeur – Jadin 2025*).

The poor preservation of skeletal remains mentioned earlier also affects LBK sites in Hesbaye. No cemeteries with inhumation burials have been excavated yet. Nevertheless, several lines of evidence suggest the existence of a (cremation) cemetery at Hollogne-aux-Pierres (*Thisse-Derouette et al. 1952*).

Post-LBK

Post-LBK sites in Belgium are attributed to the Blicquy/Villeneuve-Saint-Germain culture (henceforth BVSG; *Constantin – Demarez 1984*). The identification of the BVSG culture was based, among others, on the presence of schist bracelets and bone temper in pottery (*Constantin – Courtois 1980*; *Constantin – Demoule 1982*). In addition, the house plans of these groups become more trapezoidal as opposed to the rectangular plans of LBK groups (*Constantin 1985*).

Only two BVSG sites are known from Hesbaye: Vaux-et-Borset and Darion. In Vaux-et-Borset, the BVSG settlement is constituted by at least five badly preserved buildings, complemented by silo pits (*Caspar et al. 1989*; *Burnez-Lanotte et al. 1993*). Another BVSG site was discovered in Darion, 8 km north of Vaux-et-Borset, during rescue work on the nearby LBK enclosure (*Jadin 2003*). Excavations revealed about ten structures, several post-hole clusters, and the only BVSG burial known in Belgium.

Transition

The sharp decline in settlement activity towards the end of the LBK inhabitation in Hesbaye appears to represent a long-term trend, and only limited reoccupation of this territory occurred during the BVSG period. Furthermore, the emergence of enclosures towards the final stages of the LBK inhabitation is interpreted as an indicator for a '*major crisis amongst the local LBK populations, or between Hesbaye groups and those from other regions or cultures*' (*Bosquet – Fock 2025*). This proposal aligns with *Shennan's* (*2018*, 101–104) broader-scale interpretations, particularly in Central Europe, where such a crisis is attributed to ecological and demographic factors. Nevertheless, several continuities between the LBK and post-LBK occupation of Hesbaye are evident from the archaeological record. *Bosquet and Fock* (*2025*) also note that two BVSG sites are located close to LBK enclosures and on the western margins of the LBK occupation clusters. Moreover, analyses of lithic and ceramic technology conducted on LBK and post-LBK assemblages detected three distinct processes (*Denis et al. 2024*). Firstly, a continuity in the transmission of technical knowledge in lithic and ceramic production between the LBK and BVSG groups in Hesbaye. Despite the marked demographic decline at the end of the LBK, systems of knowledge transmission in these communities were not entirely disrupted. Certain social groups appear to have endured, ensuring the persistence of technical traditions across the transition from the LBK to the BVSG period. The second trend consists of evidence for exogenous influences from other Danubian settlement areas. These influences can be traced both to eastern (Moselle and northern Rhine) and western regions (Hainaut and the

Aisne Valley). The occurrence of exogenous technical traditions in Hesbaye during the BVSG phase indicates that increasing population mobility within the LBK sphere itself played a key role in shaping the LBK/BVSG transition in this area. Lastly, evidence of technical syncretism can be observed within pottery and lithic technical systems. This development required sustained interaction between producers from distinct learning networks (*Roux et al. 2017*). The western and eastern influences in BVSG technical subsystems thus suggest exogenous populations integrating into Hesbaye's LBK communities at the turn of the fifth millennium, creating the observed technical syncretism. Further studies of technological processes among LBK and post-LBK communities in Hesbaye will be key to refining and expanding upon these observations.

Synthesis: Going beyond the research traditions

Attempts have been made previously to connect the Dutch, German, and Belgian research traditions in the study of LBK and post-LBK in the area. In particular, the recognition of exogenous objects at LBK sites has resulted in attempts to identify exchange networks and the circulation of objects across national borders (e.g. *Zimmermann 1995*; *Allard 2005*; *De Grooth 2015*).

More recently, attention has also been drawn to potential population movements. In particular, *Balkowski* (*2017*) has argued for a migration of LBK populations between the Merzbachtal (Germany) and the Graetheide plateau (Netherlands). This hypothesis was based on a comparative analysis of settlement dynamics, focusing in particular on the number of contemporaneous houses per house generation. *Balkowski* (*2017*) demonstrates that while the population density declined in the Merzbachtal after HG XII, intensive building activity began at Elsloo, resulting in a net increase in houses during HG XIII. Such a trend could result from population movement between these areas.

Post-LBK examples also transcend modern boundaries, with evidence including BVSG contacts with archaeological cultures from the Upper Rhine Valley (Hinkelstein, Grossgartach; *Constantin – Ilett 1998*). It is documented, for instance, by shared architecture or ceramic styles and imported BVSG bracelets in Hinkelstein (*Meier-Arendt 1975*) or Rössen contexts (*Gehlen – Schön 2007*). BVSG sherds in Grossgartach pits (*Spatz 1991*) and BVSG-SWB pottery links (*Teetaert 2020*) further highlight cross-cultural exchanges, crucial for understanding post-LBK cultural recomposition.

Interpreting LBK and post-LBK cross-border activity hinges on ceramic typo-chronologies, which can radically reshape population dynamics. *Blouet et al*. (*2013*; *2021*) have pioneered this effort, expanding typo-chronologies from eastern France to Hesbaye, Hainaut, and Dutch Limburg, offering a first unified regional sequence. Yet gaps remain in integrating these sequences (*Kroon et al. in press*), and debates persist over the validity of ceramic seriation (*Trampota – Květina 2020*).

In summary, two key points emerge about the Early Neolithic in the Rhineland, Dutch Limburg, and Hesbaye. First, these clusters were tightly interconnected during the LBK and post-LBK. Second, the transition to the post-LBK period reflects instability, marked by enclosures and depopulation, without compensatory growth in surrounding areas, indicating a population decline rather than relocation. Yet, enduring technical traditions in Hesbaye reveal structural resilience amid demographic disruption. Understanding these dynamics requires aligning analytical scales, methods, and chronological frameworks.

Lithic case studies as examples of cross-border initiatives

We propose three research priorities to elucidate the overarching population trajectories and dynamics during the LBK/post-LBK transition. First, establishing a shared chronological framework, underpinned by absolute dating, is essential (*Kroon et al. in press*). Second, we advocate for the standardisation of analytical methods across research traditions, ensuring comparability and robustness in our findings. Third, integrating modelling approaches offers a critical tool for unravelling the complex interplay of socio-economic dynamics that characterised this transitional period.

Harmonisation of lithic study method: the potential

To date, lithic finds from Hesbaye, Limburg, and the Rhineland have been studied through entirely different research approaches, particularly those in Germany and Belgium (*Scharl et al. 2021*). German studies of archaeological artefacts are predominantly focused on statistical analysis of a specific set of attributes, whereas Belgian studies tend to follow a qualitative, typo-technological perspective. Studies on LBK artefacts from Dutch Limburg are heterogeneous but tend to be closer to the technological approach based on the *chaîne opératoire* concept (e.g. *De Grooth 1987*). Since 2017, the harmonisation of analytical practices of lithic assemblages between France, Belgium, and Germany has been undertaken within the framework of Franco-German collaborative projects funded by the Franco-German University (see acknowledgements section; *Scharl et al. 2021*). Harmonising methods across research teams, while respecting distinct traditions, requires time, particularly to align on raw material characterisation, reconcile the *chaîne opératoire*-approach with German SAP/SDS systems, and standardise quantitative and statistical data analysis.

The potential of this harmonised approach is evident in comparative technological analyses of post-LBK lithics from the Aldenhoven Plateau (Grossgartach–Rössen) and BVSG Hesbaye. While earlier raw material and typological studies (e.g. *Gehlen – Schön 2007*; *2009a*; *2009b*) identified regional exchanges, technological analysis also offers insights into how knowledge was transmitted between these areas.

Comparing raw materials and *chaînes opératoires* demonstrates technological transmission from Hesbaye to the Aldenhoven Plateau. A blade from Hambach 260, likely knapped from a Vaux-et-Borset core (*Fig. 3*), provides direct evidence of this link. More broadly, both regions exhibit a parallel shift toward simple flake production, a method requiring minimal knapping expertise. While this tradition was already well-established in Hesbaye, it was adopted later in the Rhineland (*Denis 2025*). This transfer of low-skilled knowledge, from Hesbaye to the Rhineland, likely occurred through social learning and oral transmission within loosely connected communities (e.g., *Perlès 2012*).

Transmission from the Rhineland to Hesbaye presents a more complex pattern. Post-LBK lithic analysis from the Aldenhoven Plateau uncovered an unrecognised technical tradition (*Fig. 4*; *Denis 2020*), characterised by dihedral butt preparation, which is absent in the broader BVSG sphere. However, these features appeared selectively in Vaux-et-Borset's learning networks, but not in Darion's assemblages. This asymmetrical adoption suggests either direct interaction between Rhineland and Vaux-et-Borset knappers or local reinterpretation of external techniques within Hesbaye's communities.

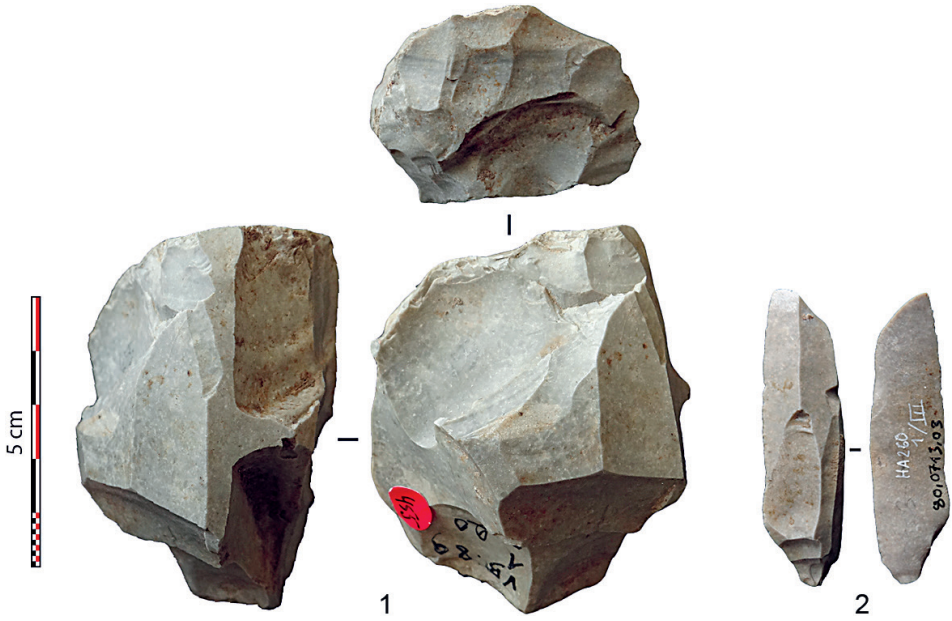


Fig. 3. Core discovered at the BVSG site Vaux-et-Borset in Hesbaye (1), and (2) a blade recovered at Hambach 260 (Rhineland). The raw material of the blade and core is identical. It is the so-called 'Ghlin-Douvrain flint' which, here, probably originated from a secondary position and is highly characteristic of BVSG lithic production of Middle Belgium. The blade identified at Hambach exhibits similar raw material and production characteristics, suggesting that it may have been produced from the same block.

Post-LBK lithic analysis reveals asymmetrical, bidirectional knowledge transfer between Hesbaye and the Rhineland, despite their distinct cultural affiliations. This exchange appears to have been more intensive than during the LBK period. Indeed, during the LBK, Campanian (Hesbaye) and Maastrichtian (Rijckholt) flint networks remained largely separate, with limited blade exchange suggesting sporadic contact (*Zimmermann 1995*; *Allard 2005*). The post-LBK surge in knowledge and artefact circulation between these regions is therefore striking. To build on these findings, expanding comparative analyses and integrating data from diverse research traditions will be essential. Further study of LBK technical traditions in Dutch Limburg (where Hesbaye flint is consistently found on sites) and in the Rhineland is needed to understand how technical skills and knowledge spread between these regions.

Modelling

Network modelling of raw material distributions

Our final research priority focuses on refining methods to study mobility and settlement dynamics in Early Neolithic populations. Network analysis, grounded in graph theory, offers a powerful quantitative approach to explore social connectivity and mobility (e.g. *Wasserman – Faust 1994*; *Barthelemy 2014*; *Crabtree – Borck 2019*; *Brughmans – Peeples 2023*).

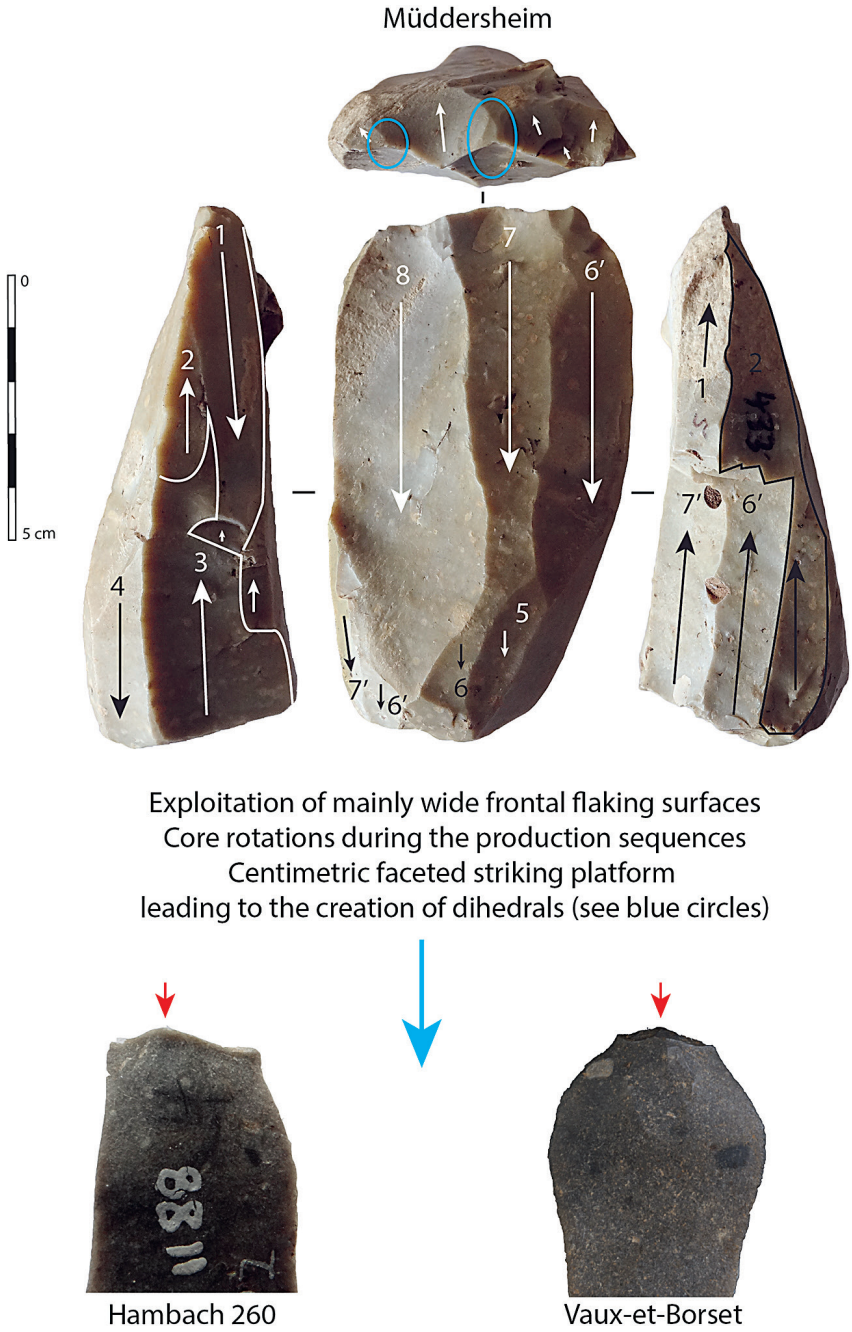


Fig. 4. Technical characteristics of specific blade production strategies during the post-LBK period in the German Rhineland. This strategy employs indirect percussion techniques for blade detachments but produces blades with dihedral butts, which is highly unusual for this technique. Traces of this strategy have also been observed on a few blades from the BVSG site of Vaux-et-Borset. These blades, especially on local raw materials, were likely locally produced, providing evidence of technical transfer between the two regions.

Raw material exchanges reflect and shape social relationships, with distribution patterns serving as proxies for social networks (*Kerig – Shennan 2015*, iv–viii). By analysing multiple raw materials simultaneously across large regions, we identify key network parameters that reveal the formation, differentiation, and long-term transformation of communities (*Kerig et al. 2023*) through the construction of similarity networks (*Östborn – Gerding 2014*). This approach does not reconstruct the exact exchange pathways but delineates 'raw material spheres' – socially meaningful connections inferred from the spatial overlap of raw materials, which also reflect information transmission.

Data

Two datasets were used to reconstruct raw material spheres in the LBK and post-LBK periods. For the LBK period, the dataset stems from the database of sourced raw materials built up during the Big Exchange project (Excellence Cluster ROOTS/Datencampus CAU Kiel). This dataset takes into account the subset of raw materials in lithic artefacts used for everyday purposes dating between 5400–4900 BC (*Kerig et al. 2023*; *Kerig – Hilpert in press*). For the western area of the LBK, the dataset covers the distribution of Rijckholt flint (based on *Zimmermann 1995*; *Allard 2005*; *Kerig 2008*; *Scharl 2015*) and Abensberg-Arnhofen flint (*Roth 2008*). This dataset was supplemented with detailed information about lithic raw materials collected by one of the authors (*Allard – Delvigne 2025*) and based on synthetic studies by *Zimmermann* (*1995*) and *Schmidgen-Hager* (*1993*). The quality of information relating to the determination of raw materials varies considerably. As a result, the frequencies of raw materials were only available for 50 sites from these combined datasets. The siliceous rocks in these structures belong to eight groups of materials, identified through naked-eye inspection: Abensberg-Arnhofen cherts (DE), Rijckholt flints (NL), Hesbaye flints (BE), Ghlin flint (BE), Rethel Turonian flint (FR), Tertiary siliceous rocks (FR), Campanian flints from the Saint-Gond marshes in Champagne (FR), and the Malm cherts of Alsace (FR).

For lithic raw materials used by post-LBK communities, we employed a dataset compiled by one of the authors, based on the work conducted during her PhD and postdoctoral research (*Denis 2017*; *Denis et al. 2019*). This dataset was complemented with further studies on the Rhineland (especially *Nowak 2013*; *2014*), on Eastern France, Luxembourg (*Asselin et al. 2017*), and on the circulation of Tertiary siliceous rocks from the Paris Basin (*Bostyn et al. 2019*; *Kempf – Denis 2024*). Note that we exclude the westernmost area of the BVSG extension in our analysis, given that raw material circulation in this area is already well-documented (*Charraud 2022*). The siliceous rocks in this database are classified into six material categories, all of which demonstrate circulation extending beyond regional studied clusters. They are generally identifiable with the naked eye, including the Rijckholt flints (NL), Rullen flint (NL), Cretaceous Hesbaye flints (BE), Ghlin flint (BE), Tertiary siliceous rocks (FR), and 'black flint', whose outcrops can not be geographically located yet (*Denis et al. 2019*).

Method

The distributions of these raw materials are not analysed at the site level but at a generalised spatial scale suitable for comparing broader patterns of availability and circulation. For this purpose, the study area is overlaid with a regular grid of 12.5 × 12.5 km cells.

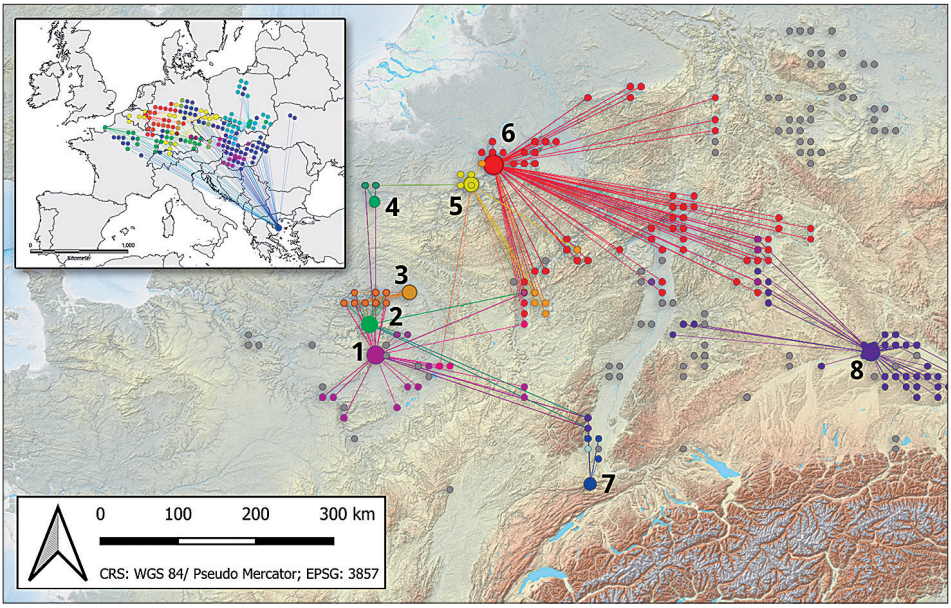


Fig. 5. Bimodal network of raw material distribution and their sources for the LBK period. Raw material sources: 1 – Campanian of Champagne; 2 – Tertiary silicites; 3 – Turonian flint; 4 – Ghlin-Douvrain; 5 – Hesbaye; 6 – Rijckholt; 7 – Malm; 8 – Abensberg-Arnhofen. Inset: comparative reference showing an earlier network visualisation of the distribution of six sourceable raw materials within the LBK after *Kerig et al. 2023* (DEM: https://emodnet.ec.europa.eu).

The corners of these cells function as points in the model. This grid cell size lies within the limit of 'local' raw material distributions as proposed by *Kerig* and *Shennan* (*2015*) or *Mateiciucová* and *Trnka* (*2015*). Moreover, the regular grid provides a scale that smoothens local variability while preserving regional patterning. Following the projection of this grid, we applied a 9 km buffer around each recorded find of a specific raw material. All grid points within this buffer were assigned the presence of the respective material. This step was repeated for each of raw material categories.

The resulting spatial dataset is first represented as a bipartite network with two sets of nodes. The first set of nodes represents the origin point of the raw materials. The second set of nodes contains the grid points. Links between nodes in these two partitions are inserted if the grid points are within the buffer around a site at which objects made with the raw material were found. Since the buffers of multiple raw materials may overlap, grid points may feature links to several raw material sources (*Fig. 5*; *Fig. 6*).

For further analytical interpretation, the bimodal networks are projected into unimodal (one-mode) networks (*Fig. 7*; *Fig. 8*). This procedure takes all grid points which share at least one raw material and connects these with a link. The strength of this link is then adjusted to reflect the number of raw materials shared. The more raw materials two grid points have in common, the higher the edge weight of the link between them. This transformation allows for the detection of spatial clusters and structural relationships which emerge from shared raw material signatures and provides a basis for modelling larger-scale interaction patterns. In the presented visualisations, colour intensity and size are according to

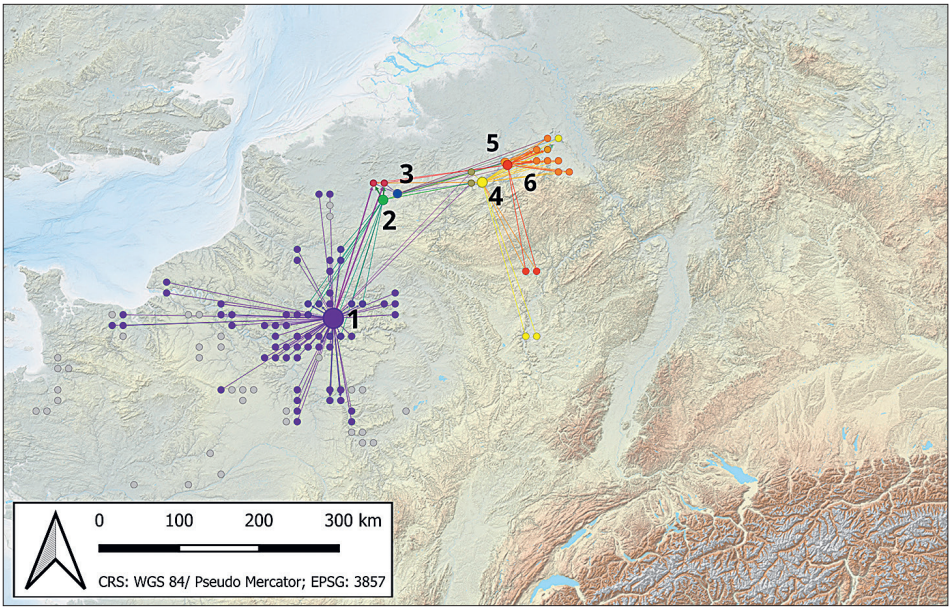


Fig. 6. Bimodal network of raw material distributions and their sources for the post-LBK period. Raw material source: 1 – Tertiary silicites; 2 – Ghlin-Douvrain; 3 – 'black flint', source area unknown; 4 – Campanian Hesbaye; 5 – Rullen; 6 – Rijckholt (DEM: https://emodnet.ec.europa.eu).

'betweenness centrality'. A node has high 'betweenness centrality' if it lies on many of the shortest paths between other nodes. In other words, it often acts as a bridge or mediator in the flow of information, resources, or interactions within the network.

Comparison between regional or large-scale LBK networks

This exploratory network analysis of regional raw material distribution (*Fig. 5*) demonstrates the value of combining fine-grained regional studies with large-scale perspectives. By incorporating previously missing data on western LBK networks, earlier inferred only from other materials like Spondylus or Atlantic shells (*Kerig et al. 2023*), the approach gains robustness.

Regional datasets reveal local dynamics, while broader syntheses provide the comparative framework to situate these within macro-regional patterns. For cross-border research on western LBK/post-LBK contexts, this multiscale integration is critical: it captures micro-regional variability alongside transboundary interaction processes, lending models both explanatory depth and spatial relevance.

Regional structures in the LBK network

Two outcomes of the network analysis stand out in this context (*Fig. 7*). The first is the weak relationship between LBK communities from Hesbaye and those which use the Rijckholt flint from Dutch Limburg. The second result is the network density in the Moselle corridor (upper Moselle Basin).

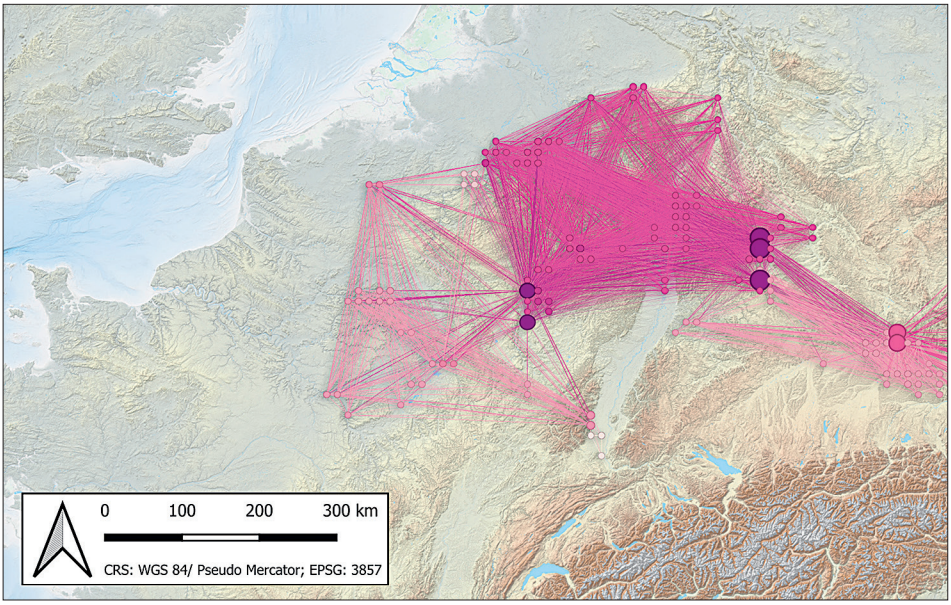


Fig. 7. Projected unimodal raw-material network of the LBK derived from the bimodal network shown in *Fig. 5*. Grid nodes are connected when they share at least one raw material; edge weights indicate the number of distinct raw materials shared. Node size and colour intensity reflect betweenness centrality.

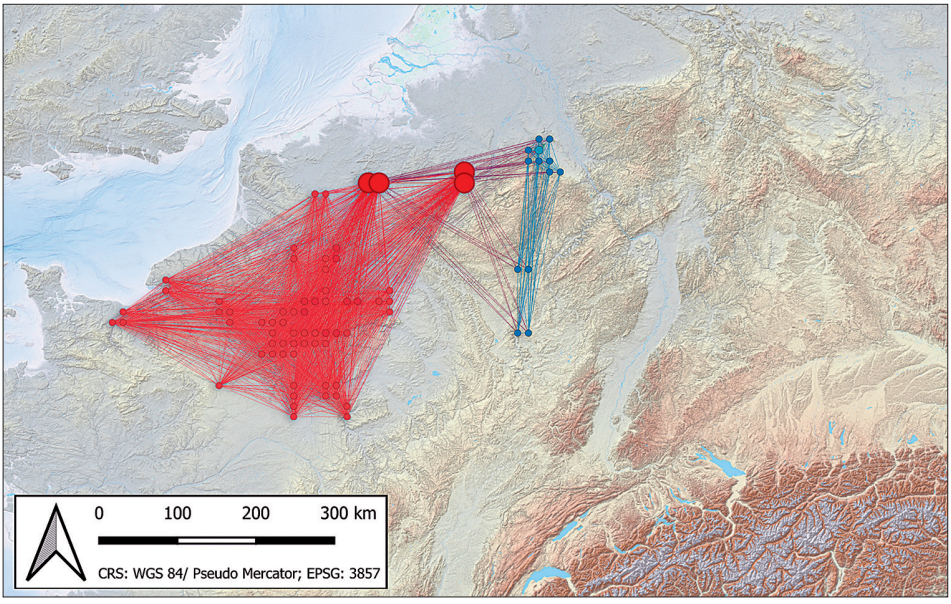


Fig. 8. Projected unimodal raw-material network of post-LBK derived from the bimodal network shown in *Fig. 6*. Grid nodes are connected when they share at least one raw material; edge weights indicate the number of distinct raw materials shared. Node size and colour intensity reflect betweenness centrality.

The separation between LBK communities employing Campanian and Rijckholt-type flint is visible both in the models and the underlying data on the frequencies of both raw materials at LBK sites. This separation seems to indicate a boundary in the supply chain for flint, although we should acknowledge that small numbers of flint artefacts do cross this boundary (*Zimmermann 1995*; *Allard 2005*; *Allard – Delvigne 2025*). The separate communities in terms of raw material sources need not indicate a deeper separation between LBK communities. In fact, no other arguments can be given for a boundary between the LBK sites in Hesbaye and those from Dutch Limburg and Rhineland. Therefore, a more parsimonious interpretation is preferred, namely that both communities rely on the nearest available flint source. In this case, the network analysis of raw material distributions substantiates a number of less systematic observations from analyses of LBK lithic assemblages.

The second observation which stands out from the network analysis is the density of the network in the Moselle basin. This observation also corroborates previous studies of lithic and ceramic industries in this area. Typological studies of decorated LBK vessels from the Moselle have shown that this region was at the crossroads of several groups whose territories and levels of influence changed over time (*Blouet et al. 2021*). In particular, communities in the Moselle basin are argued to have maintained interactions with LBK communities around the Meuse, Aldenhoven Plateau, the Main, and the Lower Neckar (*Blouet et al. 2013*). The variations in influences are significant according to the chronology. Studies of LBK ceramic technology have also demonstrated close interactions with LBK communities in Hesbaye, especially during later stages of the LBK (*Denis et al. 2024*). The Moselle area's role as a hub is reinforced by lithic studies, despite its understudied industry. Preliminary research highlights its central position in flint circulation, particularly from Hesbaye and Rijckholt (*Allard 2005*; *Blouet 2005*). During the Late LBK, the Thionville region shows strong ties to Hesbaye, with nearly 80% of its flint tools sourced from Campanian flint (*Blouet et al. 2021*). A finer chronological analysis of these networks could clarify interactions between competing systems: Rhine Valley, Rijckholt flint distribution to the Meuse Valley, and Hesbaye's circulation networks. Thus, the network-based approach applied here to the lithic raw materials corroborates the outcomes of previous studies of lithic raw materials, ceramic typology, and ceramic technology. All four approaches indicate the Moselle region functioned as a crossroads of LBK communications. However, the advantage of the network analysis of raw materials is that its outcomes and conclusions are based on explicit, quantifiable factors which contribute to the robustness and replicability of the conclusions.

Regional structures in the post-LBK network

Comparison between the outcomes of the network analysis for the LBK and post-LBK period should be approached with caution. In particular, further research is needed on stone tool assemblages from post-LBK sites in Eastern France and the Rhine region to expand our understanding of and refine the scope of post-LBK circulation networks. Nevertheless, one intriguing pattern in the networks can be highlighted: a marked change in the structural position of nodes in Central Belgium (*Fig. 8*).

Traditionally, studies of siliceous raw material circulation, especially Tertiary silicites, have been confined to the distribution of BVSG (e.g. *Bostyn et al. 2019*; *Kempf –*

Denis 2024). The Hainaut and Hesbaye clusters were deemed to be peripheral within BVSG exchange networks. The incorporation of post-LBK sites from the Rhineland and the harmonisation of analytical methods across all regions enables us to show that this marginal role is the result of the limited geographic scope. The network analysis of raw material distributions shows that Hainaut and Hesbaye were not marginal during the post-LBK period, but became major hubs for communities in Belgium and the Rhineland. The prominence of Hesbaye in the raw material networks corroborates analyses of technical traditions in lithic production. These analyses show that the flint knappers at the two BVSG sites were familiar with a wide range of technical traditions, including those from the Rhineland (see above and *Denis et al. 2024*). This observation can be understood in light of the crucial role Hesbaye played in raw material distribution networks during the post-LBK period. It may reflect its strong connective function across different cultural entities. These communities appear to inherit the prominent structural role which communities in the Moselle held during the LBK period.

Discussion

The need for more harmonisation

The harmonisation of analytical methods is essential to bridge divergent research traditions, such as the qualitative *chaîne opératoire* framework and Germany's quantitative analyses. By harmonising these approaches, researchers can transcend mere raw material sourcing and instead trace the transmission of technical knowledge and social learning across communities. When combined with network modelling, this integration offers a robust quantitative toolkit to map social connectivity and mobility. Network analysis not only identifies structural hubs through transparent, replicable data but also reveals hidden patterns of connectivity, challenging traditional assumptions about marginality. Together, these methods link micro-regional nuances with macro-scale dynamics, demonstrating that regions once considered peripheral often functioned as critical nodes of cultural and economic exchange.

This call for harmonised cross-boundary analysis must extend to other technical subsystems. In this respect, the analysis of ground-stone tools has made great progress. Pioneering studies were performed on finds from the Aldenhoven plateau (*Zimmermann 1988*; *Graefe 2004*). These studies set a baseline for the typology of these tools and the analysis of ground stone tools in LBK settlements in their landscape. Since then, studies conducted in the Paris Basin (*Hamon 2006*; *2022*), Hainaut (*Hamon 2008*), Hesbaye as well as in Dutch Limburg (*Verbaas – Van Gijn 2007*; *Van Gijn – Verbaas 2009*; *Verbaas 2014*) were based on a systemic technological approach which looked at the provenance, shaping operations, and use-wear of ground stone tools. They highlighted that structured quern hoarding is a practice more intensively represented in the north-western LBK (Belgium and the Paris Basin), whereas these tools are entirely absent from Dutch deposits and are traditionally placed in burials rather than domestic pits within the Rhineland (and Alsace). Furthermore, the transition to the post-LBK (BVSG) is marked by the replacement of long overlapping grinders with short types, probably reflecting more cultural shifts than functional ones.

In stark contrast, ceramic technology studies have not benefited from the same level of systematic investigation, making harmonised analysis particularly urgent in this field. To date, technological analyses of LBK and post-LBK pottery have been conducted in the Paris Basin and Belgium (*Van Doosselaere et al. 2013*; *2016*; *Gomart 2014*; *Teetaert 2020*). However, no such study exists for LBK or post-LBK pottery from the Aldenhoven Plateau or Dutch Limburg. A postdoctoral research project led by one of the authors (EK) will address this gap by examining several LBK sites on the Aldenhoven Plateau.

Our challenge is to expand regional best practices across LBK and post-LBK communities, using high-end artefact analysis to trace the contacts and technological exchanges that defined these periods. This cross-boundary approach will ultimately reveal the hidden connectivity of communities once considered peripheral, offering a more inclusive and nuanced understanding of prehistoric cultural and economic networks.

The LBK/post-LBK transition

The transition from LBK to post-LBK across the Rhineland, Dutch Limburg, and Hesbaye is marked by a pronounced decline in settlement activity, though the rhythm and intensity of this decline vary regionally. Despite these regional declines, the post-LBK period eventually saw a resurgence after a gap in some areas, such as the Rhineland, where Rössen settlements expanded into less fertile soils and reached population levels comparable to the LBK (*Broich 2021*). In contrast, Dutch Limburg remained largely unoccupied until the Rössen period (ca. 4700 BC), with only sporadic evidence of SWB interactions (*Amkreutz 2016*). The Hesbaye region, while hosting a few BVSG sites, did not recover its LBK-level density, suggesting a long-term demographic shift.

Architectural traditions during the transition reflect both continuity and innovation. LBK longhouses were standardised, mostly rectangular, with internal subdivisions, often featuring rear foundation trenches. In the post-LBK Rhineland, Grossgartach and Rössen houses adopted ship-shaped or trapezoidal plans, with some Rössen houses exhibiting internal subdivisions (*Broich 2021*). Dutch Limburg lacks evidence for post-LBK houses, but Rössen influences are attested in the southern Netherlands (e.g. Maastricht-Randwijck; *Van Wijk in preparation*). BVSG houses became more trapezoidal, diverging from LBK rectangularity (*Constantin 1985*). However, no well-preserved house plans have been documented in Hesbaye. The persistence of longhouse architecture indicates a selective retention of LBK building traditions, albeit adapted to new socio-economic contexts.

Funerary practices highlight regional disparities in the visibility of the transition. In the Rhineland, LBK cemeteries (e.g. Arnoldsweiler-Ellebach) persisted until the end of the period, with bi-ritual burials (inhumations and cremations) suggesting social cohesion despite demographic stress (*Peters 2024*). A paucity of cemeteries marks the post-LBK period. Rather than a mere absence of data, this pattern may reflect a broader transformation in ritual behaviour, including a possible sacralisation of the domestic sphere (see *Hamon 2020* for the Middle Belgium area).

The standardised production of short blades by indirect percussion, combined with a very uniform toolkit, represents the hallmark of LBK groups across all studied regions (e.g. *Allard 2005*). Further research is required to define the precise technical traditions, as recent studies have revealed diversity between LBK groups (e.g. *Denis et al. 2024*). By the Late LBK, all three regions experienced a shift toward specialised blade production,

generating surplus beyond household needs. This development paralleled the expansion and density of LBK circulation networks, which largely collapsed at the dawn of the 5th millennium BC. Post-LBK lithic analyses reveal a marked increase in simple flake-based productions, indicating a reorganisation in the distribution and transmission of knapping skills. While blade production became quantitatively marginal, it displays growing technical variability across the study area, pointing to increased mobility and the integration of external influences.

Ceramic technology remains understudied, yet available evidence reveals comparable patterns of continuity and transformation. In Hesbaye, LBK ceramic traditions persist into the BVSG phase, blending with exogenous influences from neighbouring LBK regions (*Van Doosselaere et al. 2016*; *Denis et al. 2024*). However, the Aldenhoven Plateau and Dutch Limburg still lack systematic technological investigations, leaving significant gaps in our understanding of post-LBK pottery developments. The presence of BVSG sherds in Grossgartach contexts (*Spatz 1991*) and the documented BQY/SWB ceramic connections (*Teetaert 2020*) suggest cross-cultural interactions, though the extent and social implications of these exchanges remain poorly defined.

Network modelling can help to improve the understanding of these dynamics. The raw material distribution reveals structural shifts between the LBK and post-LBK periods. During the LBK, the Moselle corridor acted as a central hub, linking Hesbaye, the Aldenhoven Plateau, and the Main/Neckar regions (*Blouet et al. 2021*; *Kerig et al. 2023*). In the post-LBK, Hesbaye and Hainaut emerged as major nodes, replacing Moselle's dominance and facilitating exchanges between Belgium and the Rhineland. The Rhineland's post-LBK settlements expanded into sandier soils, reflecting new strategies (*Broich 2021*), while Dutch Limburg's role diminished, with SWB communities mediating contacts with Blicquy and Grossgartach groups (*Louwe Kooijmans 2022*), perhaps along riverine corridors. The transition thus involved a reconfiguration of connectivity, with peripheral regions (e.g. Hesbaye) gaining prominence as former hubs (e.g. Moselle) declined. This shift challenges traditional assumptions about marginality and underscores the dynamic nature of Neolithic communication spheres.

The LBK/post-LBK transition in northwestern Europe invites interpretation through several non-exclusive, interconnected hypotheses. Demographic decline is consistently observed across all regions, though its tempo (*Kroon et al. in press*) and underlying causes, whether climatic stress, disease, internal conflict, or migration, likely varied. Regardless of the specific triggers, instability marked the Late LBK phase in the study area. Yet, the persistence of technical traditions, such as lithic knapping practices or pottery making in Hesbaye, indicates that social learning networks endured despite demographic disruption. Migration and mobility also appear to have contributed to the transition mechanisms. For example, regional repopulation, as seen in the Grossgartach resettlement of the Aldenhoven Plateau, is potentially driven by groups originating from outside the core study area. Meanwhile, the adoption of Neolithic traits by SWB communities in the Netherlands points to cultural hybridisation rather than wholesale population replacement. Finally, economic reorganisation is suggested by the transition from LBK surplus production to post-LBK diversification, including the establishment of new raw material networks or subsistence strategies. Together, these dynamics reflect the adaptive resilience of social structures amid environmental and demographic disruptions, with formerly peripheral regions emerging as key nodes within reconfigured exchange systems.

Conclusion

This article offered us the opportunity to create an up-to-date overview of the current state of knowledge about the LBK and the transition from the LBK to the post-LBK in Hesbaye, Dutch Limburg, and the German Rhineland. Moreover, it enabled us to bring together researchers from the different national research traditions in which these areas are normally studied. Only through such a collective effort can we identify the limits of our current understanding of this period and outline potential new avenues for research.

The examples presented are not an end in themselves. Significant work remains to fully unlock the potential of this cross-boundary research. In the future, we must expand the lithic technological dataset, especially on the numerous LBK sites. We should also shift our modelling focus, moving beyond material circulation to examine the transmission of technical knowledge. By mapping learning networks, we can gain deeper insights into mobility patterns and interactions between groups. This approach will provide a more nuanced understanding of how skills and innovations spread across prehistoric communities.

The LBK/post-LBK transition across the north-western European corridor is a multifaceted phenomenon in which demographic decline, social restructuring and cross-regional exchange intersect. Current obstacles, as fragmented chronologies, divergent analytical traditions, limited spatial modelling, sparse funerary evidence, and scant genetic data prevent a fully integrated interpretation.

We show that in all three regions, the transition from the LBK to the post-LBK period is a phase of instability. Further studies are required to verify and better understand the rhythm and dynamics at play during the transition from LBK to post-LBK. In particular, the harmonisation of the analytical method of artefacts can shed new light on knowledge transmissions between the studied regions. Initial steps have been initiated but require further effort from scholars working in all three areas. Lastly, we have shown the outcome of new efforts to model the raw material distribution networks of LBK and post-LBK communities. This network modelling approach not only moves beyond initial interpretations to renew our understanding of connectivity and proximity between LBK and post-LBK cultural entities, but also establishes a quantitative, scalable, and reproducible framework for analysing their interactions. Its future potential lies in integrating spatial, technical, and temporal dimensions, for example, by cross-referencing distances between technical traditions (cf. method developed for pottery analysis in *Kroon 2024*) with high-resolution radiocarbon chronologies. This parameter is indeed fundamental to refining our understanding of connectivity between the different regions. The work conducted by *Kroon et al.* (*in press*) highlights both the challenges and, above all, the urgent need to renew efforts in absolute dating of archaeological remains from this period. By synthesising raw material distributions, technical knowledge, and chronological data, this method offers a pathway to reconstruct Neolithic societal transformations as interconnected systems.

We believe that implementing a coordinated research agenda which integrates better dating protocols, shared analytical frameworks for artefacts, and sophisticated spatial modelling will enable archaeology to move beyond the confines of modern political borders in understanding key transformations in Neolithic societies. Such a collaborative framework will lay the foundations for a new generation of comparative studies, significantly advancing our understanding of Early Neolithic societies in Western Europe.

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