Lithic industries and stylistic entities during the Early Neolithic (LBK) in the Rhine-Meuse-Seine basins

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Abstract:

The study of the decorated ceramics of the *Rubané* or *Linearbandkeramik* (LBK) has long structured the construction of the chronological sequence of the Early Neolithic of northwestern Europe. Recent contributions make it possible to individualize regional stylistic groups. Examination of the different regional corpuses shows that, following the break-up of a common stylistic stage known as the Flomborn entity, the decorative elements of each region evolved differently giving rise to individualised entities that sometimes seem very homogeneous in terms of the style of decorations used (*e.g.,* the Rhine-Meuse ensemble of the Middle *Rubané*).

This contribution aims to compare the results obtained from the ceramic corpus with those of the lithic industry. It shows that out of a common base, regional differences emerged that are also quite significant, whether from the point of view of the procurement of raw materials, reduction process or tool typology. For example, the geographical networks of raw material circulation reveal preferential axes between certain regions (such as the northern and southern parts of the Ardennes Massif) or, on the contrary, border effects that must be compared and contrasted with the entities previously defined on the basis of decorated ceramics. The theoretical significance of these initial observations and the contribution that the techno-economic analysis of lithic industries can drive to the understanding of the relations between communities in the Early Neolithic of the Rhine-Meuse-Seine basins will be examined through network analysis.

Keywords: lithic industry; Early Neolithic; *LinearbandKeramik*; circulation network; technological traditions

All the term followed with an asterisk (*) are defined in a lexicon at the end of this paper.

1. Introduction and background

The study of decorated ceramics has long structured the construction of the chronological sequence from the Early Neolithic to the Linear Ceramic or *Linearbandkeramik* (LBK; *Rubané* in French), *i.e.*, 5400-4950 BCE. Even though the LBK phenomenon undoubtedly constitutes a coherent complex, particularly from the point of view of the architecture of houses and the organization of settlements, since the beginning of research archaeologists have observed stylistic variations in ceramic decoration that appear to be linked to regional

Journal of Lithic Studies (2025) vol. 12, nr. 2, 25 p. DOI: https://doi.org/10.2218/jls.9961

Published by the School of History, Classics and Archaeology, University of Edinburgh
ISSN: 2055-0472. URL: http://journals.ed.ac.uk/lithicstudies/

traditions. This is the case, for example, for the curvilinear bands of the Meuse region and the T decoration of the Seine basin (Figure 1). However, it is difficult to provide a palaeosocial interpretation of this stylistic fragmentation and in this article we propose to investigate the reality of the geographical limits of the ensembles defined on the basis of decorated pottery. To this end, we turn to the data relating to knapped lithic material because up to now this has contributed little in the context of the taxonomical construction (*sensu* Beauvais 2022) of the Neolithic.

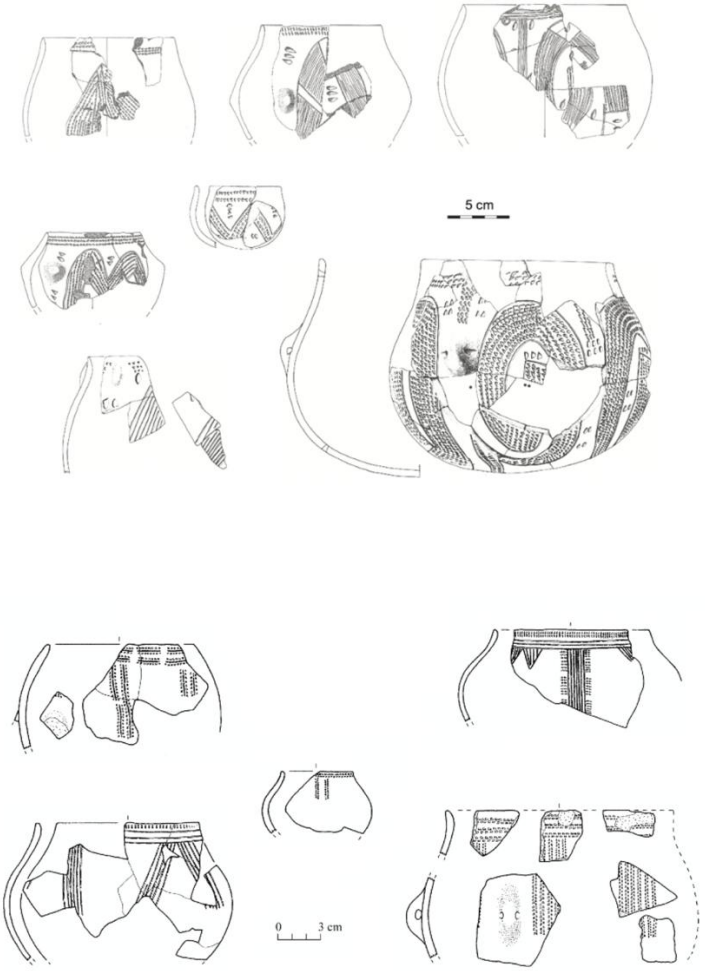

Figure 1. Decorated ceramics of LBK: curvilinear bands of the Meuse region (Blouet *et al.* 2021) and the T decoration of the Seine basin (Ilett 2012).

Our paper therefore aims to compare the findings from the ceramic corpus to those from the knapped lithic industry. These findings reveal, beyond shared features found in all houses, regional differences whether in terms of raw material supply, methods and processes of blade knapping or tool typology. By comparing these spatial patterns over a vast area, namely, northwestern Europe, we intend to discuss the reality of these spatial entities revealed by studies of archaeological material.

When seeking to distinguish social entities, it is desirable to work on quite limited chronological ranges in order to compare synchronous styles of traditions that may have been the object of intergenerational transmissions (Roux *et al.* 2017). This is why we are most particularly interested in the latest phase of the *Rubané* (≈ 150 years), which offers great potential for comparisons at the scale of the Rhine, Meuse and Seine basins. Apart from

focusing on a limited chronological range, this choice is constrained by the available data: the *Rubané* of the Seine and Meuse basins shows a significant rise in the number of settlement sites during the late phase; for the early phase few sites are known in the Seine Basin and those in Belgium are poorly documented, while for the middle phase settlements are rare and poorly documented in both of these regions (Blouet *et al.* 2021).

2. Stylistic entities defined by decorated ceramics

Since the early 20th century, numerous researchers have attempted to distinguish individual regional styles for the Middle and Lower Rhine. For example, W. Buttler (1938) identified the regional groups known as the Worms, Cologne, Wetterau and Plaidt types. At the end of the 1960s, W. Meier-Arendt proposed the existence of two LBK regions in northwestern Europe. According to this author, the first of these entities, termed the Middle Rhine and Maine Group, favoured decoration with hachured and line in-fill and occupied the current state of Hesse (Meier-Arendt 1972). The second, the Lower Rhine and Meuse Group, was spread throughout the entire Rheno-Mosan region and is characterized by decoration principally made up of bands of impressed ornament executed using a comb or point. In the 1970s, M. Dohrn-Ihmig completed this model by proposing a third entity, termed the 'Meuse-Moselle', which was distinct from the Lower Rhine group (Dohrn-Ihmig 1974).

Subsequent research has sought to fine tune the limits of these various entities, but always on the basis of stylistic and technical analysis of pottery decoration (for an overview see Blouet *et al.* 2021). However, all authors agree on the fact that, following a common stylistic stage (Flomborn, Early LBK), the decorative elements of each region underwent different evolutions that gave rise to entities which, stylistically speaking, often seem very homogenous. The large LBK territories repartition traditionally distinguished in the area that interests us are as follows: the Rhine-Meuse bloc, the Neckar Valley, Alsace and the Paris Basin (Seine Basin).

These four groups have been regularly reworked, sometimes with partial modification of the terms used to label them, thus the Rhine-Meuse *Rubané* becomes the "*Rubané* of the North West" and the Neckar *Rubané* becomes the "Wurtemberg *Rubané*" (Van Berg 1990).

The entire region also encompasses two distinct funerary traditions, defined on the basis of grave goods: Tradition I is confined to the *Rubané* of the southwest (southern Alsace and the Paris Basin) while Tradition II encompasses the three other groups (Figure 2). This division is identifiable from the very beginning of the LBK and can be traced as far as the eastern part of Central Europe. We thus observe two bands, orientated east-west, which broadly correspond to the two major axes of LBK colonization (Jeunesse 1995; 1997).

Recent work by V. Blouet and his team has provided new insights on the seriation of ceramic decoration and on the notion of style and its limits using large scale statistical analyses. Space does not allow a detailed description here, but the principal findings of the work are as follows:

- For the LBK of the Northwest, only Belgium, Dutch Limbourg and the Langweiler region witnessed the same stylistic evolution of decoration from the Early *Rubané* to the beginning of the Middle *Rubané*. From the second half of the Middle *Rubané*, differences become apparent between Belgium and Limbourg and the North Rhineland (Blouet *et al.* 2021). These tendencies become more marked in the Late *Rubané*, when the stylistic specificities of these two areas become particularly pronounced in terms of the types of motifs used in pottery decoration.
- The regions of the Meuse can be synchronised with the Moselle Basin due to the sharing of similar ornament. But strong divergences tend to distinguish the Moselle, sometimes linking it to the Main region and sometimes to the Meuse or the Hainaut

(Figure 3). In the Late *Rubané*, stylistic divergences appear to become accentuated between the Meuse and the Moselle, while exchanges with the Aisne remain very limited. These characteristics appear to be manifested in an exacerbation of regional particularisms.

- In the Late *Rubané*, the phenomenon of regionalisation also becomes accentuated in the Valley of the Rhine with the development of motifs linked to the emergence of the Šárka style in the Late LBK of Bohemia and Saxony. It underlines the persistence in this period of extensive interaction networks which gave rise to stylistic transfers whose nature varies from region to region (Blouet *et al.* 2021).

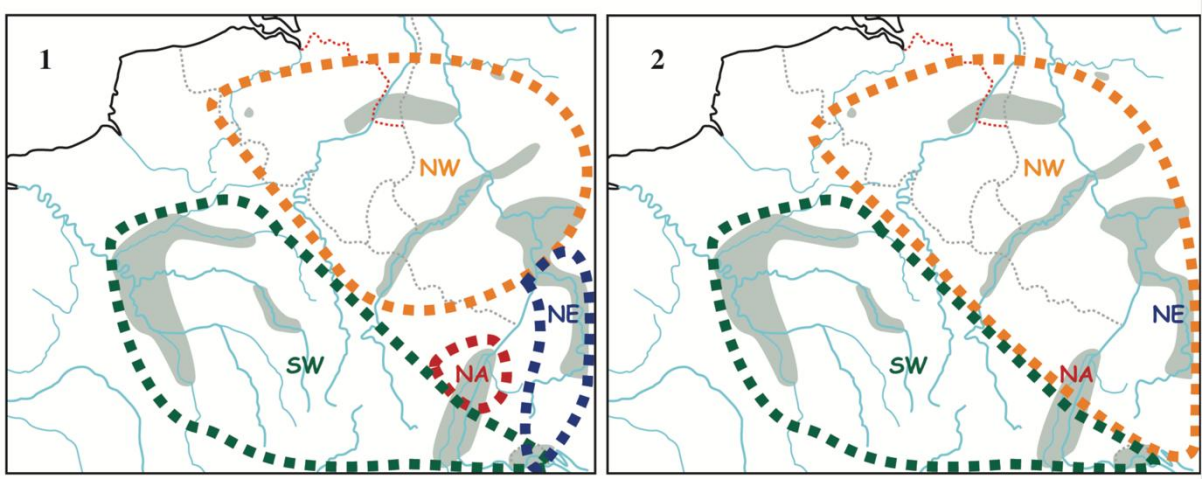

Figure 2. Ceramic regional groups (1) and funerary traditions (2) in western Europe according to Jeunesse (1995; 1997). In gray, the main areas where the LBK sites are located.

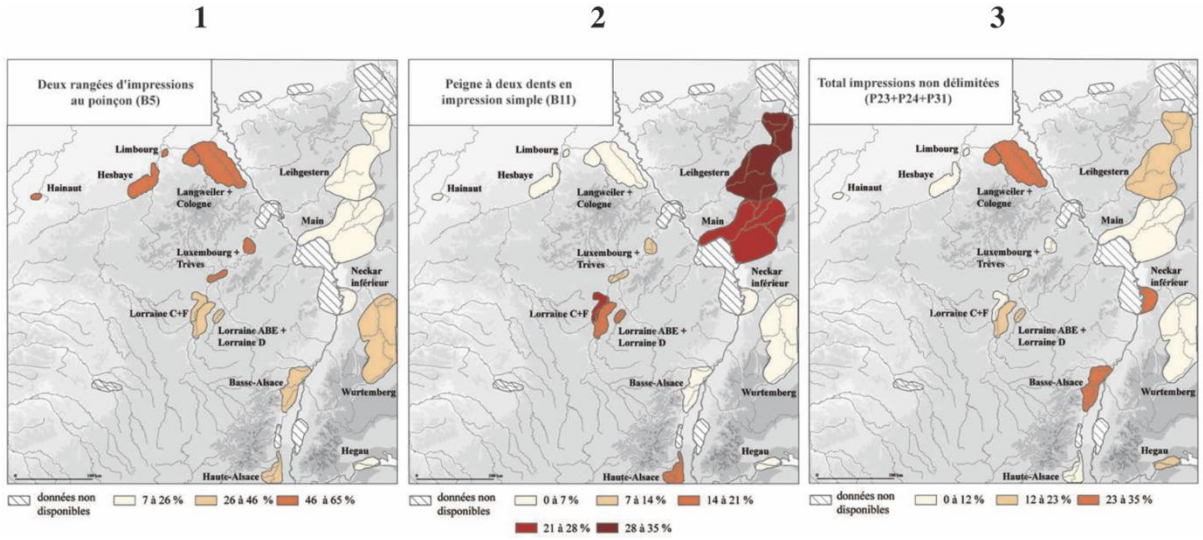

Figure 3. Ceramic regional groups during the late LBK (according to Blouet *et al.* 2021).
Examples of decoration, Map 1: 2 rows of point impressions; Map 2: 2 teeth comb impressions; Map 3: Impressions not delimited.

A review of previous studies reveals that most propose a series of large blocs spread over extensive regions, while the more recent work (Blouet *et al.* 2021) shows a mosaic of stylistic entities which vary according to the decorative criteria selected. The boundaries of the distributions are therefore blurred and suggest the notion of permanent diffusion of decorative motifs, with boundaries becoming evident when potters do not integrate certain decorations within their repertoires.

3. The contribution of knapped lithics

Within this panorama drawn on the basis of pottery decoration, and already encompassing several scenarios depending on the level of detail of the studies, we can attempt to integrate the results of analyses of various aspects of the lithic industry. Here we take the example of two distinct variables: 1) the stylistic typology of arrowheads and 2) raw material circulation networks.

3.1. A variety of arrowheads

Several types of lithic arrowheads are known from *Rubané* archaeological assemblages. The broad morpho-stylistic categories comprise symmetrical trapezes (used as transversally edged arrowheads), isosceles triangles with invasive retouch and asymmetrical triangular or trapezoidal arrowheads with or without flat inverse retouch. Numerous other criteria can be used to subdivide these three basic types - concavity of the base, the presence of a *piquant-trièdre* (micro-burin negative), lateralisation of the smallest truncation, etc, but their basic distribution across the regions already reveals a perceptible spatial organization at the scale of our study area (Allard 2005; 2007).

Symmetrical trapezes are typical of the earliest *Rubané* and rapidly disappear during the *Flomborn* (Löhr 1994). Symmetrical triangular arrowheads, which replace the transverse arrowheads of the *älteste Bandkeramik* from the earliest phase of the *Rubané*, display different evolutions in the various regions. In Dutch Limbourg they come to dominate in the early phases (Newell 1970), while in Belgian Limbourg and the Hesbaye, symmetrical points are still numerous at Rosmeer (Ulrix-Closset & Rousselle 1982). These points become rare in the Hesbaye where most of the contexts taken into account are attributed to the latest phase of the Linear Pottery Culture (phases IIc and IId of Moderman's scheme). At Darion (Be), the corpus of arrowheads contains no examples (Caspar 1988). This site has recently been attributed to the late and final phases of the *Rubané* (Jadin 1999). The site of Aubechies (Be), where one occupation phase has been attributed to the end of the *Rubané* (Constantin 1985), has yielded none, despite yielding a non-negligible assemblage of 42 arrowheads. Just as in Dutch Limbourg (Newell 1970), the evolution over time is thus clearly towards the progressive disappearance of these arrowheads. The phenomenon is clearly perceptible in Hainault where they are even rarer than in the *Rubané* of Hesbaye.

However, in Alsace, while symmetrical points are generally dominant (Mauvilly 1997), data from Lower Alsace does not allow us to determine if the frequency of these arrowheads evolves to the detriment of asymmetrical points. For the Upper Rhine, symmetrical points dominate from the beginning to the end of the sequence. This trait is a clear characteristic of the Upper Rhine, distinguishing it from all of the other *Rubané* groups of Western Europe. Furthermore, in these series we observe a small number of true asymmetrical points (Mauvilly 1997: fig. 337). These arrowheads are frequently made from non-native flint, leading researchers in Alsace to highlight them as evidence for specific circulation of arrowheads within the Upper Rhine region. These observations suggest that this region clearly diverges from the evolution of arrowheads in Western Europe and that true asymmetrical arrowheads were either absent or were a rare component of the toolkit manufactured by *Rubané* communities in Upper Alsace. This indicates that the evolution of arrowheads in Upper Alsace is in fact linked to the evolution in the Danube region (Löhr 1994).

Champagne region has yielded a corpus of arrowheads in which both principal types co-exist. Symmetrical points are relatively rare and tend to be made from blades. The chronological evolution of the arrowheads is impossible to document because of the lack of data for the Middle and Final *Rubané* in these area. On the basis of the sites of Juvigny (Fr)

and Bréviandes (Fr), we can state that symmetrical arrowheads, while in minority, appear to persist for a long time in the chronological sequence.

Finally, the *Rubané* of the Aisne, Yonne and Oise, and indeed Normandy, are totally devoid of symmetrical arrowheads, asymmetrical arrowheads being the only type present.

As regards the lateralization of arrowheads, Figure 4 is broadly in line with the synthetic study carried out by H. Löhr (1994). Lateralized on the right, they are virtually the only type found in Hainault, have a strong presence in the Aisne Valley (with variations between sites) and have a moderate presence in Hesbaye. In the southeastern part of the Paris Basin (Champagne and the Seine-Yonne confluence) and in Lower and Upper Alsace, the lateralization of arrowheads is undifferentiated. Finally, in the corridor of the middle Moselle Valley, the handful of examples retrieved from several sites are all lateralized on the left (Schmidgen-Hager 1993). The inventory of the study by H. Löhr confirms this observation as the sites of Montenach (Fr) and Marainville-sur-Madon (Fr) have yielded 13 arrowheads, 11 of which are lateralized on the left (Löhr 1994: 109). Alsace has yielded few asymmetrical arrowheads and lateralization is generally on the left (Löhr 1994: 110-111).

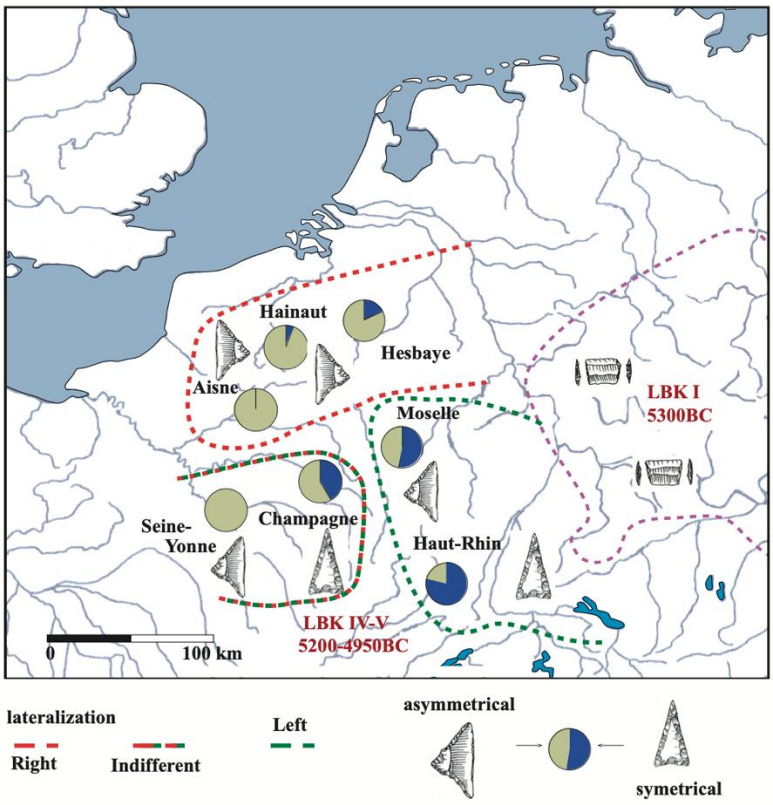

Figure 4. Ratio of arrowhead types and their lateralization at LBK in Western Europe (according to Allard 2007 modified).

3.2. The transfer of raw materials

While the work of determining the form and quantity in which non-local (> 10 km) materials were introduced to western European Late *Rubané* sites is still underway, we can present some initial findings here. Indeed "the exploitation territory of the site is located within a radius of approximately 10 km, beyond which exploitation becomes uneconomic" (Jarman *et al* 1972: 62; see also Elefanti and Marshall 2018); for a review on the notions of local, regional and distant see Delvigne *et al.* 2021b. In the context of a daily expedition from a camp/village, a value of c≈ 10 km corresponds broadly to 6 hours round trip (≈ 20 km) with

foot without a break, which is approximately equivalent to a day of activity. This value of 6 hours of round-trip walking per day is rarely reached in the ethnographic record (*e.g.,* Gould 1980; Kelly 1995; Binford 2001).

To do this we have begun to construct a database which currently includes 195 Late *Rubané* sites. However, the quality of information relating to raw materials varies considerably and only about 50 sites allow us to study the frequency of occurrence of raw materials (*i.e.,* with quantitative data). The majority of non-local siliceous rocks belong to seven groups of material that are generally identifiable using the naked eye: Rijckholt flints (Nl), Hesbaye flints (Be), Ghlin flint (Be), Rethel flint (Fr), Lhéry siliceous rocks (Fr), flints from the Saint-Gond marshes (Fr) and the Malm cherts of Alsace (Fr). The studies carried out by one of the authors (PA), combined with the syntheses published by A. Zimmermann (1995) and Schmidgen-Hager (1993), allow us to suggest that while the transfer of raw materials is evident in all areas, the intensity of this transfer varies from region to region (Figure 5).

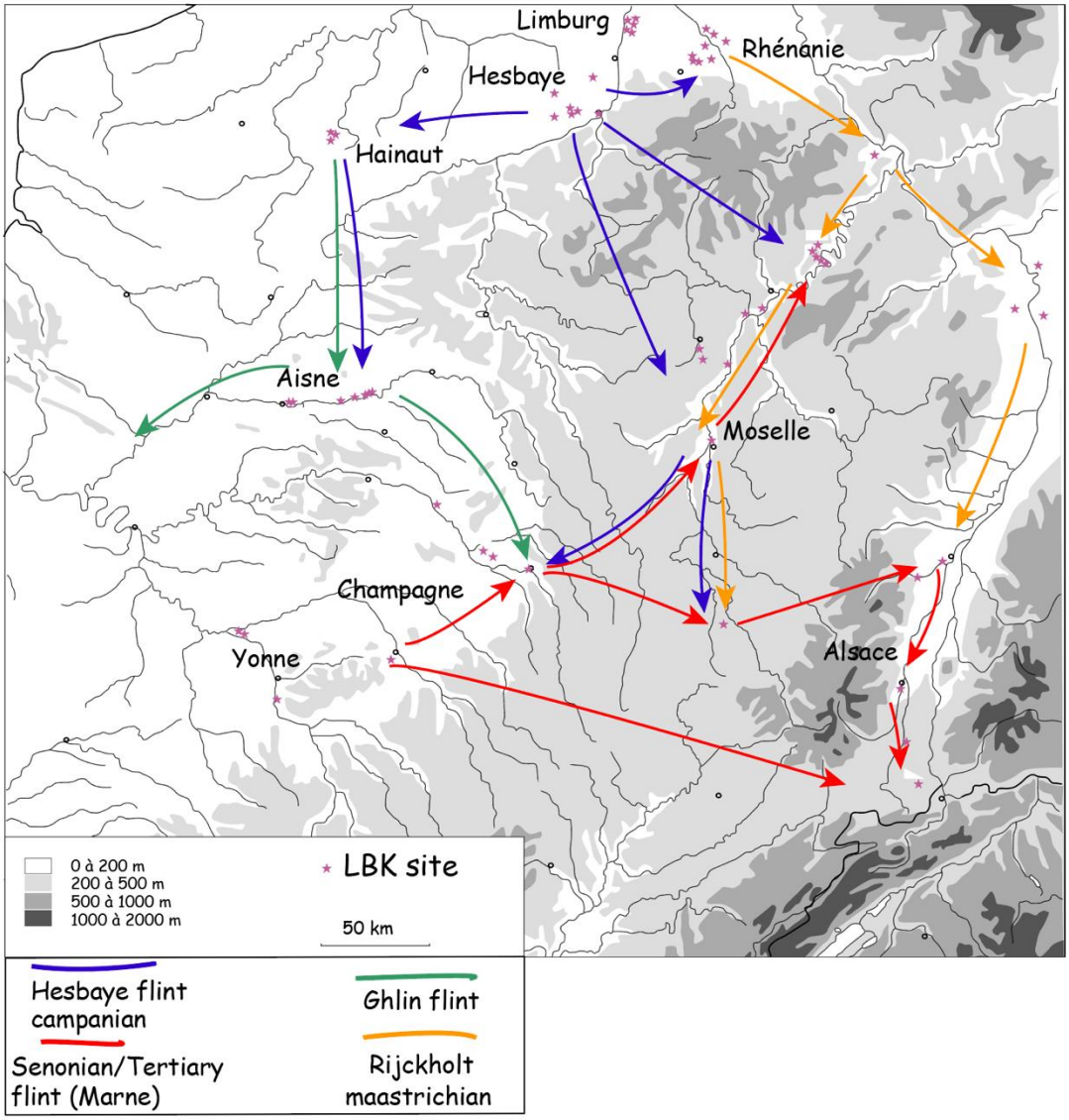

Figure 5. Circulation map of the main raw materials in the Late LBK period (5100-4950 BCE) (according Allard 2005 modified).

Most of the published studies are now quite old and the raw materials tend to be identified simply using the naked eye, relying on the experience of the various authors, with or without the support of lithic reference collections (*i.e.,* lithotheque). While this method is rapid and allows collections to be classified into broad categories, it is nonetheless limited when it comes to providing more precise information. Only a detailed petroarchaeological approach provides a sufficient level of accuracy for raw material identification. Recent advances in this field; in particular the integration of the notions of an evolutive chain (Fernandes & Raynal 2006) and sample collection and petrological analyses protocols (Delvigne *et al.* 2018; 2020; 2021a); have led to major methodological advances that are essential for guaranteeing satisfactory results that are both testable and reproducible by the scientific community. Nevertheless, since it was not possible in the framework of this article to revisit the characterisation of the sites, we have decided to confine ourselves to using the data arising from analyses conducted by the naked eye and previously published data.

From a site-centred point of view the projection of the data concerning the transfer of raw materials shows an absence of a systematic correlation between the proportion of raw materials and the distances between an archaeological site and the source site (deposit); this, for example, is the case of the site of Wiesbaden-Herbenheim (Ger) for which 70% of the raw materials (Rijckholt flint) comes from a site 197 km away (Figure 6). The same is true for the *Rubané* sites of the Moselle Valley, such as Metz-Nord, and for those of Lower Alsace such as Rosheim "Saint-Odile" (Allard 2005; Mauvilly 2000), where most of the blade assemblage is made up of non-local flints (> 10 km). For the Moselle corridor, Campanian and Maastrichtian flints from the Meuse Valley predominate until the Late *Rubané* when flints from the Paris Basin, (principally Senonian flints), replace them in the final stages (Blouet 2005). In Lower Alsace, the blade assemblage is made up of flints from the Paris Basin and the Northern Jura (Mauvilly 1997; 2000); and a frontier appears to have existed between the Dutch flints (the Rijckholt" flint here) and Belgian flints (Hesbaye Campanian flints) to the north and south of the Moselle Basin. This fact has been largely confirmed by recent excavations of settlement and burial sites.

In the *Rubané* sites of the Aisne Valley, objects made of exogenous raw materials occur sporadically. For example, we recorded a blade of Ghlin flint (Be) at Cuiry-lès-Chaudardes (Fr), Hesbaye Campanian flint at Missy-sur-Aisne and Maastrichtian flint from the north of Hesbaye at Menneville. The Ghlin flint, which abounds on *Rubané* sites of Hainaut in Belgium, is also attested at Pont-Sainte-Maxence (Fr) and at Saint-Dizier in Champagne (Fr) (a single piece from each site). The latter site also yielded a small group of blades made from Hesbaye Campanian flint (Allard 2005). This handful of objects clearly does not have an economic impact, but their information value is considerable because they attest to the existence of social relations between the various *Rubané* settlement zones.

The sites of the Seine and Yonne region are an interesting case. In this region, which is rich in siliceous rocks, the lithic series are numerically significant (sometimes containing tens of thousands of objects) and are predominantly made from Senonian flints from the immediate locality or neighbouring areas (that is to say less than 20 km away for Augereau 2004). Nevertheless, the presence of tertiary flints from the centre of the Paris Basin attests to the circulation of a few pieces over longer distances as we observe at Bréviandes ou à Etigny "le Brassot" (Augereau *et al.* 2006) which yielded a single piece each.

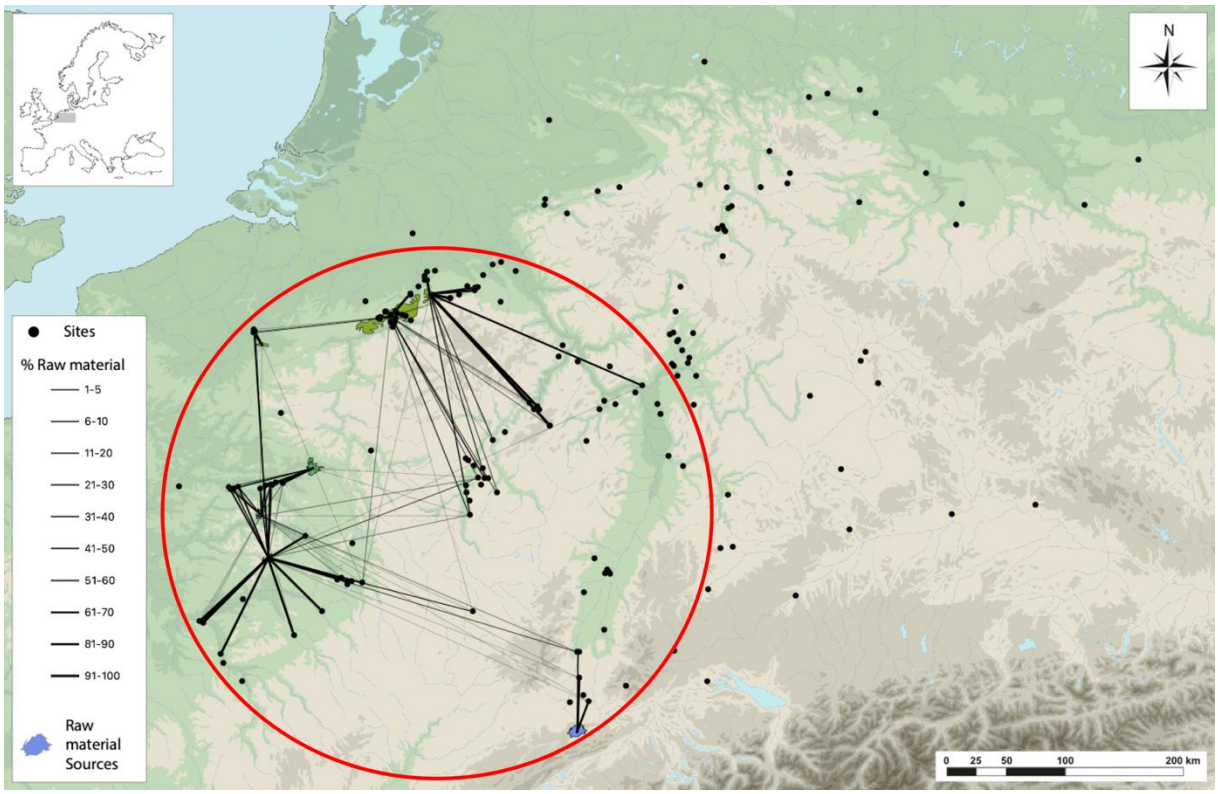

Figure 6: Mapping of transfers of the totality of lithic raw materials. All of the places form part of a bigger group (encircled in red). The raw material sources are blue for Jurassic silicite and green for cretaceous flint.

4. Cross comparison with ceramic stylistic entities

In comparison to the stylistic groups of decorated ceramics, the data from knapped lithics reveals distinct entities. This is particularly the case for the transfer of siliceous raw material which in no way coincides with the stylistic entities revealed by the ceramics. The transfer of lithics appears to be organised according to principal route ways: along the Moselle corridor and in the north of Alsace. The principal diffusion routes for flints are concentrated in these two regions, which themselves lack local sources of flint. In the panorama of stylistic entities within ceramic decoration, Lower Alsace is isolated while the Moselle corridor is integrated within a larger ensemble that excludes the Seine Basin, although raw materials from this region predominate in the late phase (Blouet 2005).

The large areas defined on the basis of typo-technological characteristics (cf. arrowheads, chapter 3.1) do not coincide with the four large geographical entities defined from decorated ceramic, neither with flint networks, funerary practices.

In addition, within what seems like relatively homogenous entities from the point of view of ceramics, like the Rhine-Meuse region, we can discern important "frontiers" in the circulations of flint. This is the case for the distribution of Hesbaye Campanian flints and Maastrichtian Rijckholt flint whose two circulation routes appear to be parallel with little reciprocal exchange (Allard 2005). The "junction point" is more than 150 km away in the Metz region where the proportions of these two raw materials change from one bank of the Moselle to the other (Blouet 2005).

5. Network analysis

From the initial results of the economic analyses (*sensu* Perlès 1991) described above, we have attempted to propose models that investigate the structure of relations between LBK sites as a function of their relative distances. In order to do this, we have used PPA type

network analyses (see below). These analyses are theoretical devices which allow the construction of models that ought to be seen as tools or hypotheses aimed at reconstructing past networks. This, therefore, involves studying the structure of the relations (links) between these entities (*i.e.,* the archaeological sites and raw material sources) in order define ensembles (or cluster) within the network. In the context of the LBK, such analyses have already been undertaken by E. Classen for the Aldenhoven Plateau (*e.g.,* Classen 2008). Here we have extended the findings to include all sites in northwestern Europe.

5.1. Method

Since the 1960s, American geographers have developed an arsenal of statistical techniques that allow space to be modelled and measured (*e.g.,* Ambrose 1969). Among these, proximity analyses or PPA (Proximal Point Analysis) is founded on the premise that in a closed system the interactions between individuals are more sustained between close neighbours than between distant neighbours. In the field of archaeology, these approaches were first applied by researchers studying Oceania in the mid-1970s (for more detail see Terell 2013), and allowed the density of relations between communities to be assessed on the basis of the distribution of archaeological sites. By varying one or two parameters, it is possible to observe general tendencies in the evolution of a network thanks to the highlighting of groups (*i.e.,* degree of clustering*), the documentation of its internal structure (*i.e.,* degree of connectivity*) and the node* weights (*i.e.,* centrality analysis*).

Depending on the value of the k parameter*, there are several different types of PPA. The best known is what is termed "nearest neighbour" analysis. In this type of analysis, the k parameter is varied as a function of the number of links* that we hope to establish with the nearest k neighbours. In the current work, we have used another type of PPA that integrates the totality of the places available to us (*i.e.,* settlement sites and raw material sources) and considers not the number of closest neighbours, but takes k as a value of distance that allows us to establish all of the links situated at a distance k from each of the nodes (or places). By varying k, we can examine the degree of connectivity of the network and thus its clustering.

In our models we only take account of geodesic distances (*i.e.,* as the crow flies) and not calculated distances (notably by Least Cost Path Analysis or LCP). Our reasons for doing this are two-fold:

1) the pathways (and thus the distances) obtained using LCPs are extremely dependent on physical parameters (palaeo-topography, palaeo-vegetation cover, the hydrodynamics of watercourses, etc.), which themselves are subject to algorithmic bias, and on socio-economic parameters (size and composition of groups, burden, procurement logic, mode of travel, etc.), which are subject to the choices of the analyst (for a critique see Verhagen *et al.* 2019). Taking into account the geodesic distances therefore allows minimal models to be obtained, which only become more complex when LCPs are considered; the reality probably lies somewhere between these two extremes (Andre 2023);

2) As demonstrated for obsidian circulation networks in Neolithic Anatolia (Brunstein *et al.* 2018), the structure of networks established on the basis of LCPs or geodesics tend to merge together when they are produced for extensive areas with poorly contrasted topography (The study area is generally quite flat, with the exception of the Ardennes massif which feature significant contrasts in relief).

PPA type network analyses are thus theoretical systems that allow the construction of models which should be seen as analytical tools (Sindbaek 2013) rather than reconstructions of past spatial realities.

In this study, the PPA models were created using QGIS v. 3.30.3-Odense software from location data for the sites (published real or approximate GPS data in Lambert 93 GPS

coordinates gleaned from published sources, fieldwork or via word of mouth) and raw material deposits via the WMS feed of the cartosilex.fr website. The latter allows the display and processing of polygons of potential siliceous rock formations for Nouvelle-Aquitaine, Centre-Val de Loire, Auvergne-Rhône-Alpes, Grand-Est, Occitanie, Provence-Alpes-Côte d'Azur and Ile de France. These data are themself sourced from the Charm-50 data base at a 1/50000 scale of the *Bureau de Recherches Géologiques et Minières* (BRGM) and adapted to the context of silicite sourcing by the *Groupe de recherche* (GDR) "Silex" and the *Projets collectifs de recherche* (PCR) "Réseaux de lithothèques" (Tufféry *et al.* 2022). Since, to the best of our knowledge, no current QGIS allow us to calculate the "distance matrices" from "vector" data sourced from polygon and point layers, we had to attribute a point value to the raw material deposit polygons. To do this, for each group of raw materials, we selected all of the polygons corresponding to its outcrop zone, and from this selection we calculated and projected the barycentre of each outcrop zone using the "centroid" tool. The points of the raw material deposits represented on the maps in this article are thus approximations: they are in fact the average value of the outcrop zone of the siliceous rock type because in petrography we consider results at the scale of geological formations.

Following the fusion of these two points layers (site and raw material deposits centroids) we created a third layer of points (entitled "table of places"). This layer combines all of the identifiers (*i.e*., the names) and locations of all sites included in Lambert 93 (therefore in a metric system, a prerequisite for the calculation of the distance matrix). The distance matrix, calculated with the *ad hoc* tool available in QGIS, is subject to an "attribute junction" on the "name" field (ID) with the "Table of places". This allows the creation of a spatialized points layer (entitled spatialized matrix) containing all of the relative point to point distances. In order to create the network of places we used the "join by lines" tool in the QGIS toolbox using the "table of places" as a pivot layer and the spatialized matrix as a target layer. This allows us to obtain a line layer (entitled "Ligne_Réseau PPA") in the form of a weighted network of places which itself can be subjected to a Proximal Point Analysis.

5.2. Results

The raw materials circulation network of the first 50 sites in our corpus (the westernmost sites: Belgium, Alsace, Paris Basin) form part of a same network, in other words all of the spaces are linked (Figure 6). However, the data that has allowed the creation of this network is not weighted and takes into account all of the raw material transfers. If we only consider the structuring raw materials (those that are significant in terms of abundance) then the raw materials transfer network reveals three distinct entities if the threshold value is 20% of raw materials on the sites (Figure 7) and five distinct entities, with a frontier between Hesbaye and Limbourg, if the threshold value is 40% of raw materials on the sites (Figure 8). For such quantities of raw materials, we can hypothesize economic structuring of the transfers by past societies; the recurrence of the links (particularly on both sides of the Ardennes) and subdivision of the network are certainly not fortuitous.

It is important to remember that the aim of the models is to observe evolution of the network structure in order to identify the scenario that corresponds most closely to the archaeological data. To do this we work on the assumptions 1) that in a closed system the interactions between individuals are more sustained between near neighbours than between distant neighbours, and 2) that relations maintained over long distances and marked by the circulation of raw materials are a non-random phenomenon for the period in question. Since the ensemble of LBK sites constitutes a chrononymic system, *i.e.,* they display a number of criteria that are considered significant by prehistorians in terms of the social construction of past communities, this involves modelling the spatial structure of the entire corpus (n=195); in

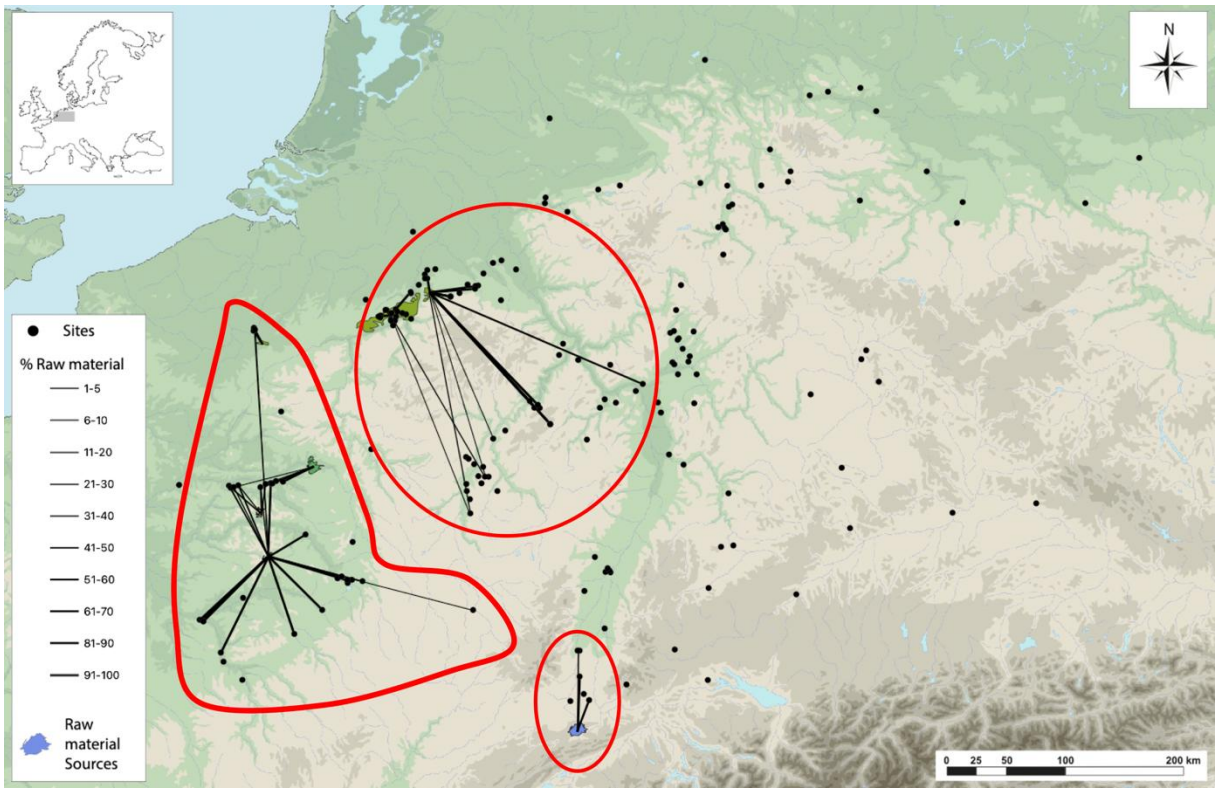

Figure 7: Mapping of the transfers of lithic raw materials, if they account for more than 20% of raw materials on a site. The places form three distinct groups (encircled in red). The raw material sources are blue for Jurassic silicite and green for cretaceous flint.

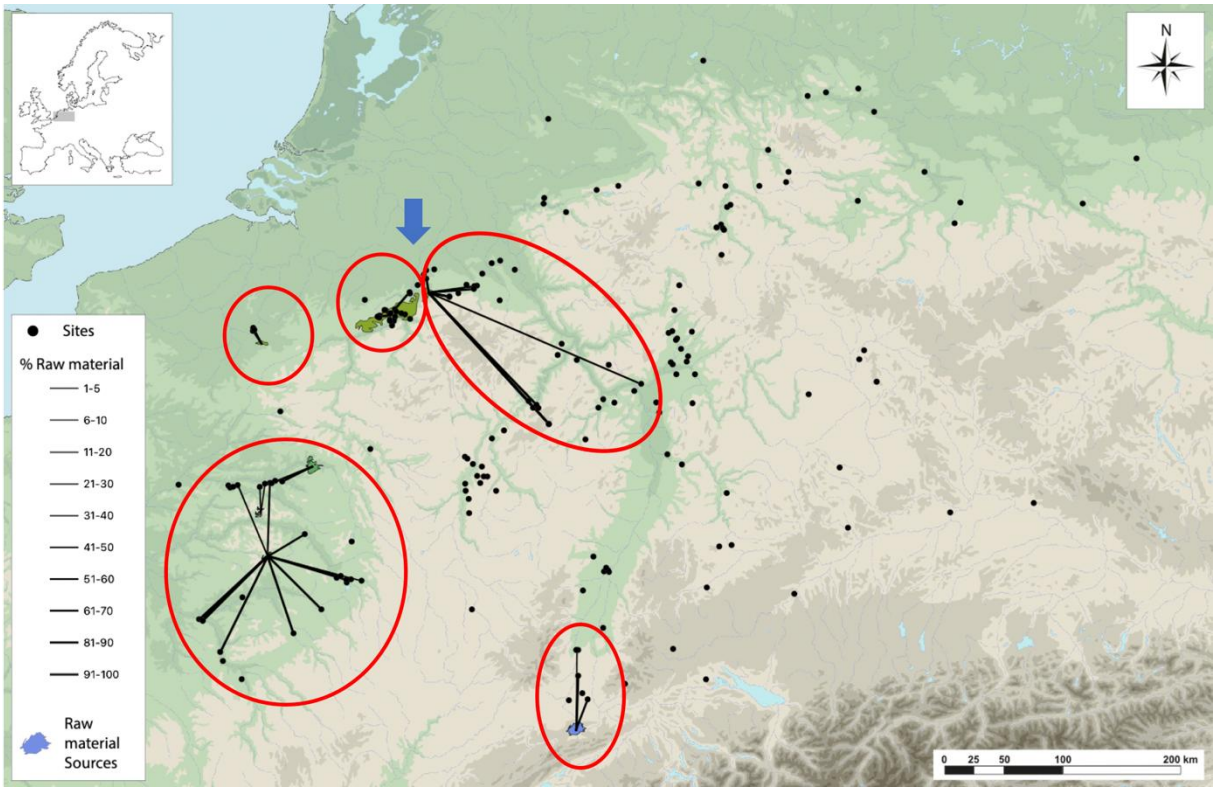

Figure 8: Mapping of the transfers of lithic raw materials, if they account for more than 40% of raw materials on a site. The places form five distinct groups (encircled in red). The raw material sources are blue for Jurassic silicite and green for cretaceous flint. A frontier appears to exist between Hesbaye and Limbourg (marked by the blue arrow).

other words, we can integrate the sites for which we do not have raw material data to see how the structure of the network of places reacts.

In the context of an interconnected system, that is to say a system in which informations are shared throughout the network (as is supposed to be the case within a chrononym, see above) it is a question of finding the value of k allowing the closure of the network (that is to say the value for which all the points are linked to each other by at least one link). In our case, when we vary the values of k from k = 0 to k = n we note that the first value for which the network closes is k=104. This distance corresponds to the geodesic distance between the sites of Zwenkau (Ger) and Dresden (Ger) (red arrow on Figure 9), *i.e.,* the two sites in the corpus that are the furthest apart with no other sites between them. This means that, in the current state of knowledge, it is necessary that regular exchanges over a distance of 104 km were maintained so that the network of LBK relations could continue to exist. Considering what we know about the organization of Neolithic society, this situation appears in part to be linked to the existence of a void (due to an archaeological reality? An history of the research? A bad conservation of the deposit? Or any other possible explanation). However, this does not appear to be the case for the entire corpus and we can suggest that the history of research on the *Rubané* and the intensity of survey work and excavations provide data that is representative of settlement density; with the exception perhaps of the south and east of Germany where the network of places is poorly connected. Given that the archaeological data is representative for a large part of the space under consideration, the variation of the k parameter (geodesic distance between the sites) in the proximity network (PPA) allows us to observe certain tendencies which we have decided to illustrate in the form of a figure (Figure 9). The model allows us to highlight a certain number of groups (encircled by dashed red line), which are generally representative of what we have identified in the archaeological record on the basis of raw material transfer data. The most strongly connected zones are thus grouped into four clusters (red dotted line).

In the centre-north of the Paris Basin, the modelled ensemble more or less corresponds to that outlined by the transfer of raw materials. In this regard, the Mons Basin (indicated by the orange arrow) is weakly linked to both the Paris Basin and Hesbaye (low degree of centrality*; respectively c = 1 and c = 5). This corresponds to what we observe in the archaeological record with regular circulations of raw materials, but which remain relatively anecdotal in terms of quantity (this is an area, however, that become central during the *post-Rubané*). We could therefore question the importance of flints from the Paris basin found at the site of Blicquy (Be), by considering the place of intermediary sites within this system, and notably the site of Wimy (Fr) for which we have no raw material data.

The same goes for the interrelations existing on either side of the Ardennes. While the ceramic and lithic technology data (Figures 2 and 4) tend to group these two entities together, the modelling shows that two (sub-) groups, with a high degree of connectivity, existed on either side of the Ardennes. However, the two groups are the most connected entities at the scale of the overall network, revealing the existence of regular intermediary points between these two spaces. While the raw material transfer data illustrates that the Ardennes were traversed throughout their extent (blue dotted circle), we believe that this is an artefact linked to the cartographic representation and that these transfers occurred preferentially via the valleys. Indeed this is suggested by the PPA modelling and could also be revealed by a Least Cost Path analysis (see before). The Meuse Valley therefore appears to have played a central role even though few LBK sites are known in the Ardennes. There are two possible explanations: 1) erosion (*e.g.,* with settlements along the major river) or the non-discovery of sites; 2) the manner in which the space was occupied may have involved regular and rapid circulation, which would have left little trace. In this regard we should consider the use of navigation as a means of transportation within the valley which, even today, acts as a

favoured route way through the massif, especially for freight. This preference for settlements along river corridors is well attested to in the South Ardennes area (shown by the purple arrow), which links the valleys of the Meuse, the Moselle, the Rhine and the Ems.

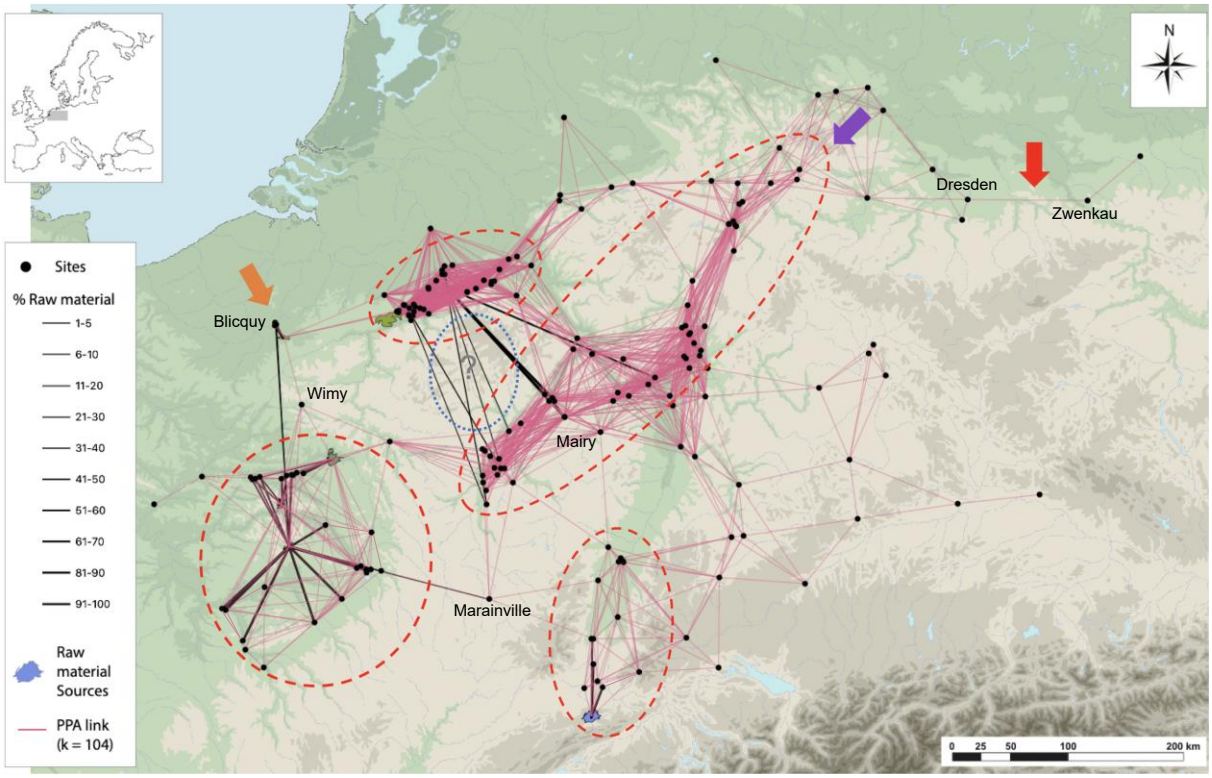

Figure 9: Proximal point analysis for the LBK places. The red circles depict the zones of highest density, the blue dotted zone corresponds to the cartographic non-correspondence between archaeological data and modelled data. The raw material sources are blue for Jurassic silicite and green for cretaceous flint. The red arrow indicates the k = 104km value; the purple arrow indicates the Rhine and Ems area and the orange arrow points to the Mons Basin.

As for the models established from the lithic and ceramic data, the PPA modelling appears to single out Lower Alsace with weak links maintained with groups in the Southern Ardennes and the Paris Basin, as well as with the sites of Southern Germany. In this latter space the (very) low level of connectivity in the network reflects either a lack of data (the recognition of LBK sites being less advanced than in the rest of the study area), or a different mode of occupation of the area (possible colonization front? different way of exploiting the land?)

Finally, in this model, certain places (sites) possess a high degree of betweeness*. These places allow the creation of bridges between the groups with high connectivity and raises the question of their position within the network (hence within the LBK area): special status of the sites? Lack of data in the sectors in which they are the sole representatives? Meeting zone? This is particularly the case for Marainville in the Vosges, which plays the role of a hub between Alsace, the centre of the Paris Basin and the southern sites of the Ardennes (as is shown by the archaeological data ; Allard 2005; 2007) as well as the site of Mairy in the Ardennes. The analysis of the network shows us that these sites must be the focus of (re)consideration if we wish to understand the relations between regional entities.

While the PPA model globally reflects the data regarding the quantity of the transfers of seven types of lithic raw material, we nonetheless observe that the frontier between Hesbaye and southern Limbourg, clearly evident in the archaeological record, does not exist in the PPA. The limit of the North Ardennes cluster is in fact located further east, between

Limbourg and the Ruhr valley. This phenomenon may reflect the existence of a past frontier (at least in the economic sense) as it does not meet the prerequisite on which this model is based.

6. Conclusion

Returning to our starting point, we can make the following concluding remarks regarding the comparison between the ceramic and lithic stylistic entities: while certain types of decoration, distributed within limited areas with well-defined borders, are sometimes interpreted by archaeologists as frontiers, the use of multiple criteria renders these models more complex. This is exactly the case here; because we have been able to observe that the lithic finds reveal elements that are coherent with or very different from the hypotheses arising from variations in decoration. As in other periods, we have been able to observe that the criteria taken into account considerably alter the spatial geometries of the defined entities (Angevin & Delvigne 2021). The weight of the selected criteria is considerable, the decorations do not reveal the same entities as the circulation of raw materials, and the typology of projectile points reveals different entities altogether. Only a broader comparison, integrating the totality of the criteria, will allow us to better understand what we discern as potential regional groups.

Finally, the analytical tools used can play a role: modelling reveals very different patterns, depending on the use of qualitative or quantitative approaches. This preliminary analysis will hopefully initiate further works to include more data regarding the transfer of raw materials in order to fine tune the parameters of the PPA model and to potentially observe socio-economic phenomena (like the Hesbaye and Limbourg frontier described above). Likewise, the integration of networks of technical similarity mirroring the PPA networks, as we have undertaken for the Aurignacian of the South of the Paris Basin and lower Magdalenian (Delvigne *et al.* 2021b; in press), would allow us to better define the regional entities that make up the LBK. In this regard, the early Neolithic of northwestern Europe constitutes a unique field of study due to the quality of the available data, even though a significant petroarchaeological and technological review remains to be undertaken at the scale of the LBK of the north-west.

Network analysis lexicon (for more information see Collar *et al.*, 2015)

Betweeness: **Betweenness centrality** of a node is defined as the fraction of the number of shortest paths that pass through that node over the total number of shortest paths between all pairs of nodes in the network. Nodes with high betweenness centrality are considered important intermediaries (or hubs) for controlling the flow of resources or information between nodes.

Centrality analysis: In network analysis, **centrality analyses** refer to a set of quantitative methods (beweenness centrality, degree centrality….) used to identify and measure the relative importance or influence of individual nodes within a network. These measures help determine which nodes occupy strategic positions for communication, control, or access to information or resources.

Degree centrality: **Degree centrality** is one of the simplest measures in graph theory for assessing the importance of a node within a network. It is based solely on the number of direct connections a given node has, without considering the overall structure of the network or the node's relative position within it. A node with high degree centrality can play a key role in the diffusion or circulation of information throughout the network.

Clustering: In the context of network analysis and graph theory, a **cluster** refers to a group of nodes that are more densely connected to each other than to the rest of the network. It differs from **cliques**, which are specific types of clusters. In other contexts, such as data analysis or classification, **clustering** refers to the grouping of similar objects based on certain features or similarity measures.

Connectivity: In network analysis, **connectivity** refers to the ability to establish connections between different nodes. The higher the connectivity index, the greater the number of possible paths between nodes, allowing for choice—such as selecting the most efficient path in terms of time or energy. A network in which every node is directly connected to every other node has **maximum connectivity**. Conversely, an **ego-network** exhibits very poor connectivity and is therefore vulnerable to various disruptions that can block communication or interactions (according to: https://geoconfluences.ens-lyon.fr/glossaire/connectivite-connexite).

Geodesic distance: A geodesic distance is the shortest distance between two points on a curved surface (such as the Earth).

K parameter: In network analysis and graph theory, the parameter **k** often refers to a threshold or a specific value used in various contexts. In clustering or neighborhood analysis, **k** can represent the number of nearest neighbors considered when defining local structure or similarity. The exact meaning of **k** depends on the specific method or analysis being used

Node: In network analysis, a **node** (also called a vertex) represents an individual entity or unit within the network. Nodes can correspond to people, organizations, computers, locations, or any distinct objects depending on the context of the network. They serve as the fundamental points that are connected by edges (links) to form the structure of the network.

Acknowledgements

We are delighted to thank Morgane de Parthenay and Alain Queffelec for the rich discussions about network analysis and its application in prehistoric contexts. We also thank the two reviewers of this paper for their help in improving the manuscript. Finally, we would like to thank Elsa Defranould and Solène Denis for inviting us to present our work in the EAA session in Budapest, which was the starting point of this paper.

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Industries lithiques et entités stylistiques au Néolithique ancien (LBK) dans les bassin du Rhin, de la Meuse et de la Seine

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Résumé:

L'étude des céramiques décorées du Néolithique ancien Rubané ou *Linearbandkeramik* (LBK) a longtemps structuré la construction de la séquence chronologique du Néolithique ancien du nord-ouest de l'Europe. Des contributions récentes permettent d'individualiser les groupes stylistiques régionaux. L'examen des différents corpus régionaux montre qu'à la suite de l'éclatement d'une étape stylistique commune, l'entité de *Flomborn*, les éléments décoratifs de chaque région ont évolué différemment, donnant naissance à des entités individualisées qui semblent parfois très homogènes quant au style des décors utilisés (par exemple, l'ensemble Rhin-Meuse du Rubané moyen). Ces études proposent une série de grands blocs répartis sur de vastes régions, tandis que les travaux plus récents montrent une mosaïque d'entités stylistiques variant selon les critères décoratifs retenus. Les limites des distributions sont donc floues et suggèrent l'idée d'une diffusion permanente des motifs décoratifs, ces limites devenant évidentes lorsque les potiers n'intègrent pas certains décors à leur répertoire.

Dans ce panorama dressé à partir des décors de la céramique, et englobant déjà plusieurs scénarios selon le niveau de détail des études, nous avons tenté d'intégrer les résultats d'analyses portant sur divers aspects de l'industrie lithique. Nous prenons ici l'exemple de deux variables distinctes : la typologie des pointes de flèches et les réseaux de circulation des matières premières. La typologie et la latéralisation des armatures montre une répartition différenciée selon la fréquence des pointes asymétriques ou symétriques et la latéralisation des armatures asymétriques montre également des ensembles distincts. Pour les circulations de matières premières, la qualité des informations est très variable et seulement une cinquantaine de sites permettent d'étudier la fréquence d'occurrence (c'est-à-dire avec des données quantitatives). La majorité des roches siliceuses non locales (> 10 km) appartiennent à sept groupes de matériaux généralement identifiables à l'œil nu : silex de Rijckholt (Nl), silex de Hesbaye (Be), silex de Ghlin (Be), silex de Rethel (Fr), roches siliceuses de Lhéry (Fr), silex des marais de Saint-Gond (Fr) et cherts de Malm d'Alsace (Fr). Les études menées par l'un des auteurs, combinées aux synthèses publiées par A. Zimmermann (1995) et Schmidgen-Hagger (1993), permettent de suggérer que si les circulations de matières premières sont évidentes dans toutes les zones, l'intensité varie selon les régions. Ainsi, d'un point de vue centré sur les sites, la projection des données concernant la circulation de

matières premières montre une absence de corrélation systématique entre la proportion de matières premières et les distances entre un site archéologique et les affleurements.

À partir des premiers résultats des analyses économiques, nous avons tenté de proposer des modèles étudiant la structure des relations entre les sites LBK en fonction de leurs distances relatives. Pour ce faire, nous avons utilisé des analyses de réseau de type PPA. Ces analyses sont des dispositifs théoriques permettant la construction de modèles qui doivent être considérés comme des outils ou des hypothèses visant à reconstituer les réseaux passés. Cette analyse préliminaire devrait permettre d'initier des travaux ultérieurs visant à inclure davantage de données sur les transferts de matières premières afin d'affiner les paramètres du modèle PPA et d'observer potentiellement des phénomènes socio-économiques Les réseaux géographiques de circulation des matières premières révèlent des axes préférentiels entre certaines régions ou, au contraire, des effets de frontière qui comparées aux groupes stylistiques de la céramique décorée révèlent des entités distinctes.

Il s’avère au terme de cette analyse que le Néolithique ancien du nord-ouest de l'Europe constitue un champ d'étude unique en raison de la qualité des données disponibles, même si un bilan pétroarchéologique et technologique significatif reste à entreprendre à l'échelle du LBK du nord-ouest.

Mots-clés : Industrie lithique ; Néolithique ancien ; *LinearbandKeramik* ; réseau de transfers ; tradition technique

Steinartefakte und stilistische Einheiten während des frühen Neolithikums (LBK) im Rhein-Maas-Seine-Becken

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Zusammenfassung:

Die Untersuchung der verzierten Keramik der frühneolithischen Linearbandkeramik (LBK) hat lange Zeit die Grundlage für die Erstellung der chronologischen Sequenz des Frühneolithikums in Nordwesteuropa gebildet. Jüngere Beiträge ermöglichen es, regionale stilistische Gruppen zu identifizieren. Die Analyse der verschiedenen regionalen Korpora zeigt, dass sich nach der Auflösung einer gemeinsamen stilistischen Phase, der sogenannten Flomborn-Einheit, die dekorativen Elemente in den einzelnen Regionen unterschiedlich entwickelten. Dies führte zur Entstehung klar abgegrenzter Einheiten, die manchmal eine große Homogenität in Bezug auf die verwendeten Dekorationsstile aufweisen (zum Beispiel die Rhein-Maas-Gruppe des mittleren LBK). Diese Studien schlagen eine Serie großer Blöcke vor, die sich über weite Gebiete erstrecken, während neuere Arbeiten ein Mosaik stilistischer Einheiten aufzeigen, die je nach den betrachteten Dekorationskriterien variieren. Die Grenzen dieser Verteilungen sind daher unscharf und deuten auf eine kontinuierliche Verbreitung dekorativer Motive hin, wobei Grenzen erst dann deutlich werden, wenn bestimmte Dekore nicht in das Repertoire der Töpfer aufgenommen werden.

Vor dem Hintergrund dieser auf Keramikdekoren basierenden Analyse, die bereits mehrere Szenarien je nach Detailtiefe der Studien umfasst, haben wir versucht, die Ergebnisse von Untersuchungen zu verschiedenen Aspekten der lithischen Industrie einzubeziehen. Hier betrachten wir zwei unterschiedliche Variablen: die Typologie der Pfeilspitzen und die Zirkulationsnetzwerke der Rohmaterialien. Die Typologie und die Lateralisierung der Projektilspitzen zeigen eine differenzierte Verteilung entsprechend der Häufigkeit von asymmetrischen oder symmetrischen Spitzen, und auch die Lateralisierung asymmetrischer Spitzen weist auf unterschiedliche Gruppen hin. Hinsichtlich der Zirkulation von Rohmaterialien ist die Datenqualität sehr unterschiedlich, und nur etwa fünfzig Fundplätze ermöglichen eine Analyse der Auftretenshäufigkeit (d.h. quantitative Daten). Die meisten nicht-lokalen silikatischen Gesteine (>10 km) gehören zu sieben Materialgruppen, die in der Regel mit bloßem Auge identifiziert werden können: Rijckholt-Feuerstein (NL), Hesbaye-Feuerstein (BE), Ghlin-Feuerstein (BE), Rethel-Feuerstein (FR), silikatische Gesteine aus Lhéry (FR), Feuersteine aus den Sümpfen von Saint-Gond (FR) und Malm-Kalke von Elsass (FR). Untersuchungen eines der Autoren, kombiniert mit den Synthesen von A. Zimmermann (1995) und Schmidgen-Hagger (1993), lassen vermuten, dass zwar in allen Regionen ein Rohmaterialaustausch stattfand, dessen Intensität jedoch je nach Region variierte. Aus einer

fundplatzbezogenen Perspektive zeigt die Projektion der Daten zur Rohmaterialzirkulation keine systematische Korrelation zwischen dem Anteil der Rohmaterialien und den Entfernungen zwischen einem Fundplatz und den Vorkommen.

Auf Grundlage der ersten Ergebnisse dieser wirtschaftsarchäologischen Analysen haben wir versucht, Modelle zu entwickeln, die die Struktur der Beziehungen zwischen den LBK-Fundplätzen in Abhängigkeit von ihren relativen Entfernungen untersuchen. Dazu haben wir PPA-Netzwerkanalysen verwendet. Diese Analysen stellen theoretische Werkzeuge dar, die als Hypothesen zur Rekonstruktion vergangener Netzwerke dienen. Diese vorläufige Analyse sollte als Grundlage für zukünftige Arbeiten dienen, die mehr Daten zum Rohmaterialtransfer einbeziehen, um die PPA-Modellparameter zu verfeinern und möglicherweise sozioökonomische Phänomene sichtbar zu machen. Die geografischen Netzwerke des Rohmaterialaustauschs zeigen bevorzugte Achsen zwischen bestimmten Regionen oder, im Gegenteil, Grenzeffekte, die im Vergleich mit den stilistischen Gruppen der verzierten Keramik unterschiedliche Einheiten erkennen lassen.

Diese Analyse zeigt letztlich, dass das Frühneolithikum Nordwesteuropas aufgrund der Qualität der verfügbaren Daten ein einzigartiges Forschungsfeld darstellt, auch wenn eine umfassende petroarchäologische und technologische Bewertung im Maßstab der nordwestlichen LBK noch aussteht.

Schlüsselwörter: Lithische Industrie; Frühneolithikum; Linearbandkeramik; Transfernetzwerke; Technische Tradition