On foot, by boat: Distribution methods of raw materials suitable for lithics in Central Europe in c. 4900-3400 BCE

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Abstract:

Thanks to long-term efforts to identify the stone raw materials of Neolithic lithics, a dataset of the proportional raw material composition at Neolithic settlements for the eastern part of Bohemia and the Morava River Basin in Central Europe has been created, which can be analysed in the period c. 4900-3400 BCE The focus of this study is on four issues: (1) the chronological evolution of the mode of distribution of the raw materials of lithics and its relation to settlement dynamics; (2) the relationship between the rate of imported raw materials and settlement density; (3) the importance of navigable rivers for the long-distance transport of raw materials; and (4) a comparison of the spatial distribution of stone raw materials and 'archaeological cultures'. In terms of chronological variations in distributional structures, it is clear that population size was an important factor affecting extra-regional distribution, particularly when compared with settlement numbers and radiocarbon density. In contrast, settlement density was not a determinant of the occurrence of imported raw materials. Navigable rivers are an important factor in the transport of goods, which is represented in the archaeological record by stone raw materials. The most evident relationship between imported raw materials and navigable rivers is in c. 4800-4500 BCE. At the end of the period under study, the construction of fortified hillforts is a significant social phenomenon, which, despite the problematic find circumstances of lithics, suggests a change in the distribution pattern. The presence of archaeological cultures (ceramic style) cannot be an explanatory factor for the changes in the distribution of stone raw materials, as the changes in internal and extra-regional distribution are not related to its changes.

Keywords: raw materials; lithics; Neolithic; central Europe; distribution

1. Introduction

The eastern part of central Europe is characterised by great geological variability, which is also linked to the wide possibilities of obtaining raw materials suitable for the production of lithics. However, the distribution of resources is not uniform and their occurrence is not directly linked to areas that were suitable for agriculture.

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The question of the origin of stone raw materials has been given increased attention for several decades (Přichystal 2013), in contrast to the issue of technological production processes. Thanks to long-term systematic efforts, the raw materials of a large number of lithic assemblages have been gradually identified. This currently allows the use of the dataset to analyse them with an emphasis on the social or natural variables that influenced their distribution structure.

An analytical approach to understanding the spatial distribution of raw materials in the Neolithic was used for the territory of the Czech Republic by P. Šída (2006), who used the proportional representation of raw materials to quantify the spatial occurrence of each significantly exploited raw material, though on the basis of a small dataset. F. Trampota (2015) used a similar approach in the Thaya River Basin (part of the Morava River Basin) in his dissertation. Inna Mateiciucová (2008) focused in detail on the raw materials used and the typological character of LBK (in German, Linearbandkeramik) lithics in central Europe, but also paid some attention to the post-LBK period. Long-distance transport was further explored based on empirical evidence in the works of M. Kuča *et al.* (2009), F. Trampota (2012) and I. Mateiciucová & G. Trnka (2015), who also attempted to define the raw materials of the lithics according to the distance categories to which they were imported. The current state of knowledge is mainly based on empirical knowledge, which, however, sufficiently captures the main characteristics of the distribution of individual raw materials in Bohemia, Moravia and neighbouring regions.

Given the dataset of the raw material composition from a total of 123 sites, spatial, chronological and statistical analysis is possible. The main questions we address are (1) the character of the evolution of raw material distribution in c. 4900-3400 BCE based on the quantified data. In (2) we ask whether there is a correlation between the occurrence of imported raw materials and settlement density. In social terms, the question is directed at more densely populated areas, where higher demand for exotic raw materials could reflect an interest in acquiring a prestigious exotic good and the possible existence of some vertical social stratification. The third (3) issue then is the extent to which imported raw materials are found around navigable rivers. The demonstration of this relationship may reflect the main directions of transport and exchange. We do not assume that the transport was primarily of lithics, but of commodities whose existence cannot be archeologically recorded. The raw materials of the lithics would then have been distributed because it was more possible than desirable. This is also related to the fact that the Morava River Basin in particular is a region with numerous raw material sources and imports of other raw materials are not critically necessary. Finally (4), we are interested in how the spatial distribution of stone raw materials relates to the extent of ceramic traditions, or archaeological cultures.

The study region is the Morava River Basin with a relatively large number of dates. This area is compared with the eastern half of Bohemia. In this way, it is possible to trace the development of the distribution patterns of raw materials in two separate settlement regions (Figure 1). The study focuses on the period which, in terms of ceramic decoration, corresponds to the decorative symbolic styles of Stroked Pottery (in German, Stichbandkeramik, hereinafter SBK), Lengyel pottery (in German, Lengyel-Kultur, hereinafter LgK), Epi-Lengyel or Jordanów pottery (hereinafter EpiLgK) and Funnelbeakers (in German, Trichterrandbecherkultur, hereinafter TRB), which are found in the Morava River Basin together with pottery of the Retz-type (in German, also Furchenstichkeramik).

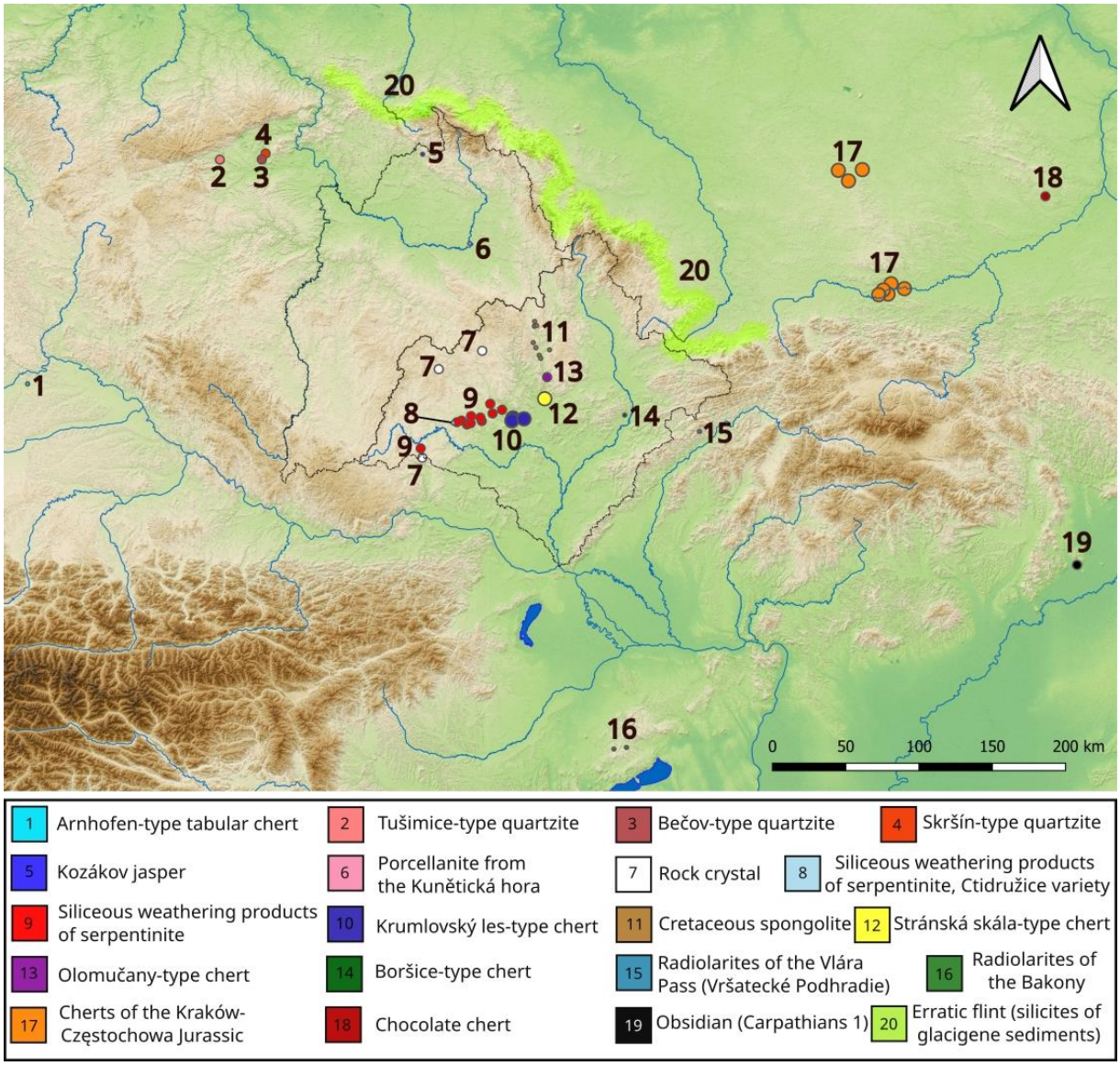

Figure 1. Localisation of the studied areas (east Bohemia in the west, the Morava River Basin in the east) with the sources of raw materials used in the Neolithic. Large circle: dominant raw material in at least one period, medium circle: locally important raw material, small circle: sporadically occurring raw material.

2. Data and methods

The database of the proportional representation of lithic raw materials (Supplement 1) with 132 assemblages (entities), was created mostly on the basis of published analyses and a few newly determined assemblages. In the case of multiple survey seasons at one site from which the lithics are published separately, these assemblages are converted into a single entity. Conversely, in the case of multiple phases of site occupation, the assemblages are split into multiple entities. Only data from assemblages for which a relatively precise chronological determination is known on the basis of a related ceramic typology, *i.e.*, not based solely on the general ceramic tradition (archaeological culture), but with knowledge of their basic subdivision into two or three phases, proceeded to the analysis. Occasionally, in the absence of specific ceramics, radiocarbon dating was used, the results of which are related to the ceramic typology. The coordinates are defined in the database in the S-JTSK (*Systém jednotné trigonometrické sítě katastrální*) Krovak East North system (EPSG:5514). Each site is identified by the form 'Cadastre-Site name'.

2.1. GIS

To calculate the relationship between the representation of imported raw materials and settlement density, we used a dataset of Neolithic settlements for the region under study (Pajdla & Trampota 2021), which can be chronologically classified in the same way as the database of raw materials of lithics. Based on points representing individual settlements, a raster layer for kernel density estimation (standard deviation = 10 km) was calculated for each period in QGIS (v. 3.22). The KDE (kernel density estimation) values were then subtracted using the 'Zonal statistics' function for points representing settlements with lithic assemblages with the identified raw materials.

To calculate the distance to navigable rivers, the shapes of watercourses prior to their regulation were digitised based on the Second Military Survey (1836-1852 CE) and 5th generation LIDAR scanning. Subsequently, the closest distance between lines representing navigable rivers and each lithics assemblage was calculated using the 'Find all closest points for each feature' function. We consider the Morava and Elbe rivers to be navigable rivers.

2.2. Statistics

The Jamovi project (2021) and R Core Team (2020) were used for statistical analysis of the values obtained using the R package for correlation by Kim (2015). The relationship between the distance of lithic assemblages from the navigable river and the relationship of the ratio of imported raw material to settlement density kernel density estimation (hereinafter KDE) was expressed using a correlation matrix and the data was visualised using a scatter plot and linear regression.

2.3. Chronology

In terms of chronology, the concept of archaeological culture (or its sub-chronological division) is traditionally used to explain the development of changes in society (*e.g.*, Podborský 1993). Each archaeological culture is time specific by different groups of artefact types and in agricultural prehistory always has only the specificity of decoration and the morphology of ceramic vessels in common. Even this is not defined on the basis of graspable criteria, so we turn to a reproducible notion of chronology. The ceramic typology is particularly suitable for chronological description, since lithics almost always accompany it. The chronological dispersion of the general ceramic groups (stages of archaeological cultures) is defined on the basis of a modelling of the C-14 data by Trampota and Květina (2020) and, in view of the ambiguous results, generalised. We use summed probability density (SPD) and KDE to explain the evolution of archaeological data (or the lithic raw materials) for all radiocarbon data that come from anthropogenic contexts in the Neolithic. The resulting curve (Figure 2) is validated by the number of settlements subdivided by ceramic traditions (archaeological cultures) and by general ceramic groups (stages of archaeological cultures). Source data and other information are published in an article on settlement structures in the same area (Trampota & Pajdla 2022).

While the dynamics of the two types of data more or less correlate in the Morava River Basin, in Bohemia there are significant data biases and a smaller data base. Therefore, we derive the subsequent chronology from the situation in the Morava River Basin, knowing that later results may differ in Bohemia. In the Morava River Basin, the basic data structure is divided into three peaks. If we understand the frequency of occurrence of the C-14 data as a population proxy, three population events become evident - Neolithic A, B and C. Neolithic A corresponds to LBK and is not the focus of this study. There is an apparent decrease in the density of C-14 data between Neolithic A and B, which should correspond to a decrease in

population. Neolithic B includes several ceramic traditions, most notably Stroked Pottery, Lengyel Pottery and Jordanów or Epilengyel pottery. There is a conspicuous absence of C-14 dates between Neolithic B and C, which seems to correspond to a population hiatus between approximately 4000 and 3800 BCE Neolithic C is then associated with the Funnelbeakers and Retz-type pottery, whose occurrence is parallel, particularly in the Morava River Basin. The end of the Neolithic C is artificial, as data collection was terminated programmatically with the end of the occurrence of the Funnelbeakers.

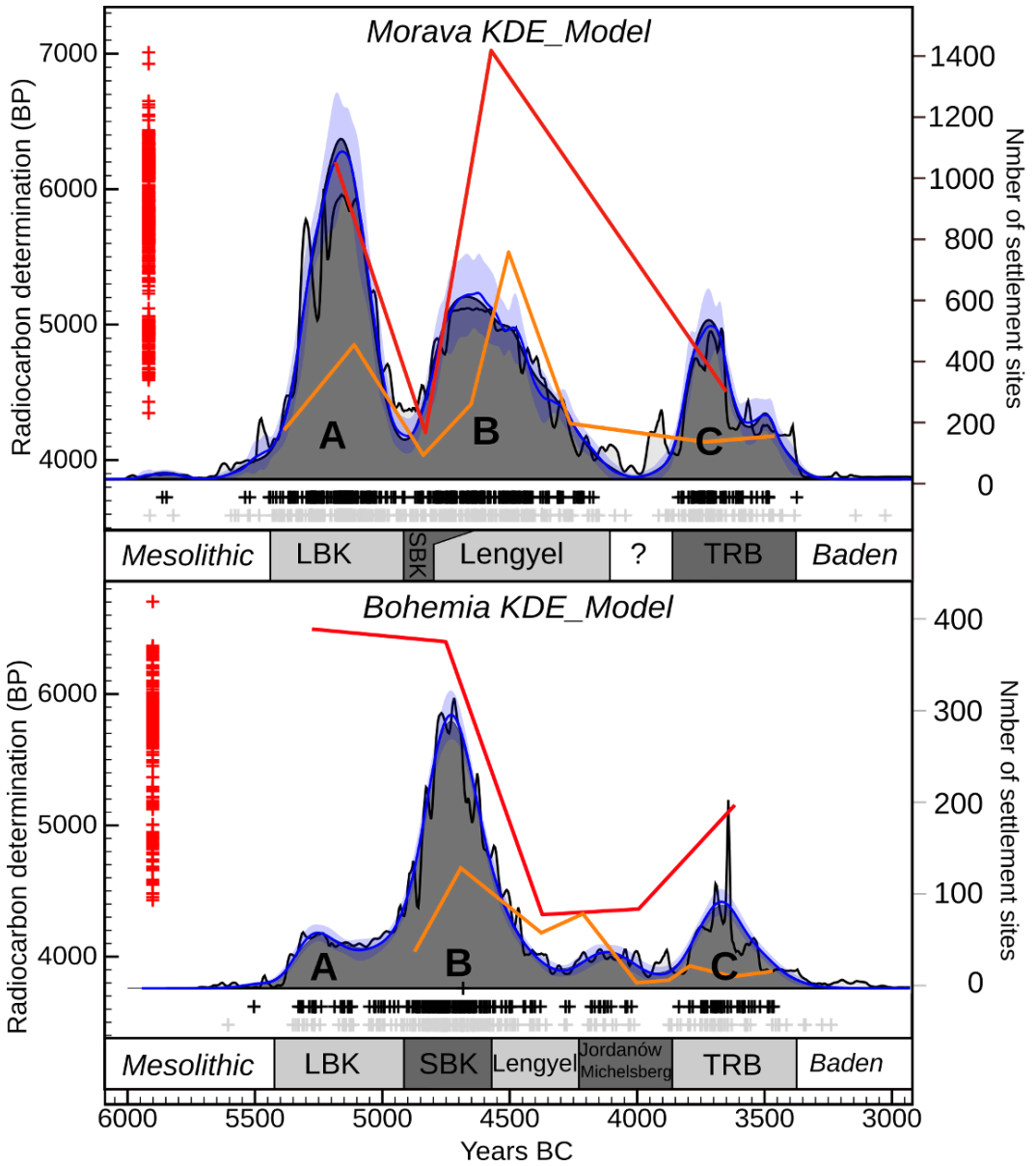

Figure 2. Summed probability distribution (SPD) and kernel density estimation (KDE) of 14C data from anthropogenic contexts in the Morava River Basin (above, n = 516) and in Bohemia (below, n = 299). The red curve shows the number of settlement sites defined by pottery traditions; the orange curve shows the number of sites based on a more detailed pottery typo-chronology.

The abandonment of archaeological culture as an explanatory concept of phenomena during agricultural prehistory is based on the idea of reconstructing past societies using the polythetic theory by D. Clark (1978), through S. Shennan's (1989) critique of the concept of archaeological culture to M. Furholt's (2021) contemporary conception of past human societies.

2.4. Terminology

The two arising questions are related to the issue of imported raw materials, so it is necessary to define the term 'imported raw materials'. In doing so, we start from a general data structure. In the Morava River Basin, two dominant raw materials from local sources are found, namely Krumlovský Les-type chert (hereinafter KL-type chert) in the southern part of the area and erratic flints in the northern part. As the distribution radius of both raw materials is about 60 km from the dominant point of view, we therefore consider this value as the distance defining the regional distribution from extra regional.

In Bohemia, the situation is markedly different, as there are no significantly exploited resources in the studied half of Bohemia and lithic assemblages are almost always dominated by erratic flints, which predominate up to a distance of 100 km. In view of the unequal possibilities of obtaining raw materials in the two study regions, this fact must be taken into account in the asymmetrical concept of import. Therefore, we consider imported raw material in the Morava River Basin from a distance of at least 60 km and in Bohemia from a distance of 100 km.

3. Results

3.1. Evolution of distribution networks

When comparing the sizes of lithic assemblages (Figure 3: A), it is evident, particularly in Neolithic B, that the number and size of assemblages generally correlates with both the KDE curve of the radiocarbon dates and the number of settlements. In Neolithic C, the assemblage size is significantly higher in the Morava River Basin, reflecting the assemblages found in the vicinity of chert-type sources at Stránská skála (see below) and specifically in the Boleráz phase at the hillforts. A similar pattern is also observed for the nominal number of raw materials at individual sites (Figure 3: B). In periods of presumed low population density, the number of exploited raw materials is low and vice versa. This pattern is broken by the Boleráz assemblages, which come mainly from hillforts, which were probably a new structuring element for the distribution of stone raw materials or other goods.

At the beginning of the period under study (c. 4900 BCE), which is characterised by the early phase of Stroked Pottery, we assume a low population level. The Morava River Basin is mainly populated in the western part of the area and there is an obvious settlement affinity towards the sources of raw materials for lithics (Trampota & Pajdla 2022). KL-type chert completely dominates in the studied assemblages (Figure 4). In the northern part, erratic flints dominate, but KL-type chert is also significantly represented here. A completely anomalous situation is represented by the Určice-Záhumení site (Čižmář & Oliva 2001), where quartzites from northwest Bohemia (Tušimice and Skršín types) completely dominate, occasionally supplemented by KL-type chert. We are not sure of the correctness of the raw material determination, potentially local quartzite to quartz conglomerates (sun boulders) may be involved. Either way, this is an anomalous assemblage. Quartzites from northwest Bohemia are also found at other Stroked Pottery sites (Olomouc-Slavonín) (Mateiciucová 1999), including the grave context (Těšetice-Kyjovice site) (Kazdová 1990). In the eastern half of Bohemia, only two erratic flints-dominated assemblages are available, supplemented by local porcelanite, and to a small extent also by quartzites from northwest Bohemia.

This period is characterised by the import of quartzites from Bohemia into the Morava River Basin (if correctly determined) and by a relatively discernible distribution within east Bohemia, which is specific compared to the following period. In addition, the number of raw materials represented in the Morava River Basin is very low; apart from the completely dominant chert of the KL-type, all others are practically unused. An absence of raw materials

from Poland is also apparent, especially chert of the Kraków-Częstochowa Jurassic (hereinafter CKCJ).

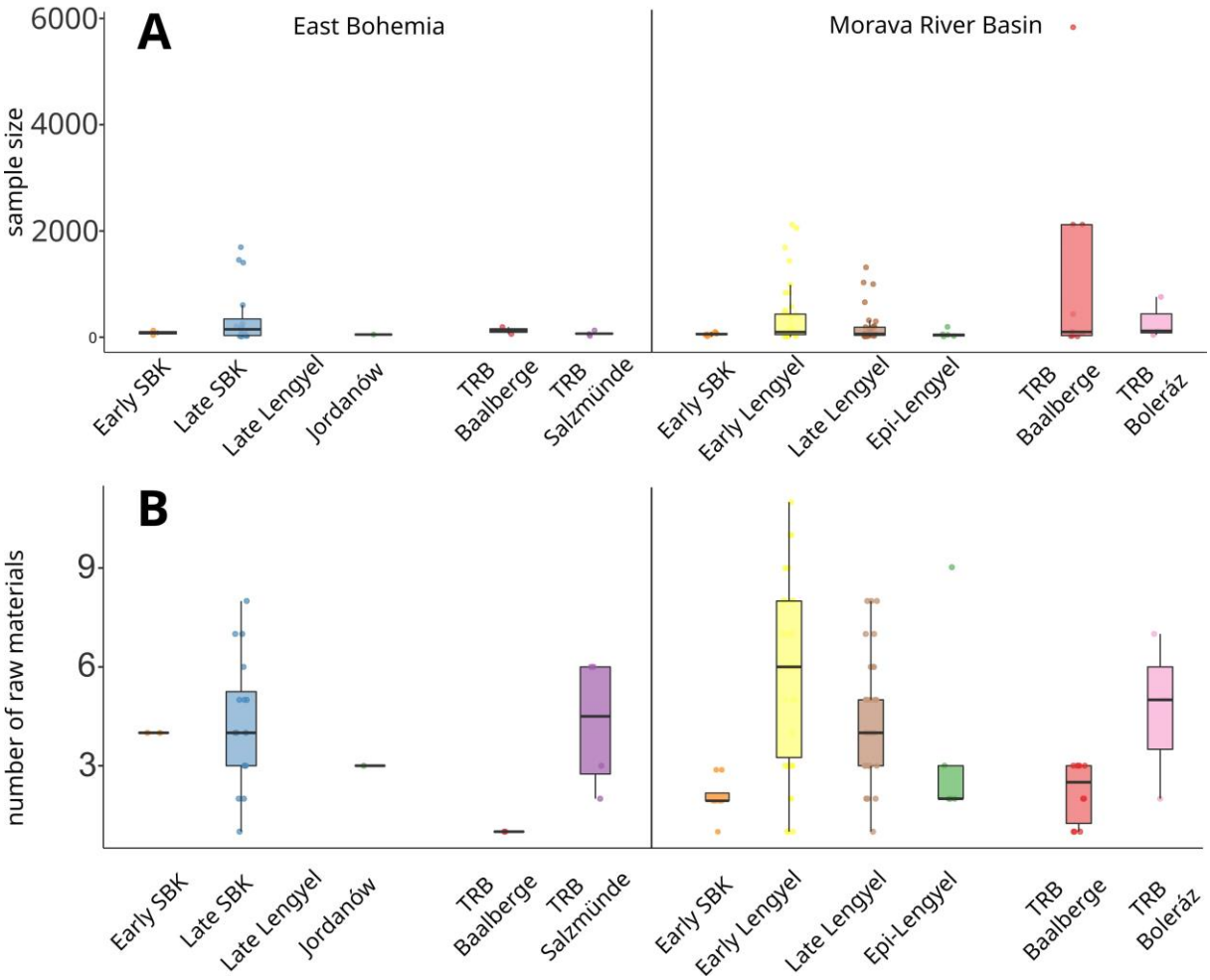

Figure 3. A. Size of study assemblages classified by chronological phases. B. Nominal number of raw materials represented in each assemblage by chronological phase.

The period of c. 4800-4500 BCE is characterised by Early Lengyel in the south of the Morava River Basin and late phase of Stroked Pottery in Bohemia and the north of the Morava River Basin. There is a radical reversal in the use of raw material resources (Figure 5). In the Morava River Basin, KL-type chert predominates in the south and erratic flints in the north, but in many microregions local raw materials, mainly rock crystals, siliceous weathering products of serpentinite and sporadically Olomučany and Stránská skála cherts, predominate. The assemblages from sites located along the Morava River are mainly characterised by CKCJ, erratic flints, chocolate chert and obsidian. In all the assemblages, apart from the dominant raw material, a wide range of other local and imported raw materials occur. In this period, we also record the largest number of imported raw materials, mainly CKCJ and chocolate chert from Poland, obsidian from the Carpathians 1 source in eastern Slovakia, and Bavarian Arnhofen-type tabular chert. Radiolarites are sporadically imported from the vicinity of Vršatecké Podhradie near the border of Moravia and Slovakia, while imports of radiolarites from the Hungarian Bakony are negligible.

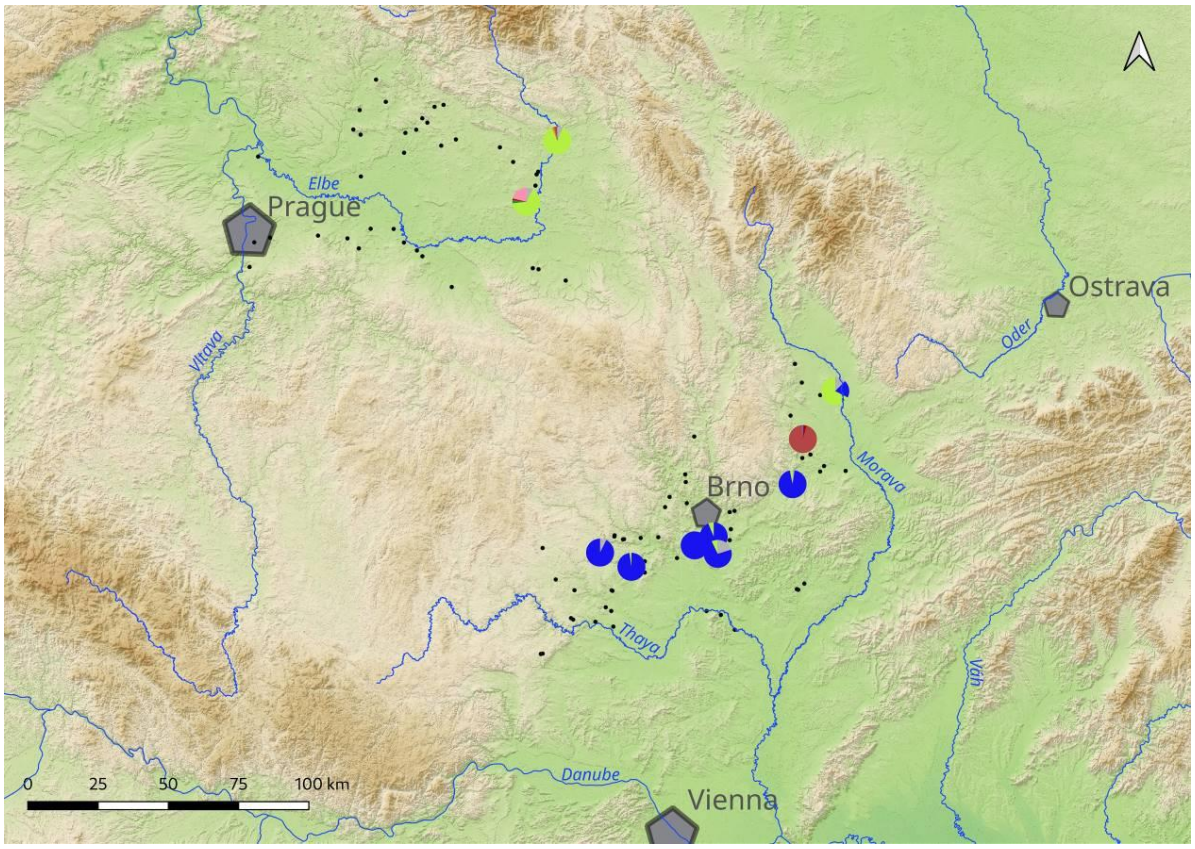

Figure 4. Pie charts representing raw material proportions at Early SBK settlements (c. 4900-4800 BCE). For legend, see Figure 1.

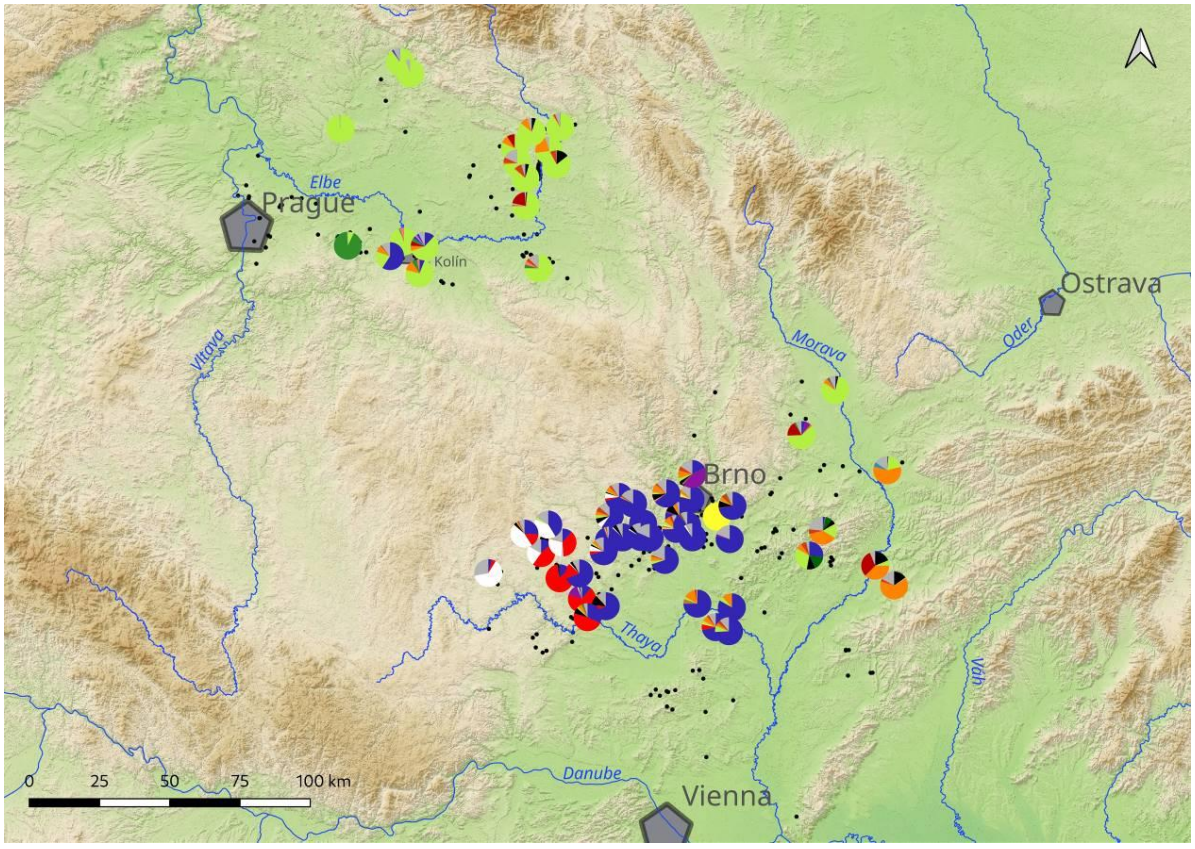

Figure 5. Pie charts representing raw material proportions at Late SBK and Early Lengyel settlements (c. 4800-4500 BCE). For legend see Figure 1.

In the eastern half of Bohemia, the situation is specific with regard to sub-regions, which differ mainly in the composition of imported raw materials. While erratic flints are the dominant raw material, in the upper Elbe River the composition of imported raw materials (for details, see Burgert 2019) consists mainly of CKCJ and chocolate chert from Poland and obsidian. In the broader area of present-day Kolín, the composition of imported raw materials is dominated by KL-type chert from Moravia, CKCJ, chocolate chert, and Bavarian Arnhofen-type tabular chert, which rarely forms the majority of the assemblages (Chotýš site) (Burgert *et al*. 2018). The assemblages that are significantly more distant from the Elbe River contain only a minimum of imported raw materials.

The subsequent period is characterised by Late Lengyel in both regions (Figure 6). While a number of quantified assemblages are available from the Morava River Basin, none are known from Bohemia. This is not necessarily a state of knowledge; no Lengyel settlements with numerous sets of lithics are known from previous research. It is therefore possible that the low number of pieces of lithics in the settlement layers is a concomitant phenomenon of the Late Lengyel in Bohemia.

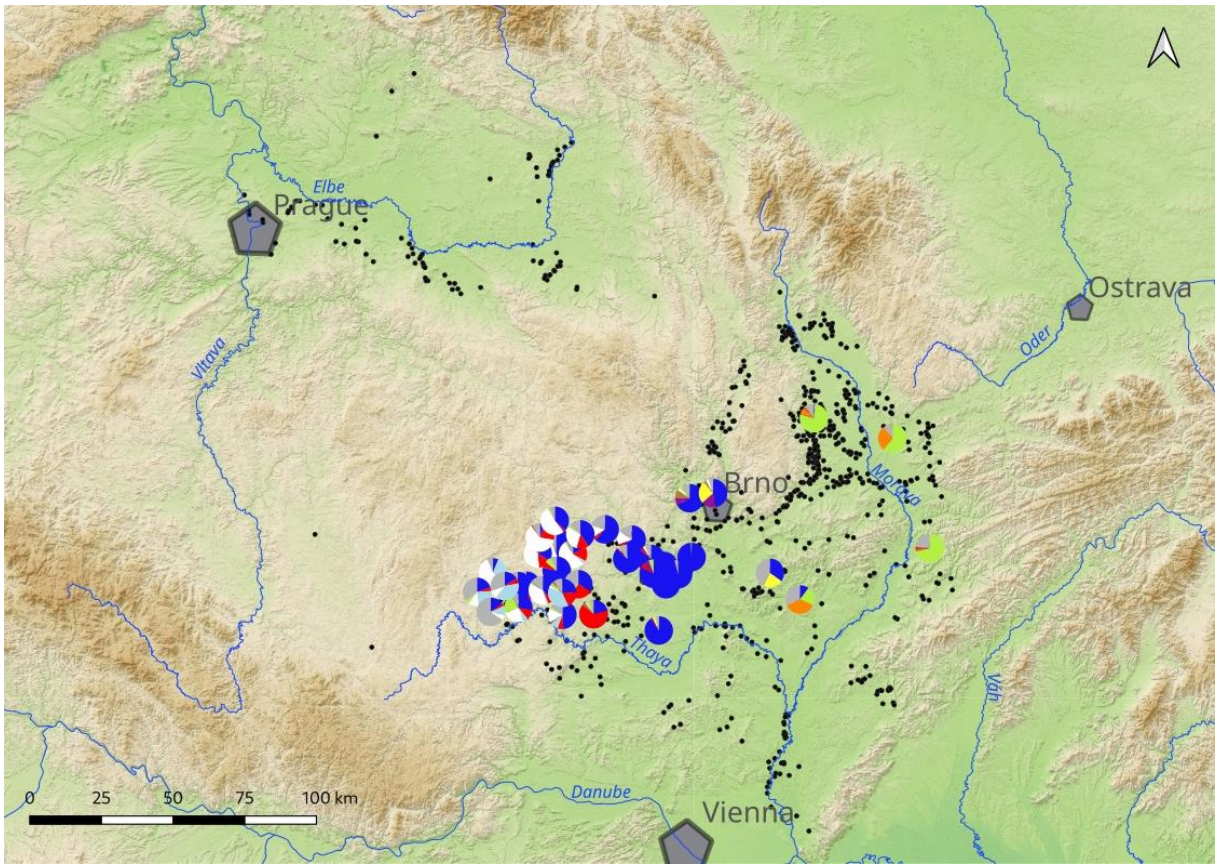

Figure 6. Pie charts representing raw material proportions at Late Lengyel settlements (c. 4500-4300 BCE). For legend, see Figure 1.

In the Morava River Basin, there is a decrease in the nominal frequency of the number of raw materials and a decrease in imported raw materials. Of these, only CKCJ occurs more significantly, which is found in larger quantities only in the vicinity of the Morava River. For raw materials of local origin, the established trend continues, where KL-type chert dominates regionally, or siliceous weathering products of serpentinite (including the Ctidružice white variety) and rock crystal predominate locally. However, the knowledge of the raw material composition of the assemblages of lithics is geographically very uneven in favour of southwest Moravia.

The end of Neolithic B is represented by the Epi-Lengyel or Jordanów pottery. In both regions, occupation areas are shrinking and the number of settlement sites is decreasing. While in the Morava River Basin, settlements are concentrated in the northern part, in Bohemia then in the wider vicinity of Prague. In the lithic assemblages in the Morava River Basin (Figure 7), the trend of a smaller number of used raw materials continues. The local raw materials are mainly erratic flints, KL-type chert and Stránská skála-type chert. Of the imported raw materials, only CKCJ is concerned, which is found only in the northern part of the Morava River Basin. Only one analysed assemblage is known from Bohemia (Praha-Ďáblice, Legionářů st.) (Dobeš *et al*. 2007). In general, it can be stated that it does not deviate from the expected raw material composition with the predominance of erratic flints and rare imports of Arnhofen-type tabular chert.

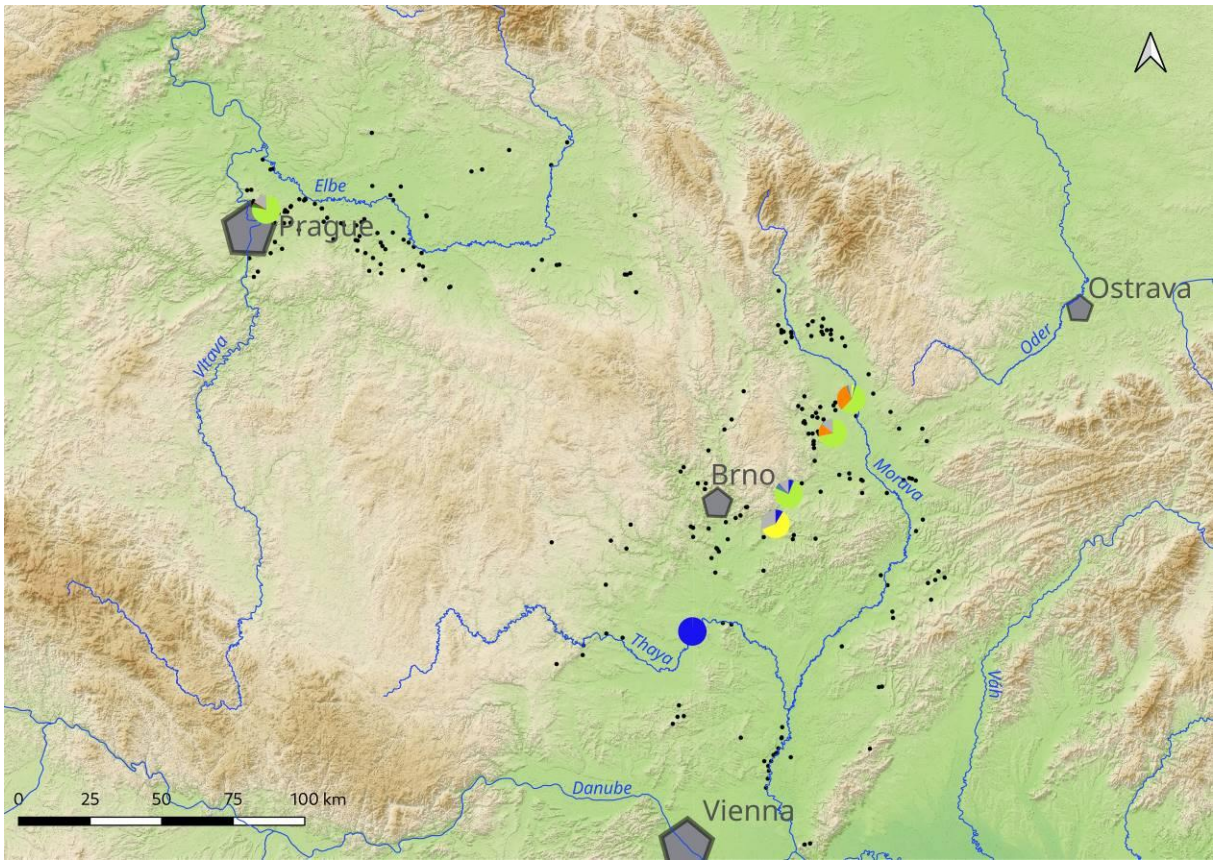

Figure 7. Pie charts representing raw material proportions at Epi-Lengyel and Jordanów culture settlements (c. 4300-4000 BCE). For legend see Figure 1.

After the end of the hiatus of human activities around 3800 BCE, settlements with the Funnelbeakers of the Baalberge phase appear in both regions, often accompanied by Retz-type pottery in the Morava River Basin. There is a marked change with regard to the raw material composition of lithic assemblages, especially in the Morava River Basin, where several representative assemblages come from (Figure 8). Quantitatively, Stránská skála-type chert becomes the dominant raw material, but it is distributed only in the vicinity of Brno up to a distance of c. 20 km. However, it is also found in large numbers at settlements. Outside the Brno region, larger assemblages of lithics are rarely found at settlements and their numbers usually do not exceed 10 pieces (Šmíd 2017: 199). In southwest Moravia, the distribution of chert is related to the KL-type, while in the northern part of the Morava River Basin, erratic flints predominate with the isolated presence of imported CKCJ (Lazce u Troubelic-U Staré Matky site) (Konopová 2013).

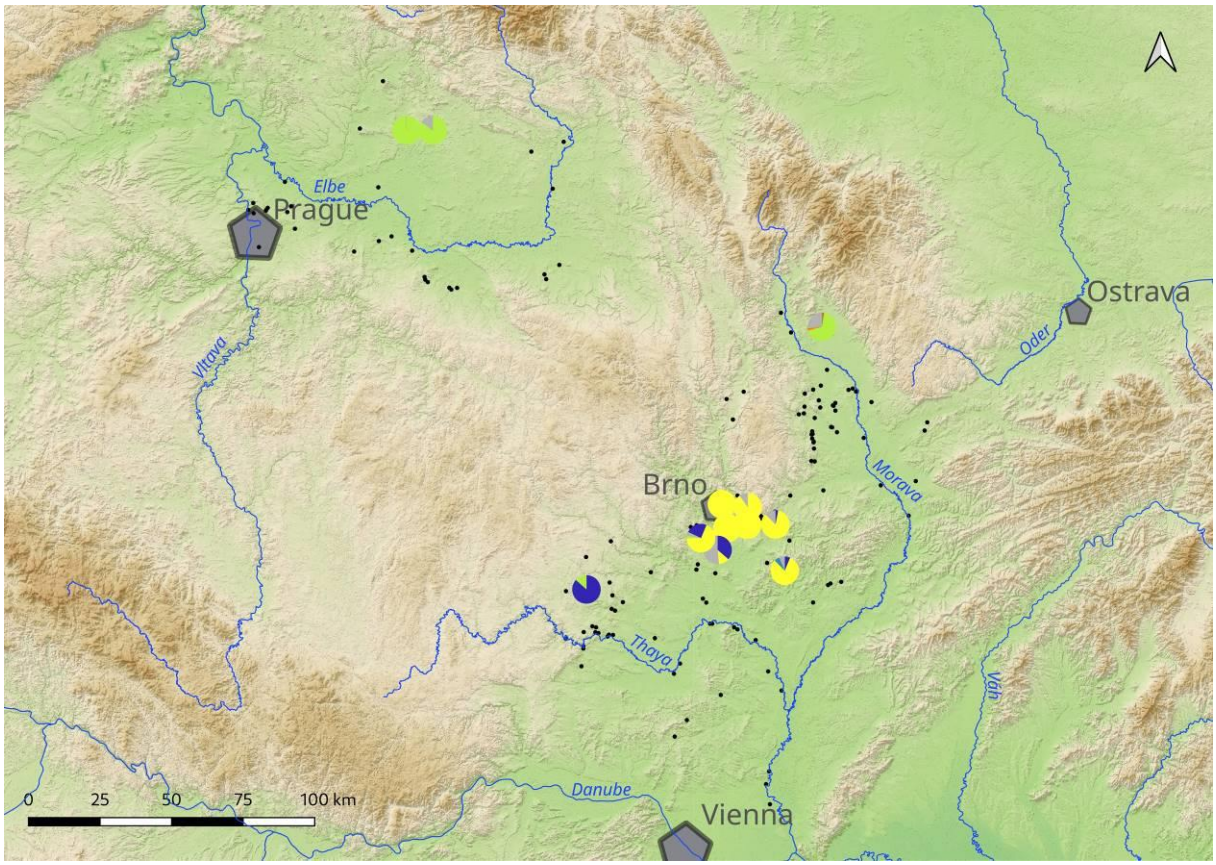

Figure 8. Pie charts representing raw material proportions at Early TRB (Baalberge) settlements (c. 3800-3550 BCE). For legend see Figure 1.

The final phase of this study is represented in the Morava River Basin by the Boleráz phase of the Funnelbeakers (it can also be perceived as the earliest Baden phase). The Salzmünde phase of Funnelbeakers occurs separately in Bohemia and locally also the Boleráz phase in the vicinity of Kutná Hora. In Bohemia, we observe a major reversal in the raw material composition (Figure 9), but only on the basis of two assemblages from the vicinity of Prague and a mixed assemblage from Kutná Hora (Cimburk site) (Vencl 2000). Tušimice and Skršín-type quartzites have a significant proportion here. Erratic flints do not have a dominant position, unlike in previous periods. Imported raw materials are represented at the Cimburk hillfort near Kutná Hora, where, in addition to quartzites, KL-type chert and Arnhofen-type tabular chert occur in small quantities. It is evident that north Bohemian quartzites became more important in this period and their distribution radius increased.

In the Morava River Basin, the numerous assemblages of Stránská skála-type chert near Brno begin to disappear and there is a change in the occurrence of large lithic assemblages. While at ordinary lowland settlements the previous situation in which the number of pieces found is very small applies, larger sets, on the contrary, are found at hillforts. Due to the long-term occupation of these areas, which often begins at the end of the Baalberge phase and continues at least into the Baden, these assemblages cannot be considered unequivocally reliable. Since all three are from the northern part of the Morava River Basin, erratic flints dominate here. Imported raw materials are represented here in small proportions by CKCJ and quite sporadically by chocolate chert and Świeciechów flint, which, however, is more likely to be associated with the classical Baden.

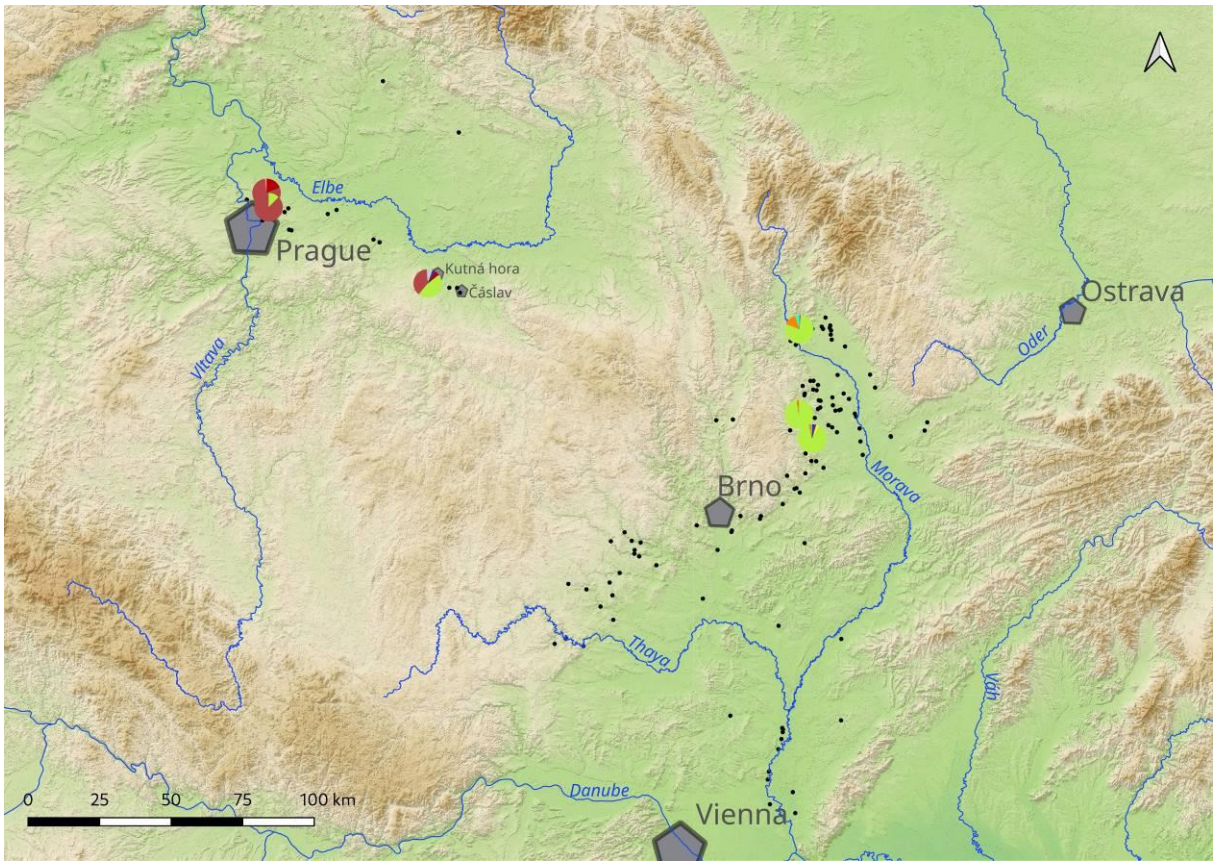

Figure 9. Pie charts representing raw material proportions at Late TRB (Boleráz and Salzmünde phases) settlements (c. 3550-3400 BCE). For legend see Figure 1.

3.2. Relationship between kernel density of settlements and the amount of imported raw materials

The results of the relationship between settlement density and the amount of imported raw materials (Table 1, Figure 10) for the whole dataset show a slightly negative correlation for the Morava River Basin, while the correlation in Bohemia is very low and statistically insignificant, as are the only two chronological phases that could be taken into account.

Data from the Morava River Basin, divided into individual chronological phases, mostly show a slightly negative correlation, except for the Epi-Lengyel and especially Boleráz phases, where the correlation is positive and almost absolute, albeit based on only three sites.

A more pronounced negative and significant correlation is then found during the Early Lengyel, when it is clear that the ratio of imported raw materials decreases with the density of settlements.

The expected association between more densely populated regions and higher demand for exotic raw materials is not confirmed. An exception to this finding may be the Boleráz phase, where it will be interesting in the future to see whether the high correlation between settlement density and the ratio of imported raw materials will be confirmed by more data. The fact that most lithic assemblages are located at hillforts, a new social phenomenon, gives a different dimension to the question of exchange and distribution.

Table 1. Results of the correlation (R) between the amount of imported raw materials, kernel settlement density and distance from navigable rivers. Significant results have p-values less than 0.05.

		Settlement KDE		distance from river	
	Chronological group	**R**	**p-value**	**R**	**p-value**
East-Bohemia	Early SBK	-	-	-	-
	Late SBK	-0.092	0.736	-0.121	0.656
	Late LgK	-	-	-	-
	Jordanów	-	-	-	-
	TRB - Baalberge	-	-	-	-
	TRB - Saalzmünde, Boleráz	-0.273	0.6	-0.329	0.525
	all data	0.087	0.639	-0.174	0.427
Morava Basin	Early SBK	-0.309	0.457	-0.514	0.192
	Early Lengyel, Late SBK	-0.46	0.002	-0.616	<.001
	Late Lengyel	-0.106	0.523	-0.411	0.009
	Epilengyel (Jordanów)	0.311	0.61	-0.26	0.673
	TRB - Baalberge	-0.673	0.047	-0.264	0.461
	TRB - Boleráz	0.992	0.078	-0.999	0.031
	all data	-0.293	0.004	-0.563	<.001

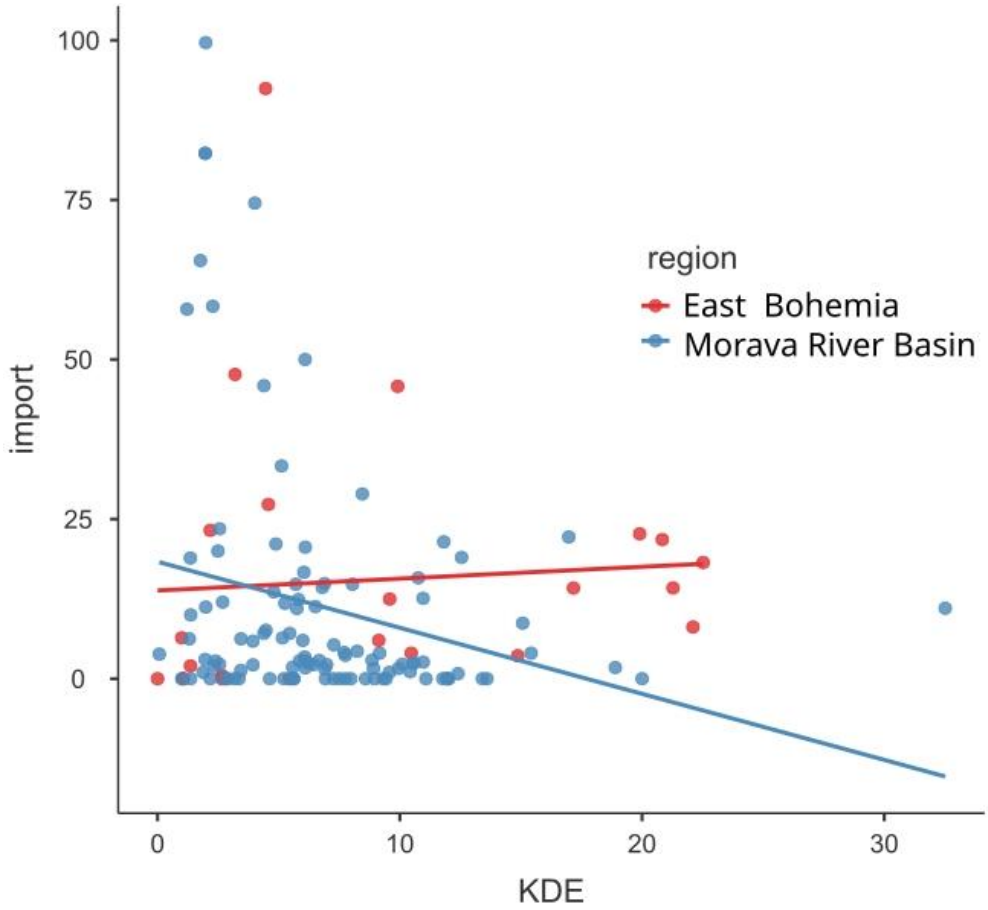

Figure 10. The scatterplot with regression line expresses the relationship for the whole dataset between the ratio of imported raw materials and kernel density estimation (KDE).

3.3. Relationship between distance from the navigable river and the amount of imported raw materials

The results of the correlation between the ratio of imported raw materials and distance to a navigable river (Table 1) are only feasible in Bohemia in the context of the whole dataset and in the case of the Late SBK, where no significant correlation is found. This is mainly because most of the assemblages come from a short distance from the Elbe and are thus statistically dominant compared to the three sites located at distances greater than 20 km from the river (Figure 11). However, these do not show any significant proportion of imported raw materials and therefore it can be assumed that the proportion of imported raw materials decreases with an increasing distance from the river.

In the Morava River Basin, a fairly strong negative correlation between the amount of imported raw materials and distance from the Morava River is evident in most of the periods studied (Table 1). In three periods, the results can also be described as statistically significant (p-value < 0.05). These are the Early Lengyel and Late SBK, Late Lengyel and the Boleráz phase. During the Early Lengyel, CKCJ, chocolate chert, obsidian and, on the Lower Morava River, erratic flints are mainly represented in the vicinity of the Morava River (Figure 5). In the Late Lengyel, there is a decrease in imported raw materials and in the area along the Morava River, mainly CKCJ is found in the lithic assemblages (Figure 6). The last and almost absolute correlation is the Boleráz phase, where a practically direct negative correlation between the ratio of imported raw materials and the distance from the river emerges. The problem with this finding is that there are only three sites examined and the maximum share of imported raw materials is at c. 13%, which is significantly less than in previous periods.

3.4. Distribution of lithic raw materials vs. distribution of pottery styles (archaeological cultures)

During the Early SBK (c. 4900-4800 BCE), we observe a unique distribution structure in which Polish raw materials are virtually absent in the relevant assemblages; quartzites from northwest Bohemia were imported into the Morava River Basin. In this respect, a connection with the spread of the symbolic style can be seen, as the distribution of raw materials was dominantly within individual regions and was supplemented by imported raw materials associated with the region where the same symbolic style was spread.

From c. 4800 BCE, the Lengyel ceramic style, which originated in the western part of the Carpathian Basin, spread to the southern half of the Morava River Basin. The transformation was not only related to the ceramic style but to many other aspects of artefacts. In Bohemia and in the northern part of the Morava River Basin, Late SBK pottery continues. Despite the numerous sources of stone raw materials in the Carpathian Basin, there is no evidence of the transport of raw materials to the Morava River Basin. On the contrary, the distributional connection between Bohemia and the Morava River Basin continues, which is manifested by imports in the opposite direction from the previous period. In particular, the area of present-day Kolín contains a relatively large proportion of the KL-type chert. This distributional trajectory is supported by the numerous finds of painted Lengyel pottery in Bohemia (*e.g.*, Trampota 2012: 452; Zápotocká *et al.* 2015).

Quantitatively, the most pronounced distribution of stone raw materials was from the geographic context of the Malice culture in Lesser Poland (CKCJ, chocolate chert) and obsidian from the Tisza culture area in eastern Slovakia. The image of distribution structures in relation to archaeological cultures completely reversed during c. 4800-4500 BCE compared to the previous period. While there is no evidence of distribution in the context of one's own ‘culture’, there is, on the contrary, intensive evidence of distribution to all surrounding regions other than one's own.

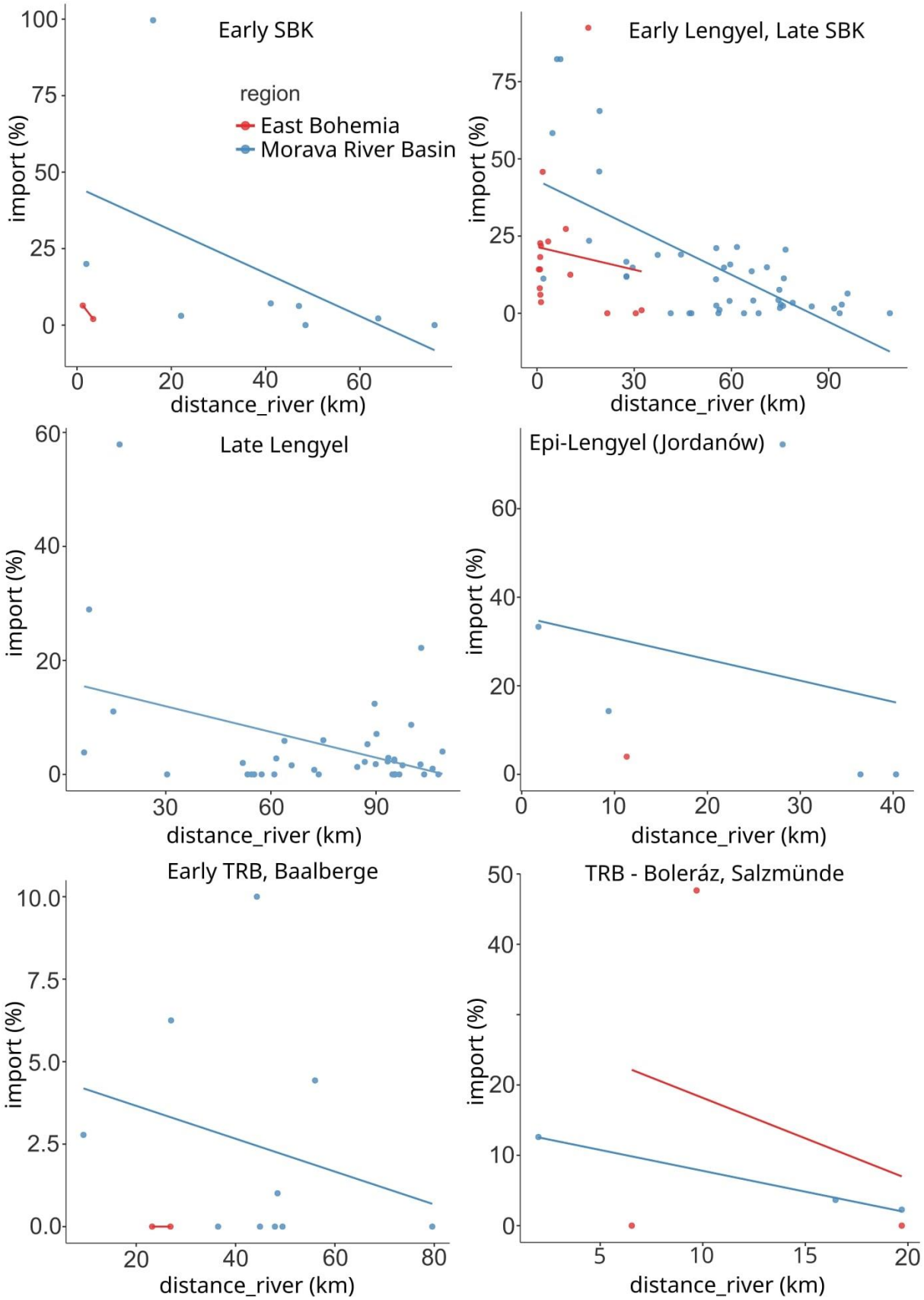

Figure 11. The scatterplots with regression lines expresses the relationship between the ratio of imported raw materials and the distance from a navigable river. The data are classified by chronological phases. Red colour represents East Bohemia and blue represents the Morava River Basin.

In the next period, the Lengyel style (Late Lengyel) spreads to much of central Europe, including Bohemia. Again, distribution patterns change in this context, as there is no evidence of any transport of stone raw materials between Bohemia and Moravia. Moreover, evidence of extra-regional transport is generally declining and is limited to the CKCJ. The Epi-Lengyel or Jordanów culture (c. 4300-4000 BCE) is then relatively ill-defined, probably reflecting the continuous variation of ceramic style across central Europe. Despite the small number of known assemblages, there continues to be only a limited supply of CKCJ from the Late Malice culture area.

Around 3800 BCE there is a significant resurgence of settlement in both study regions. While the Funnelbeakers (Baalberge phase) are of Nordic origin, Retz-type pottery, which has its centre of occurrence in the western part of the Carpathian Basin, is frequently found in the same contexts in the Morava River Basin. With regard to the distribution of stone raw materials, however, we do not observe distribution from or to any of these areas and the use of raw materials is only regional.

The last phase studied is the Salzmünde group in central Bohemia and the Boleráz group in the Morava River Basin and a small area of Bohemia (Kutná Hora and Čáslav regions). While the Salzmünde group is seen as the final stage of the Funnelbeakers, the Boleráz group is native to the Carpathian Basin, where it is seen as the oldest stage of the Baden. In the Morava River Basin in particular, however, the Boleráz pottery bears the characteristic features of both the Funnelbeakers and the Baden. In Bohemia, the two analysed Salzmünde group assemblages correspond only to regional distribution, while in the Morava River Basin we see no evidence of transport from the Carpathian Basin on the basis of three assemblages of uncertain chronological position. The only evidence of raw material imports here is CKCJ from the southeastern group of the Funnelbeakers and the Lublin-Volhynian Culture.

Finally, it is important to mention the relationship between the Morava River Basin and the local Boleráz group in the Čáslav Basin in Bohemia. Although there is no representative assemblage of lithics from well-defined contexts, there have been finds of KL-type chert (Kutná Hora-Cimburk) (Vencl 2000), which thus demonstrates isolated imports from the same area in which the same ceramic style occurs.

4. Discussion

An analysis of the chronological evolution of the distributional structures reveals three major findings: (1) in periods when the C-14 data density and settlement pattern suggest that the population is low, lithic assemblages tend to be few and less numerous. The exceptions to this may be samples from around the raw material sources. We assume the frequency of imported raw materials (2) on the same basis as in the previous point, where in periods with lower populations there is no significant quantity of imported raw materials and vice versa. In periods of low population density in central Europe, the situation probably did not allow for safe long-distance travel to transport artefacts. A possible additional reason could have been the low demand for goods, which did not outweigh the risks associated with the costs of operating a long-term distribution structure. The basic Neolithic distribution by population peaks (3) also reflects significant changes between the distribution modes of the lithic raw materials. While the Neolithic B in the eastern part of Bohemia is dominated by erratic flints, in the Neolithic C, Skršín- and Tušimice-type quartzite become more important in terms of regional distribution, which correlates to evidence of their extraction (Neustupný 1966). In the Morava River Basin, the Neolithic B is characterised by the local dominance of erratic flints in the north and KL-type chert in the south. In the Neolithic C, the area around Brno is then characterised by the use of Stránská skála-type chert, though with a very limited distribution, and, furthermore, the situation at the settlements is characterised by a large decrease of lithics

compared to the Neolithic B. Larger lithic assemblages are found at hillforts from the end of the Baalberge phase onwards.

On the question of whether the density of settlements may have influenced the lithic raw material structure in favour of imported raw materials in densely populated areas, it can be concluded that it did not and quite the opposite. For most periods we observe a negative correlation. In the Morava River Basin, two periods under study, which are not based on a large number of assemblages, stand out from this pattern: the Epi-Lengyel and the Boleráz. In both periods, settlements are mainly located in the northern part of the basin (Trampota & Pajdla 2022), which may be determined by geographical circumstances. First, the proximity to the strategic area of the Moravian Gate and second, the navigable Morava River that flows through it.

The third question, *i.e.*, whether the presence of a navigable river (Elbe, Morava) influences the distribution of imported raw materials, can be answered in the affirmative in some periods (Early and Late Lengyel in the Morava River Basin), in others rather in the affirmative in view of the smaller amount of data and not significant correlations. In addition, in Bohemia, in the wider area around present-day Kolín, there is a tendency towards a higher incidence of imported raw materials from three main directions, *i.e.*, from south Moravia, Lesser Poland and Bavaria. It is here that there is a distinct cluster of settlements directly on the banks of the Elbe (Figure 5), whereas in the context of central Bohemia other settlements are more distant from the Elbe. Therefore, we venture the hypothesis that this region was an important area for the exchange of goods in the Neolithic precisely because it lies directly on the banks of a navigable river. Raw materials from Moravia and Bavaria were brought in on foot, while from Lesser Poland they were brought in by foot and boat.

In interpretive terms, then, the question is what distributional context the significance of the navigable river reflects. It is very likely that in the Morava River Basin, with its numerous sources of lithic raw materials, there was no need to import large quantities of raw materials, especially from Lesser Poland. We therefore assume that the stone raw materials are the only surviving reflection of extra-regional transport of organic matter or salt. It is the salt that emerges in the form of brine at Wieliczka near Kraków, in an area not far from the CKCJ sources. Evidence of salt extraction in the Neolithic is documented here by the discovery of salt-drying vessels precisely from the Middle Neolithic in the form of briquetage, but it is generally assumed that salt extraction was already taking place from the LBK (Saile 2012). We infer river navigation in the Neolithic from the relatively large quantities of imported raw materials found in the vicinity, while the raw materials we believe were transported by foot occur in significantly smaller quantities.

The final issue studied is the degree of joint distribution of ceramic styles (archaeological cultures) and the distribution of lithic raw materials. Here the ambiguous relationship between these two aspects of human activity comes to light. In some periods (Early SBK, Boleráz) an extra-regional distribution can be observed precisely between regions where the same decorative ceramic style is found. However, this is not a quantitatively significant phenomenon, usually involving a small proportion of raw materials or a quite isolated larger imported assemblage. On the contrary, during the Early Lengyel, when the exchange of raw materials was by far the most intense, there is evidence of distribution of raw materials only from or to areas where Lengyel pottery was not found; in the context of the Lengyel circle, the extra-regional distribution of lithic raw materials is not recorded at all. This is also true for other periods.

Based on this finding, it can be summarised that the ceramic style (archaeological culture) is not a suitable means for explaining the nature and changes in the distribution of stone raw materials.

5. Conclusion

The article deals with the general characteristics of the distribution of raw materials suitable for the production of lithics in the period of c. 4900-3400 BCE in the eastern half of Bohemia and in the Morava River Basin. Other issues addressed are the relationship between the kernel density of settlements and the frequency of imported raw materials. A statistically positive relationship is completely ruled out and, on the contrary, it appears to be slightly negative for most of the periods studied. Another question dealt with the relationship between the quantity of imported raw materials and distance from navigable rivers. It is shown to be significant in the Morava River Basin during the Lengyel period (c. 4800-4300 BCE); in most other periods this relationship is visually evident but not yet very statistically demonstrable. In the eastern half of Bohemia, the database is relatively small and a decreasing relationship of imported raw materials with distance from a navigable river can be assumed so far only for the Late SBK (c. 4800-4500 BCE).

In the last section, we discussed the relationship between imported raw materials and the distribution circles of ceramic styles, which are the main defining factor of 'archaeological cultures'. Imported raw materials are related to ceramic style depending on the periods. While in the Early SBK (c. 4900-4800 BCE) this relationship can be observed, during the Early Lengyel (4800-4500 BCE), on the contrary, extra-regional distribution is not explicitly related to the distribution of ceramic style.

In general, it can be stated that the greatest quantities of imported raw materials, represented mainly by CKCJ, are related to the presence of navigable rivers. Quantitatively less imported raw materials (KL-type chert in Bohemia, Arnhofen-type tabular chert) were then transported by overland routes. It is likely that the period of higher intensity of extra-regional distribution is related to the higher population density of central Europe.

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Data accessibility statement

The authors confirm that the data of this study are available within the article and its supplementary materials without any restriction.

List of supplementary files

Supplementary file 1
"TRAMPOTA_PRICHYSTAL-Supplement_1.xls"
The file contains an excel spreadsheet with the sites where the raw material composition of the lithics was analysed. The coordinates of individual locations, the name of the location, the total number of analysed pieces, the relative chronology, the ratio of individual raw materials and the source of information are listed here.

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Pěšky, na člunu: způsoby distribuce surovin vhodných pro štípanou industrii ve střední Evropě během cca 4900-3400 př. n. l.

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Abstrakt:

Díky dlouhodobému úsilí při určování kamenných surovin štípané industrie v neolitu byl vytvořen datový soubor poměrného surovinového složení na neolitických sídlištích pro východní část Čech a povodí Moravy ve střední Evropě, který lze analyzovat v období cca 4900-3400 př. n. l. Soubor celkem čítá 132 entit. V záznamu keramické produkce se tato studie pohybuje mezi starší fází vypíchané keramiky a bolerázskou skupinou.

Studie je zaměřena na čtyři otázky: (1) jaký byl chronologický vývoj způsobu distribuce surovin štípané industrie a jeho vztah k dynamice osídlení; (2) jaký byl vztah mezi mírou importovaných surovin a sídelní hustotou; (3) jaký význam měly splavné řeky pro přepravu surovin na dlouhé vzdálenosti a (4) srovnání prostorového rozložení kamenných surovin a „archeologických kultur“.

Definici pojmu ‚importovaná surovina‘ jsme odvodili od poloměru dominantní regionální distribuce surovin místního původu. V povodí Moravy to jsou rohovec typu Krumlovský les v jižní části a silicity glacigenních sedimentů v severní části území. Jejich poloměr dominantní distribuce je okolo 60 km. Naopak ve východní polovině Čech jsou dominantní surovinou pouze silicity glacigenních sedimentů, jejichž poloměr dominantní distribuce je okolo 100 km, proto zde považujeme za importované suroviny ty, které pocházejí z větší něž této vzdálenosti.

Z hlediska chronologických proměn v distribučních strukturách je zřejmé, že velikost populace byla důležitým faktorem ovlivňujícím nadregionální distribuci, zejména ve srovnání s počtem sídlišť a hustotou radiokarbonových dat (Figure 2). To se jmenovitě projevuje nízkým počtem malých souborů v souvislosti se starší fází vypíchané keramiky, nebo v epilengyelu, kdy evidujeme především dominanci surovin místního původu. Naopak v době odhadovaného populačního růstu během 4800 – 4500 př. n. l. je výrazná variabilita jak místních, tak importovaných surovin. Po sídelním hiátu, který odhadujeme v období 4000-3800 př. n. l. dochází k výrazné proměně využívaného surovinového spektra i distribučních způsobů.

Hustota osídlení nebyla určující pro výskyt importovaných surovin a naopak je většinou zřetelná opačná tendence, kdy v hustěji osídlených oblastech je proporčně nižší výskyt importovaných surovin (Table 1, Figure 10). To zjištění souvisí s dalším sledovaným aspektem.

Splavné řeky jsou důležitým faktorem při přepravě zboží, která je v archeologickém záznamu neolitických společností zastoupena viditelně prostřednictvím štípané industrie. Nejzřetelnější vztah mezi dováženými surovinami a splavnými řekami je v cca 4800-4500 př. n. l. (Figure 11). Koncentrace importovaných surovin podél splavných řek odráží směr distribuce, především organického zboží nebo soli, které byly primárním distribučním artiklem, přičemž štípané kamenné artefakty byly distribuovány díky existenci takovýchto sítí. V Čechách je zajímavou oblastí Kolín a okolí v kontextu mladší vypíchané keramiky. Ve středních Čechách jako jeden z mála regionů přímo přiléhá k toku Labe. Zde byla dosud zjištěna největší četnost i diverzita importů štípaných kamenných artefaktů, což patrně odráží společenský význam tohoto regionu, i ve vztahu k distribučním strukturám.

Výstavba opevněných hradišť je na konci sledovaného období (boleráz) významným společenským fenoménem, který i přes problematické nálezové okolnosti štípané industrie naznačuje změnu v distribučním schématu a koncentraci štípaných artefaktů právě na hradištích.

Přítomnost archeologických kultur (keramického stylu) samotných o sobě nemůže být vysvětlujícím faktorem pro změny distribuce kamenných surovin, neboť změny vnitřní a nadregionální distribuce nesouvisejí s jejími změnami. V některých obdobích lze vypozorovat určitou vazbu mezi keramickým stylem a transportovanou surovinou, například transportem západočeských křemenců na Moravu ve starší fázi vypíchané keramiky, nebo importů rohovců typu Krumlovský les v průběhu bolerázu na Cimburk u Kutné Hory. Naopak keramika staršího lengyelu nijak neodkazuje na směr transportu surovin štípané industrie do Karpatské kotliny a transportní vazby jsou orientovány na všechny ostatní směry kromě toho, který odkazuje na původ daného keramického stylu.

Klíčová slova: suroviny, štípaná industrie; neolit; střední Evropa, distribuce