Theoretical and Methodological Considerations in Central European Neolithic Archaeology

Proceedings of the 'Theory and Method in Archaeology of the Neolithic (7th - 3rd millennium BC)' conference
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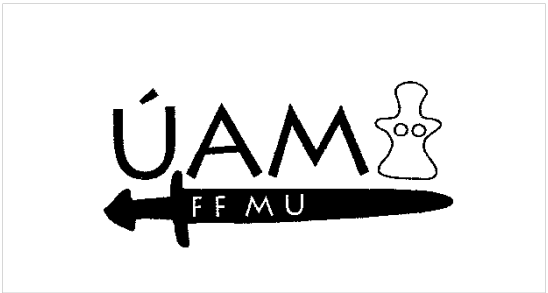

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Ceramics From the 'Sutny' LBK Settlement at Těšetice-Kyjovice, Moravia, Czech Republic: Processing and Statistical Analyses

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Abstract: *The aim of this article is to demonstrate the use of multivariate analysis of ceramics to verify the chronology of the 'Sutny' Linearbandkeramik culture (LBK) settlement at Těšetice-Kyjovice, in the Znojmo district of Moravia, Czech Republic. In this article we present the results obtained from the ceramics that have been processed to date. Based on this analysis we dated the settlement to approximately the Ib-IIa phase of the Moravian LBK.*

A new method for processing Moravian LBK ceramics is suggested, along with a proposed descriptive system, as a formalized description is very important to subsequent statistical evaluation.

We introduce several statistical analyses suitable for the evaluation of ceramic assemblages and demonstrate the application of other methods of analysis and possible alternatives for archaeological data visualization. For this purpose we used the'R' open statistical software package. We hope that this article will contribute to the development of a unified method of processing Moravian LBK ceramics, demonstrate new possibilities for evaluating archaeological data, and simplify its interpretation.

Keywords: *LBK, method, statistics, pottery, chronology, Těšetice-Kyjovice, R software*

Introduction

The principle aim of this article is to demonstrate the use of multivariate analysis of ceramics to verify the chronology of the 'Sutny' Linearbandkeramik culture (LBK) settlement at Těšetice-Kyjovice, in the Znojmo district of Moravia, Czech Republic, and to present possible alternative methods of statistical evaluation. The site is well-known largely for its Lengyel settlement and rondel architecture (Kazdová 1984; Podborský 1985; 1988; Kuča *et al*., 2010). However, as early as the beginning of the Neolithic, the site was occupied by people bringing the LBK culture, though the finds have not yet been completely evaluated. The material processed so far includes polished and other stone industry (Vokáč 2005), part of the osteological material (Dreslerová 2006) and the chipped industry (Mateiciucová 2008, 240-244). Previous ceramic analysis was completed for the goods from five graves (Dočkalová and Koštuřík 1996; Koštuřík and Lorencová 1989-1990). The settlement pottery of the LBK culture has only been partially evaluated to date (Vostrovská 2010).

The method of processing was adapted to the proposed hypothesis assuming the chronological significance of the technique of execution of the linear ornament as it is closely tied to social tradition and can be used as proof of its changes (Pavlů 1977, 37-41; 2000, 149-186). Archaeological finds from within houses reflect the activities of their inhabitants. One of the options is to provide the evidence of relations between the individual houses in time, based on a comparison of chronologically relevant characteristics. We tested this hypothesis on Moravian material and performed a preliminary chronological analysis, the results of which we would like to present here. We also prepared a proposal for a descriptive system for the LBK pottery processing based on the work of I. Pavlů, P. Květina, Z. Čižmář, E. Lenneis and J. Lüning. Its importance lies in the possibility of its use in the analytical processing and statistical analysis of LBK pottery.

We would like to also introduce 'R', a free web-based statistical software platform, to the Czech archaeological community, and its potential usage in archaeological data processing. By means of multivariate analyses we will use it to verify the results of the preliminary chronological analysis. We also show examples of suitable statistical

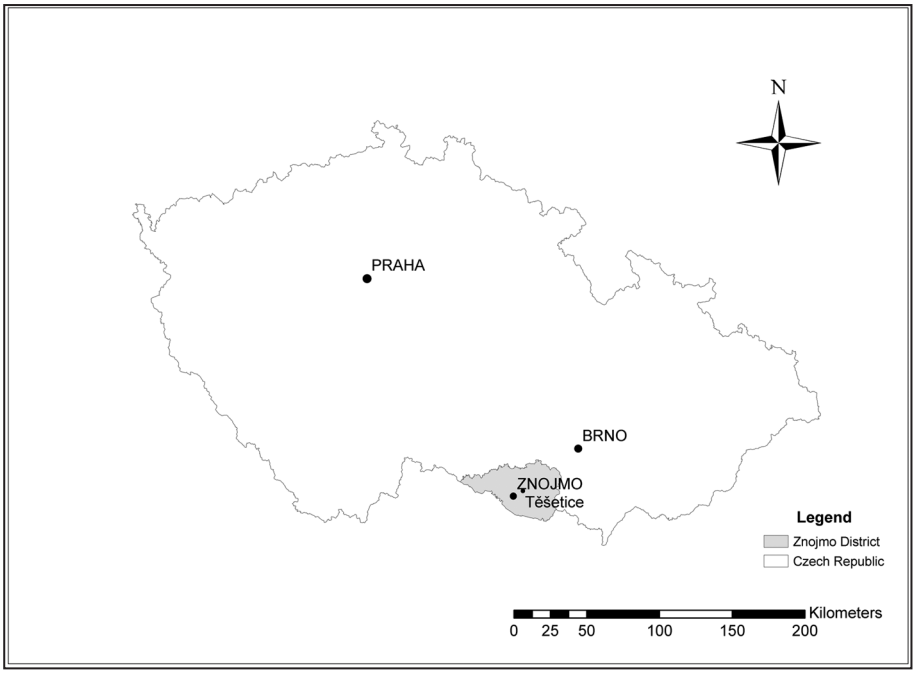

Figure 1. Site location.

analyses (e.g. seriation, cluster analysis, correspondence analysis) and data visualization alternatives, some of which have not yet been applied to archaeology (e.g. bar plot, ternary diagram, Chernoff faces diagram, mosaic plot, Bertin plot, heat map).

The 'Sutny' Neolithic settlement in Těšetice-Kyjovice

'Sutny' is situated in south-west Moravia in the district of Znojmo (Figure 1). Systematic excavation of the site by Masaryk University has been under way since 1967 and has uncovered a Neolithic settlement with LBK, Stichbandkeramik culture (StBK), Lengyel culture and a rondel (Figure 2). In the post-Neolithic period the site was occupied by the Baden culture, with traces of Bell Beaker culture. Dated to the Bronze Age are several features from the Únětice culture, the Věteřov group and the Velatice phase of the Central Danubian Urnfield culture. The prehistoric occupation of the site came to an end with the Hallstatt Horákov culture (Podborský *et al*., 2005).

The LBK settlement is concentrated in the north-east section of the excavated area where over 70 features were uncovered together with 17 badly preserved outlines of post-hole houses and 10 inhumation burials (Kazdová 2007, 39-42). Most of the burials originate from the LBK Ib (H18-H23). A cluster of eight graves along the western side of house D25 represents a smaller family burial site (Koštuřík and Dočkalová 1996; Vostrovská 2010). The settlement also yielded a depot of three vessels with linear decoration, one with anthropomorphic features (Kazdová 1999). A geophysical survey identified that the LBK settlement extends further towards the north-east. The density of features even increases there and more household complexes are identifiable. It is clear that the previous excavation identified only a small portion of the settlement (Milo and Kazdová 2008, 183-185).

In terms of methodology we should point out the presence of several chronological components on the site. The area of the settlement with LBK pottery partly intersects with StBK and both overlie an extensive Lengyel settlement, including a rondel. As a result of the long-term occupation of the site the older features were prone to destruction and their content to mixing as far back as the time of their pre-historic occupation. These formative processes were most damaging to features with LBK ceramics, the earliest phase of settlement on the site. Culturally homogenous features are rare. In processing LBK ceramics from the site we were therefore faced with the problem of the incompleteness of the assemblage. Although an agreement on the origin of the content of the settlement pits has not been reached, it is expected that given their proximity to the house outlines that they were related to the activities of their inhabitants. The ceramic chronology of Neolithic settlements is still based on this hypothesis (Soudský 1962). As has been shown, it is possible to work with the contents of features with intrusions, in a manner similar to less fraught assemblage (Kazdová 1998, 60-63). We are therefore inclined to the possibility of working with these assemblages, including intrusions, and to try to eliminate the consequences of the formative processes by suitable methods. One key method is by recording the degree of pottery fragmentation, the position of shards within the feature, and the quantitative ratio of the pottery sets in the individual chronological groups or, alternatively, the ratio of their masses (Květina 2002, 25 and 29).

Hypothesis and Method of Pottery Processing

The processing of the LBK settlement was based on the household complexes hypothesis of B. Soudský (1962) and a study by I. Pavlů (1977). To arrive at the internal layout of the settlement they use vertical stratigraphy and the principles of horizontal stratigraphy, since it is

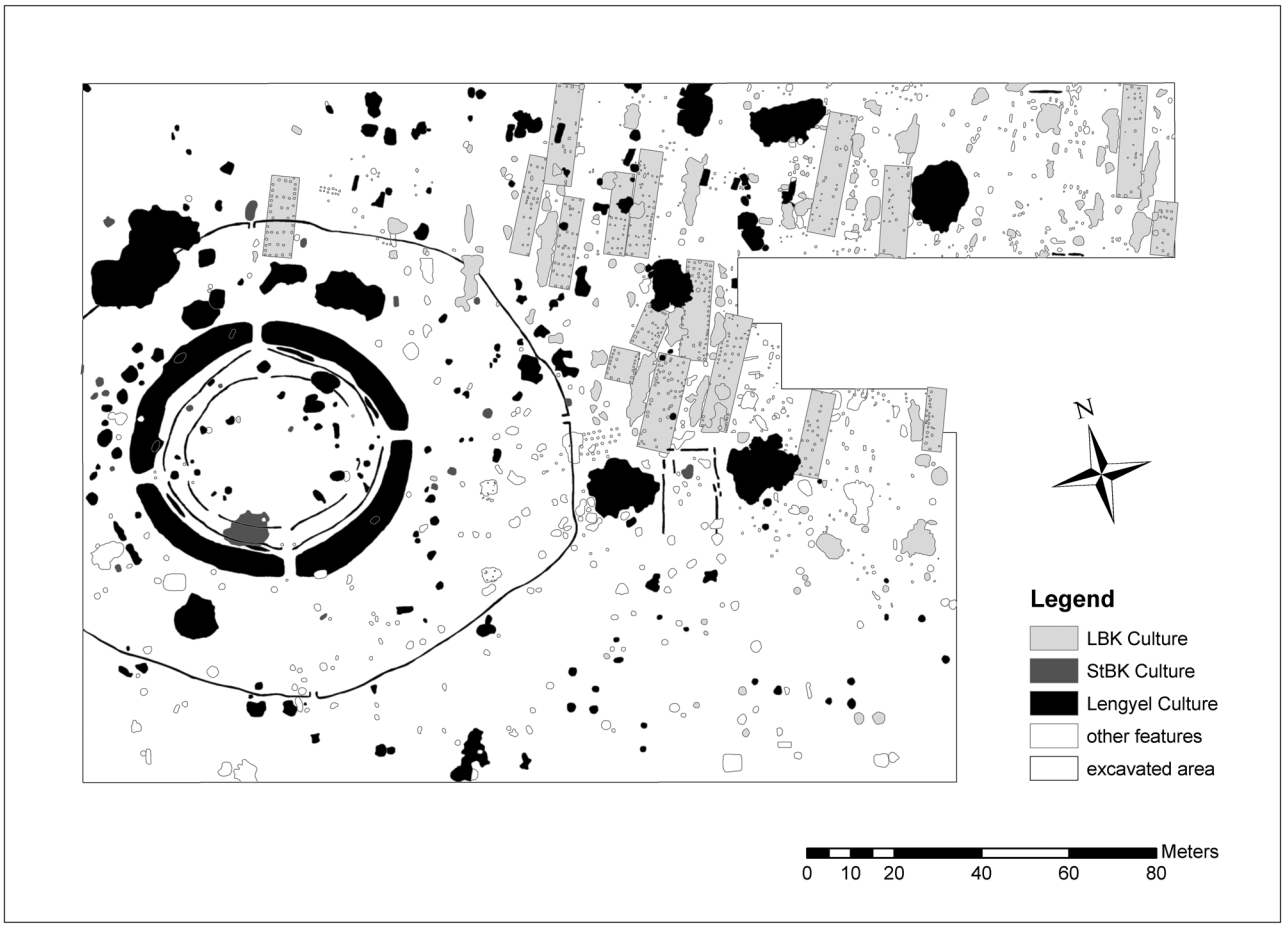

Figure 2. Neolithic settlement on the site (c. 5600-4500 BC).

the horizontal stratigraphic relations that prevail in LBK settlements. Within the settlement the household complex is considered the basic spatial-chronological and economic-social unit. It is made up of a post-hole outline and adjacent features within 5m from the posited house wall. The area within 1m of the walls is excluded, so that features reaching as far as the wall are included only tentatively or excluded (Pavlů 1977, 19-21; Květina 2007, 16). The hypothesis also presumes that the material from longitudinal building pits (and possibly other features) is more or less contemporary (with about 80% probability). Based on the material from the nearest features it is possible to characterize and date the whole household complex.

We concentrated on pottery, which is chronologically the most change sensitive, and is firmly bound with social tradition that unifies the changes and slows them down in space and time. Conversely, links to social units have a powerful momentum that can separate it in time and space (e.g. Dietler and Herbich 1989; Masson 2001).

The most important properties of LBK pottery in terms of chronology are the linear ornamentation technique, production technology and vessel shapes (Pavlů 1977, 39-44; 2000, 158-166; 2010, 15-18; Pavlů *et al*., 1986, 314-351). We consider the linear decoration, its execution and tools employed, to have substantial significance. This can be observed mainly on the width, cross-section, and number of lines, shape and position of the notes and the number of lines under the rim that are typical for Moravia. Each element of the linear decoration has a specific validity. On the other hand, for example, the curvature of the linear ornament connected with the gender-based division of society (van de Velde 1979, 112; Pavlů 2000, 112-113). Types of technical ornament are continuous throughout the whole LBK culture and serve more a functional purpose.

The hypothesis proposed assumes that the technique has chronological significance and required adapting the method of pottery processing, using the formalized description as outlined by D. L. Clarke (1968) and E. Neustupný (1993; 2007). The formalized description method is tailored to work with information in the form of data contained in databases. Entities (pottery fragments) are assigned qualities, by which we describe the observed characteristics (pottery attributes). In this way it is possible to record all the important characteristics on the pottery in the most objective way and achieve a state when artefacts from a single culture within a given geographical region will be evaluated in the same manner. This will enable us to solve a number of problems more easily, such as the development and relations of individual LBK communities in Moravia,

and relations between different regions within Europe. The benefit of systematically recording data is the possibility of its use in subsequent statistical analyses which can help reveal hidden structures and gain new knowledge. It is only through analytical processing of archaeological material (in this case LBK pottery) that we can draw conclusions based on statistical evidence in compliance with standard archaeological methods (Neustupný 1993; 2007).

The style of decoration of the LBK culture was spread over a large section of Europe. Being such a vast territory it is only logical that there are regional differences in the material culture. Each geographical region has a typical linear decoration and only the basic elements are shared with the others. The formative description method for evaluating LBK pottery was first used by German archaeologists processing material fom the excavation at Aldenhovener Platte (Stehli 1973; 1977). P. Stehli in collaboration with H. Ch. Strien and the team from the Stiftung Archäologie im Rheinischen Braunkohlenrevier worked in the Bandkeramik online project [1], and developed a descriptive system for processing German decorated LBK pottery. This was followed by a similar project, the Nordmitteleuropäische Neolithische Keramik (Mischka in print)[2] , by the team from the Institut für Ur- und Frühgeschichte der Universität zu Kiel. Based on the works by B. Hulthén (1974), P. Stehli (1973; 1977) and J. Czebreszuka (*et al*., 2006) a system for processing Neolithic pottery from several cultures (Ertebølle, Funnel Beaker, Single Grave and Bell Beaker) north of central Europe was developed.

The descriptive system for Bohemian LBK pottery was developed from material from the Neolithic settlement excavation in Bylany near Kutná Hora (Pavlů and Zápotocká 1978; Soudský *et al*., 1985; Květina and Pavlů 2007). A descriptive system for Lower Austrian LBK pottery was devised by E. Lenneis and J. Lüning processing the Neckenmarkt and Strögen sites (Lenneis and Lüning 2001).

For the processing of LBK pottery from Těšetice-Kyjovice 'Sutny' we designed our own descriptive system inspired particularly by the structure and the monitored characteristics of the systems valid for the regions bordering Moravia, i.e. Bohemia and Lower Austria. In completing the characteristics of Moravian LBK pottery we drew from the works by Z. Čižmář (1998; 2002). The descriptive system is divided into three main sections. The first section is dedicated to the description of the pottery production technology, especially the nature of the pottery material, tempers, surface treatment and records of vessel fragmentation. The second part deals with the metric data and vessel shape. The last section describes the linear, plastic and technical decoration. The greatest emphasis is placed on the description of the technique of execution of the linear ornament, in particular the number of lines that constitute the linear ornament, the shape of the line cross-section imprinted by the tool employed, the shape of the notes and their position within the linear ornament, type of the tool employed, number of lines under the rim, curvature of the linear ornament, types of the principal and auxiliary decorative motif. We also tentatively introduced the line width and the diameter of the notes. In processing the settlement material, noting how the decoration is executed is very convenient as whole vessels or large fragments thereof survive only rarely. We are thus prevented from identifying the principle decorative motif and the complementary ornaments that can be indiscernible to us on the fragments. Our goal is to verify the results of the chronological analysis. Here we will concentrate on evaluating the description of the technique of execution of the linear ornament.

Results

Firstly we have obtained parent population of 7385pcs of ceramic fragments and weight about 179,216g from 37 features. We defined statistical threshold for this assemblage as a five individuals with linear decoration per feature. For the following statistical analyses we have had standard population of 6811pcs and weight about 167,123g from 19 features.

We started by comparing the chronologically significant variables describing the technique of execution of the linear ornament by means of one-dimensional statistics (in the form of categorized histograms). Subsequently, it was possible to divide the assemblages into two to three groups that represent stages (two groups) or phases (three groups) of the relative LBK chronology (Figure 3). In a similar way we compared assemblages based on variables related to pottery production technology and the vessel shape morphology.

The first group is typified by the prevalence of an orange-black-orange pottery class of coarse ware and a dark-grey pottery class of fine ware. The share of ceramic vessels with an organic admixture is considerable. The linear decoration in most cases consists of an incised line 2mm wide with a U-shaped cross-section. A note appears rarely, if at all, and is mainly circular or oval and situated at the beginning of a line. A band filled up with stabs appears. The main decorative motif consists of an arch, festoon or a revolving system of spirals. Occasionally a single line appears under the rim. Linear decoration is often complemented by small circular and oval horizontal lugs. Globular shapes prevail only slightly over bowls. Conical bowls exhibit double-sided graphitic. This group is thought to be from the Ib phase of the Moravian LBK (see Figure 4).

In the second group, the orange-black-orange coarse ware and the dark-grey fine ware are represented equally, just as the share of ceramic vessels with an organic or

[1] For more information on the project go to Stiftung Archäologie im Rheinischen Braunkohlenrevier [online], [cit. 2011-01-06], URL: < http://www.archaeologie-stiftung.de >.

[2] For more information on the project go to Nordmitteleuropäische Neolithische Keramik [online], [cit. 2011-01-06], URL: < http://www.nonek.uni-kiel.de >.

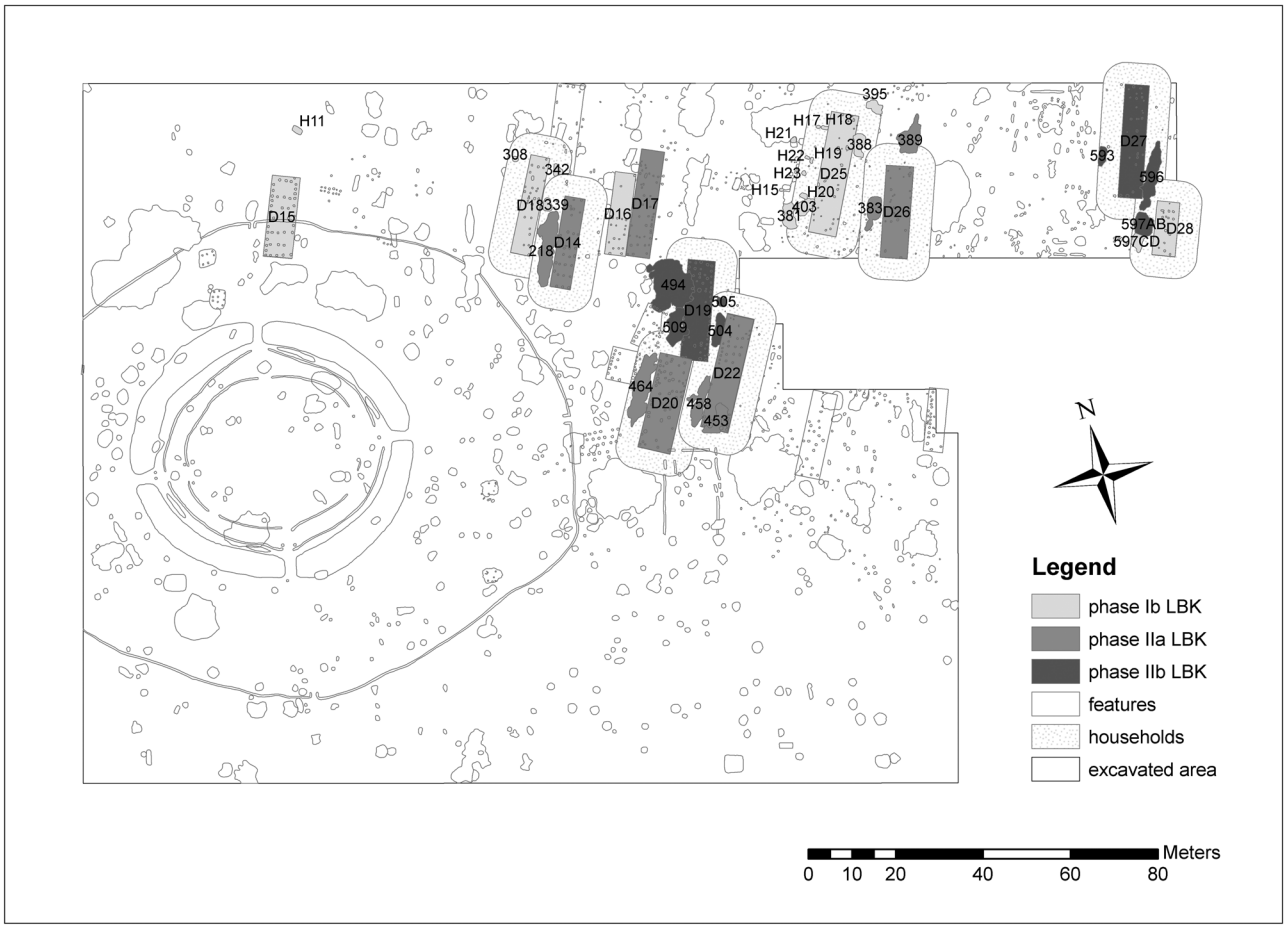

Figure 3. Expected development of the LBK settlement.

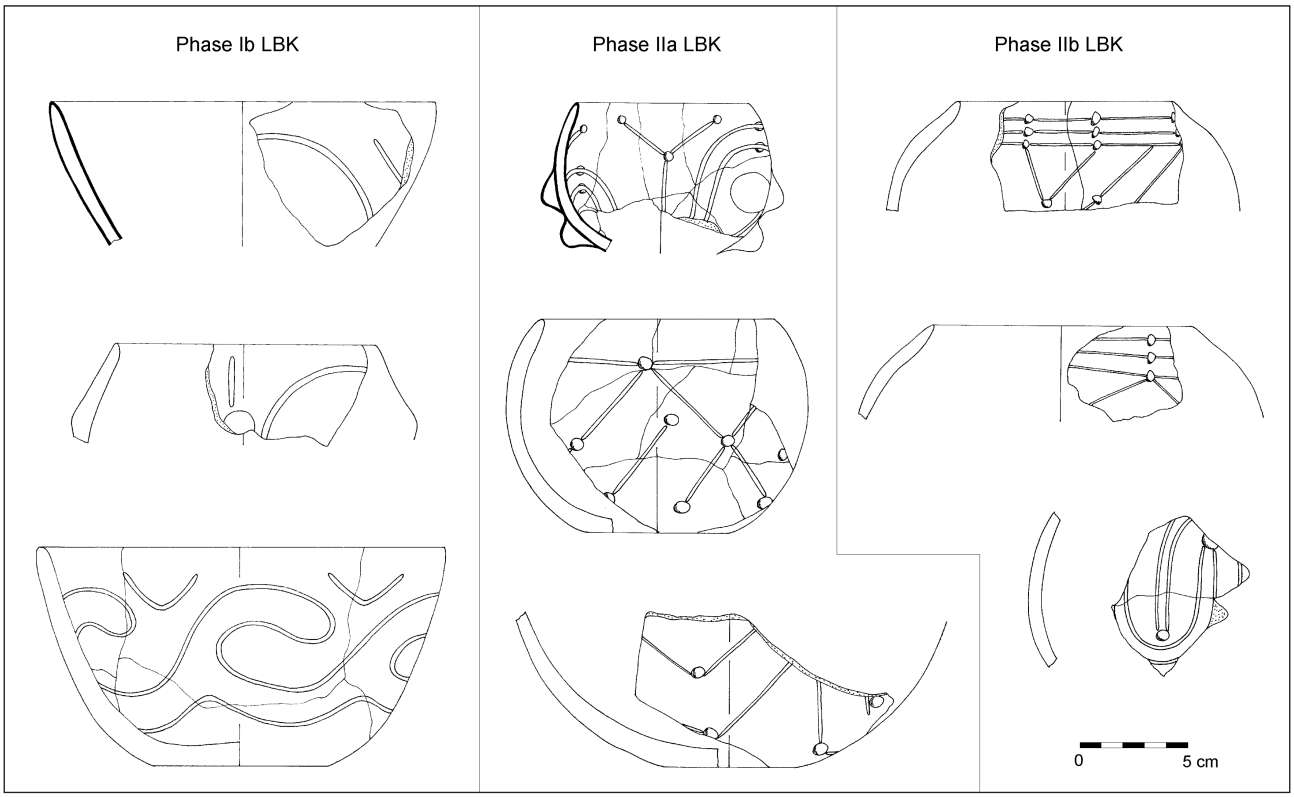

Figure 4. Pottery of the LBK culture from the individual specified phases.

inorganic admixture. Linear decoration consists of an incised line 1mm wide with a U- or V-shaped cross-section accompanied by a less frequented line 2mm wide and a groove 4mm wide. The notes are circular and oval, less frequently semi-circular and situated at the ends, angles, and intersections of lines. The number of lines under the rim increases, with one to two occasionally three lines appearing. The notes under the rim are arranged one below the other, positioned on a line and aligned with the notes of the main decorative motif. A band with stabs is quite common. The main decorative motif is represented by geometrically arranged lines and less often by revolving motifs. Globular shapes are predominant over bowls. This group is identified as Moravian LBK IIa (see Figure 4).

In the third group dark grey fine ware predominates over orange-black-orange coarse ware. The share of ceramic vessels with an organic or inorganic admixture is balanced. Linear decoration consists of an incised line 1mm wide with a U- or V-shaped cross-section, accompanied by a less frequently found 2mm wide line and 4mm wide groove. The occurrence of a semi-circular note, situated at the ends, angles and intersections of the line is striking. The so-called proto-Želiezovce elements (e.g. two lines leading to a single note and a double-line band made by a two-pronged tool) appear infrequently. The main decorative motif created by geometrically arranged lines is usually connected to the band under the rim by a line without a note in the intersection. The band under the rim is made up of one to three lines. A band with stabs is common. Globular shapes are predominant over bowls. This group is identified as Moravian LBK IIb (see Figure 4).

Given the results of the quantitative analysis of the linear decoration technique and after comparing them with the settlement situation it was possible to propose a preliminary characterization of its development. Based on horizontal stratigraphy we also included the outlines of houses D15-D17, where no LBK features are situated in the immediate vicinity. The LBK settlement shifted in the earlier phases of its development in time towards the north-east. At least six other household complexes in this direction were confirmed by geophysical measurements (Milo and Kazdová 2008, 183-185). The houses form specific clusters in the settlement, evidence of redevelopment in subsequent phases. New houses were built along the eastern side of the original house. The household complexes D20 and D22 overlap. House D22 may be a little older, but this difference is not evident in the quantitative analysis of the ceramic material. Interestingly, part of the assemblage studied included intrusions from Lengyel features which could also be assigned to the household complexes. The intrusions of LBK pottery in these features may constitute relics of LBK building pits damaged by the subsequent Lengyel settlement. However, these results need to be verified using multivariate statistics.

Possibilities of statistical analysis for data evaluation

Our aim is to verify the preliminary chronological analysis. Again, we will concentrate on variables describing the technique of execution of the linear ornament and the vessel morphology, in particular line width, number of lines, shape of the line cross-section, shape of the note, position of the note, and number of lines under the rim. The individual pottery assemblages will be compared based on the above characteristics using a number of statistical methods. To a large extent we deal with nominal variables. Their evaluation by means of statistical analyses is therefore only possible based on a matrix of absolute frequencies in the forms of contingency tables[3]. We will use standard visualization methods for closed data (bar plot, ternary diagram, mosaic plot, Chernoff faces diagram) and generally applied methods in seriation analyses – reorderable matrices (cluster analysis, heat map, Bertin plot) and correspondence analysis (Djindjan 1991, Shennan 1998, Banning 2002) because we try to find relations between characters and similarity in assemblages.

For statistical data evaluation we chose the R web-based open source software (version 2.12.1). R is a language and environment for statistical computing and graphics. It is a GNU project which is similar to the S language and environment which was developed at Bell Laboratories by John Chambers and colleagues. R can be considered as a different implementation of S and was developed by R. Ihaka and R. Gentleman from the University of Auckland (Ihaka and Gentleman 1996). There are some important differences, but much code written for S runs unaltered under R. R provides a wide variety of statistical (linear and nonlinear modelling, classical statistical tests, time-series analysis, classification, clustering, etc.) and graphical techniques, and is highly extensible. The S language is often the vehicle of choice for research in statistical methodology, and R provides an Open Source route to participation in that activity. R can be extended (easily) via packages[4]. One of R's strengths is the ease with which well-designed publication-quality plots can be produced, including mathematical symbols and formulae where needed. Great care has been taken over the defaults for the minor design choices in graphics, but the user retains full control. R is available as Free Software under the terms of the Free Software Foundation's GNU General Public License in source code form. It compiles and runs on a wide variety of UNIX platforms and similar systems (including FreeBSD and Linux), Windows and MacOS[5].

Bar plot and ternary diagram (Friendly 2000; Wilkinson 2005)

The bar plot is commonly used in archaeology. The bars

[3] From technical reasons it is not possible to insert frequency table of the analysed variables in the archaeological features, because we followed up nearly 40 characters. This data are freely available from the authors.

[4] Freely available at Comprehensive R Archive Network [online], [cit. 2011-01-18], URL: < http://cran.r-project.org/ >.

[5] Taken from The R Project for Statistical Computing [online], [cit. 2011-10-14], URL: < http://www.r-project.org/ >.

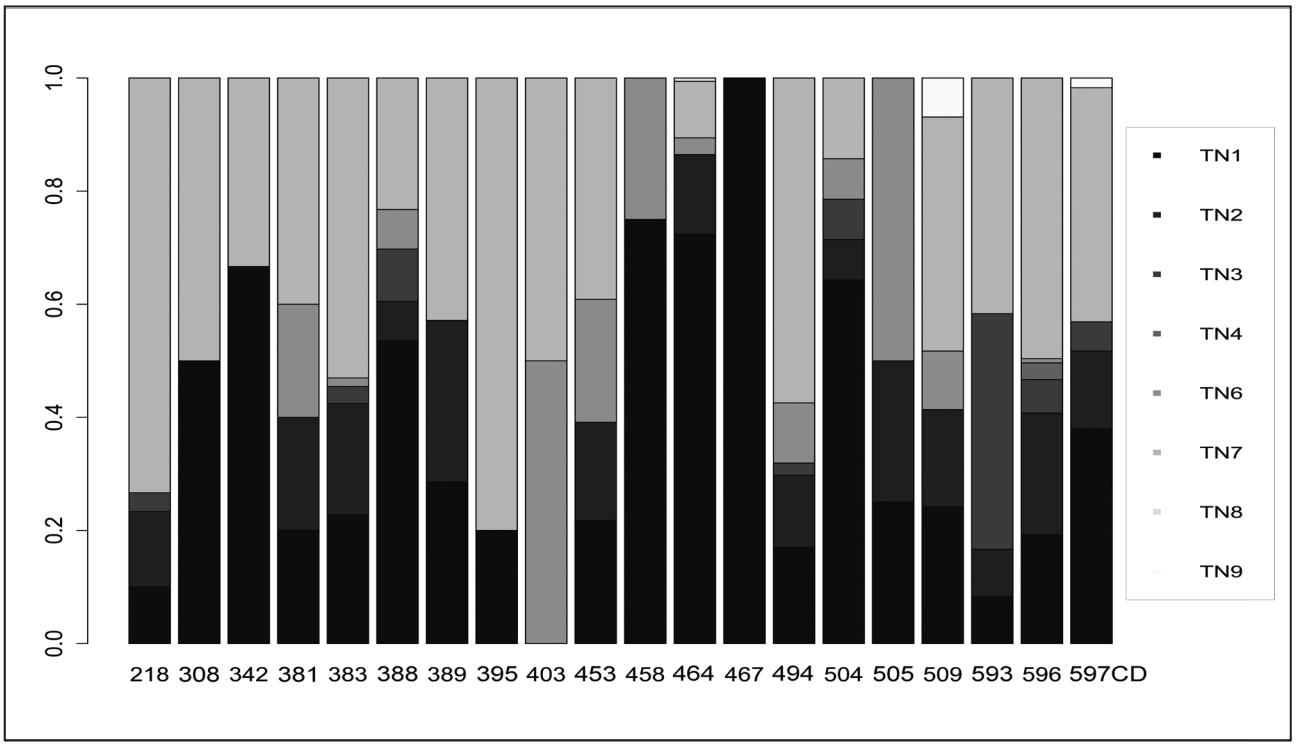

Figure 5. Bar plot – spectra of the represented note shapes in the studied features (circular note (TN1), oval note (TN2), lenticular note (TN3), notch (TN4), triangular note (TN6), semi-circular note (TN7), chevron note (TN8), miniaturized note (TN9).

(columns) represent the individual pottery assemblages and the representation of note shapes is converted to relative values. To obtain a clearer overview the output can also be reordered. We can see a similar composition of the spectra of characteristics in features no. 308, 342 and 395(?); 381 and 453; 388 and 504, etc. (Figure 5). We can also notice some specifics, e.g. miniaturized notes appear only in assemblages from features no. 509 and 597AB and the assemblages in features no. 403 and 593 are represented by very rare spectra of note shapes. In general it can be seen that either circular or semi-circular notes predominate in all of the spectra.

On the other hand, a ternary diagram can be a novelty for archaeologists. It visualizes compositional, 3-dimensional data in an equilateral triangle. Points' coordinates are found by computing the gravity centre of mass points using the data entries as weights. It is used in petrology, mineralogy, metallurgy and other physical sciences to show the compositions of systems composed of three species. Also, in this case we can use a matrix reordered with seriation. In this way it is a specialized display for a 3-column contingency table or for three variables whose relative proportions are to be displayed. We can see the distribution of the individual assemblages based by category of reconstructed vessel shapes (Figure 6). Bowls clearly prevail in features 403, 467 and 597CD, globular vessels in features 218 and 464 and buckets in features 308. Generally, a high number of globular vessels can be observed in all features.

Chernoff faces diagram (Chernoff 1978; Wilkinson 2005)

In this approach different data dimensions were mapped to different facial features, for example face width, the level of the ears, the radius of the ears, the length or curvature of the mouth, the length of the nose, etc. Each parameter is represented by a number between 0 and 1. Facial features represent trends in the values of the data, not the specific values themselves. While this is clearly a limitation, the knowledge of data trends could help to determine which sections of the data were of particular interest. We used the 'aplpack' package in the R software. In this way each part of the face represents a quantity of note shapes (Figure 7). A striking similarity of the spectra can be seen in features no. 308, 339, 342, 395, 467 and 597CD; 218, 389 and 403; 458 and 504; 388, 453 and 505. The occurrence of note shapes in the assemblages from features no. 464 and 596 is profoundly different from the whole. At a general level we observe a diversity of the assemblages.

Mosaic plot (Hartigan and Kleiner 1984; Friendly 1994, 2000)

A mosaic plot is an area proportional visualization of a (possibly higher-dimensional) table of expected frequencies. It is composed of tiles (corresponding to the cells) created by recursive vertical and horizontal splits of a square. The area of each tile is proportional to the corresponding cell entry, given the dimensions of previous splits. The widths of the bars show the relative frequencies of one variable and the heights of the sections in each bar show the relative

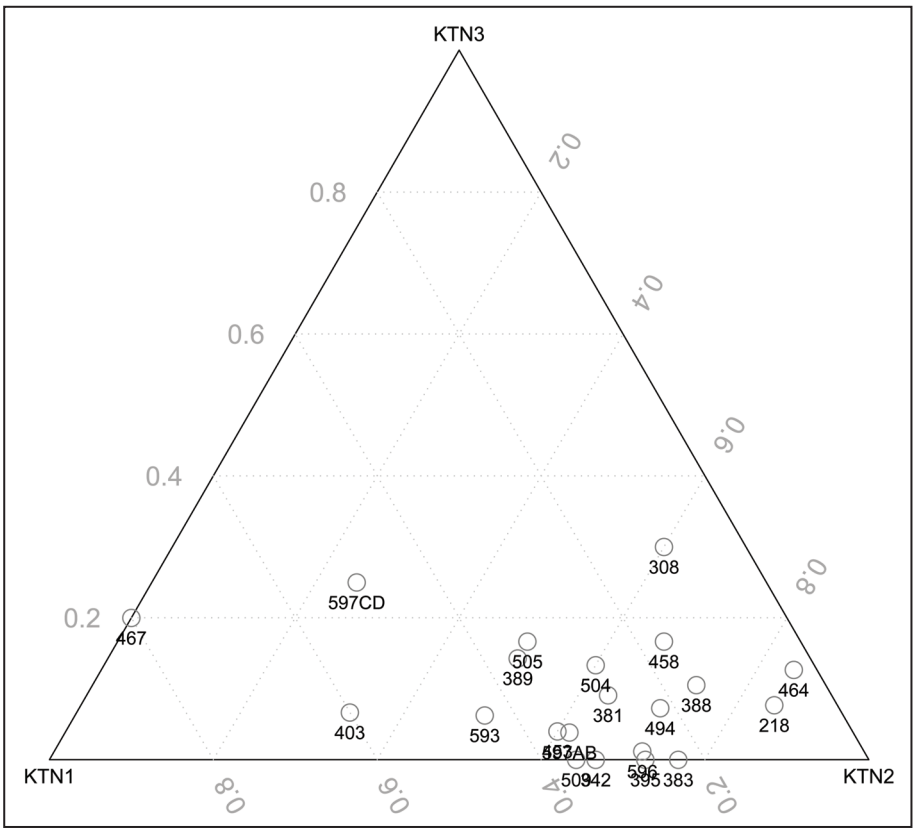

Figure 6. Ternary diagram – grouping of the individual assemblages based on the represented vessel shapes (bowls (KTN1), globular vessels (KTN2) and buckets (KTN3)).

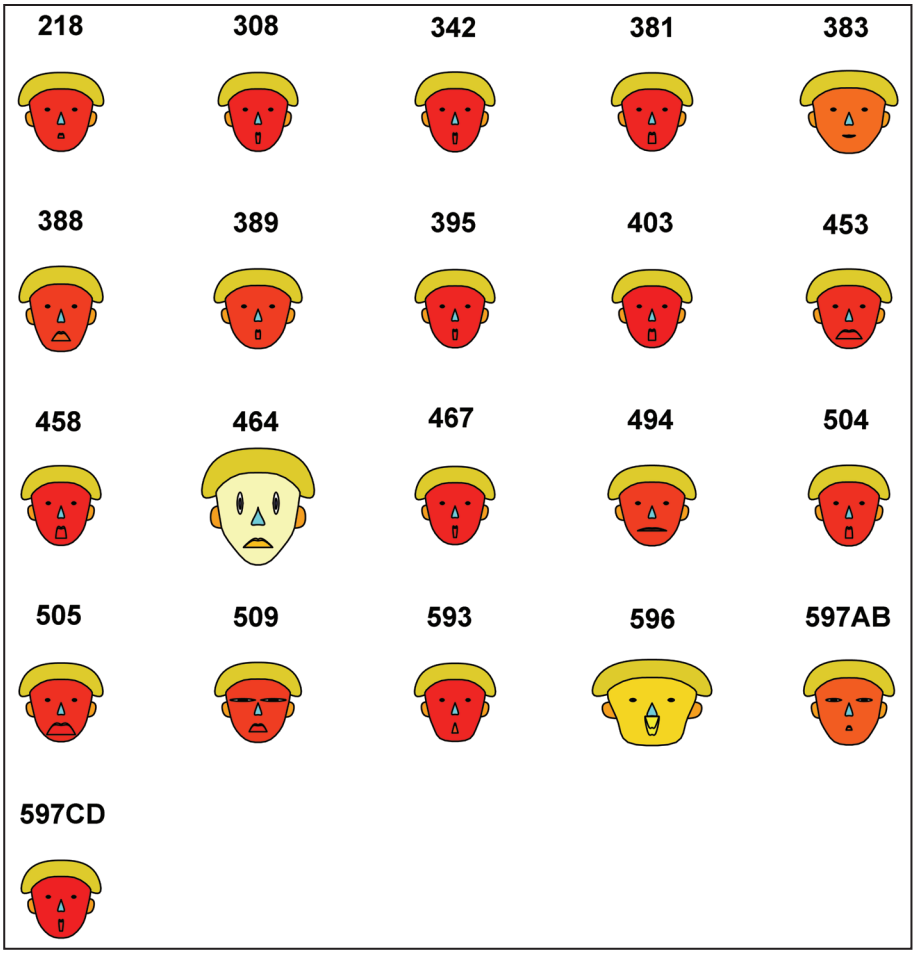

Figure 7. Chernoff faces diagram – note shapes represented in the studied features (modified items: height of face (circular note), width of face (oval note), structure of face (lenticular note), height of mouth (notch), width of mouth (triangular note), smiling (semi-circular note), height of eyes (chevron note), width of eyes (miniaturized note), height of hair (circular note), width of hair (oval note), style of hair (lenticular note), height of nose (notch), width of nose (triangular note), width of ear (semi-circular note), height of ear (chevron note)).

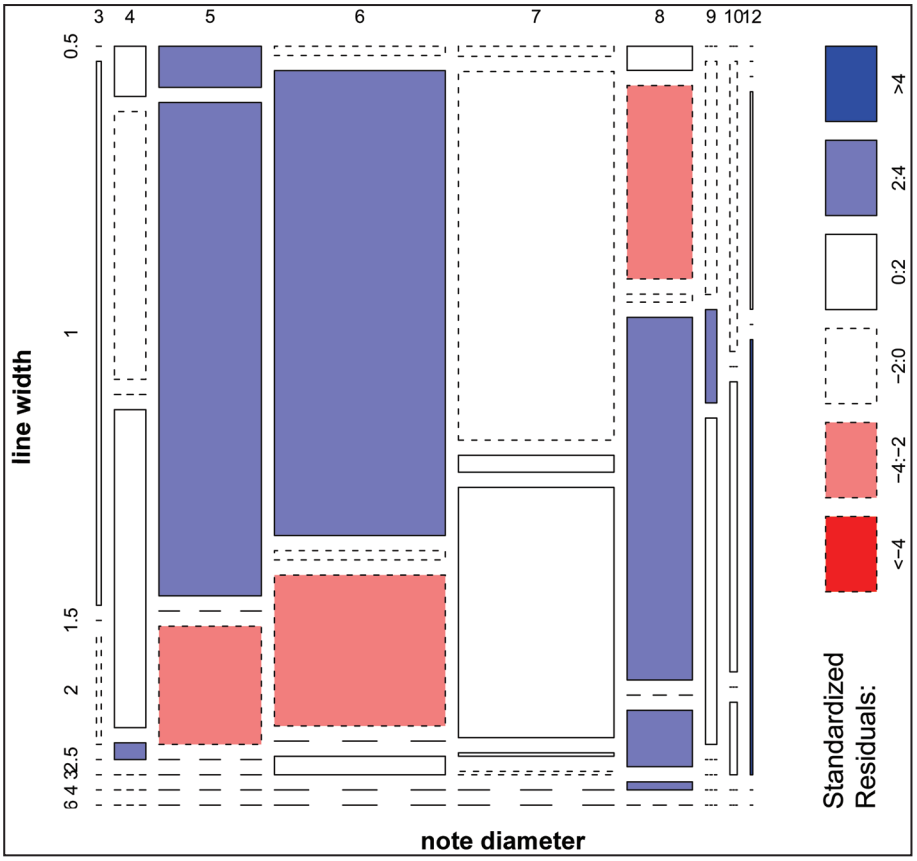

Figure 8. Mosaic plot – represented combinations of the variables of line width and note diameter.

frequencies of the second variable. Negative residuals are drawn in shades of red and with broken outlines; positive ones are drawn in blue with solid outlines. Thus, mosaic plots are perfect for visualizing associations within a table and to detect cells which create dependencies[6]. We used the 'aplpack' package in the R software. Therefore, we compared line width and note diameter (Figure 8), and showed that notes with a greater diameter are usually combined with wider lines and vice versa. Notes 5-6mm in diameter are accompanied by lines 1-1.5mm wide while notes 7-10mm wide with lines 1.5-3mm wide. As an exception, with notes 4mm in diameter the prevalent line is 2mm wide.

Seriation – Bertin plot (de Falguerolles et al., 1997; Siirtola and Mäkinen 2005)

As far as seriation is concerned we will perform a complex analysis of the relations between the variable describing the technique of execution of the linear ornament, number of lines making up the linear ornament, shape of the line profile determined by the tool employed, shape of the notes and their position within the linear ornament, number of lines under the rim and, based on those, the relations between the individual pottery assemblages. In order to allow for nominal data to also be entered in the analysis, we created a matrix of absolute frequencies in the form of a contingency table. As one of the possible outputs of seriation we opted for Bertin plot. Bertin matrices are means to analyze structures in a matrix using two-dimensional display techniques. Basic data structures for Bertin analysis are implemented as class based on matrix, using additional attributes[7]. It is an association plot for absolute values, which provides means for visualizing the residuals of an independence model for a contingency table. We used the 'seriation', 'ade4' and 'labdsv' packages in the R software. We arranged the matrix using the BEA-TSP method, which clearly ordered the most non/represented variables in the studied features (Figure 9). Based on the combinations of the characteristics non/typical for the individual assemblages we can observe their mutual similarity in these groups:

1. 342, 381, 389, 395, 403, 597CD
2. 383, 388, 395
3. 453, 458, 494
4. 464, 504
5. 509, 597AB

Characters such as line width 1mm, U-shaped line, simple line, line width 2mm and their mutual combinations are the most significant. From seriation results primary division into two stages of the LBK culture is apparent. The first, and part of the second group, correspond to LBK Ib. Features in groups no. 3-5 represent the residues of the settlement from the LBK II. We think of individual groups as settlement

[6] Taken from R Graph Gallery [online], [cit. 2011-01-14], URL: < http://addictedtor.free.fr/graphiques/RGraphGallery.php?graph=94 >.

[7] Taken from R Project [online], [cit. 2011-01-14], URL: < http://bertin.r-forge.r-project.org/ >.

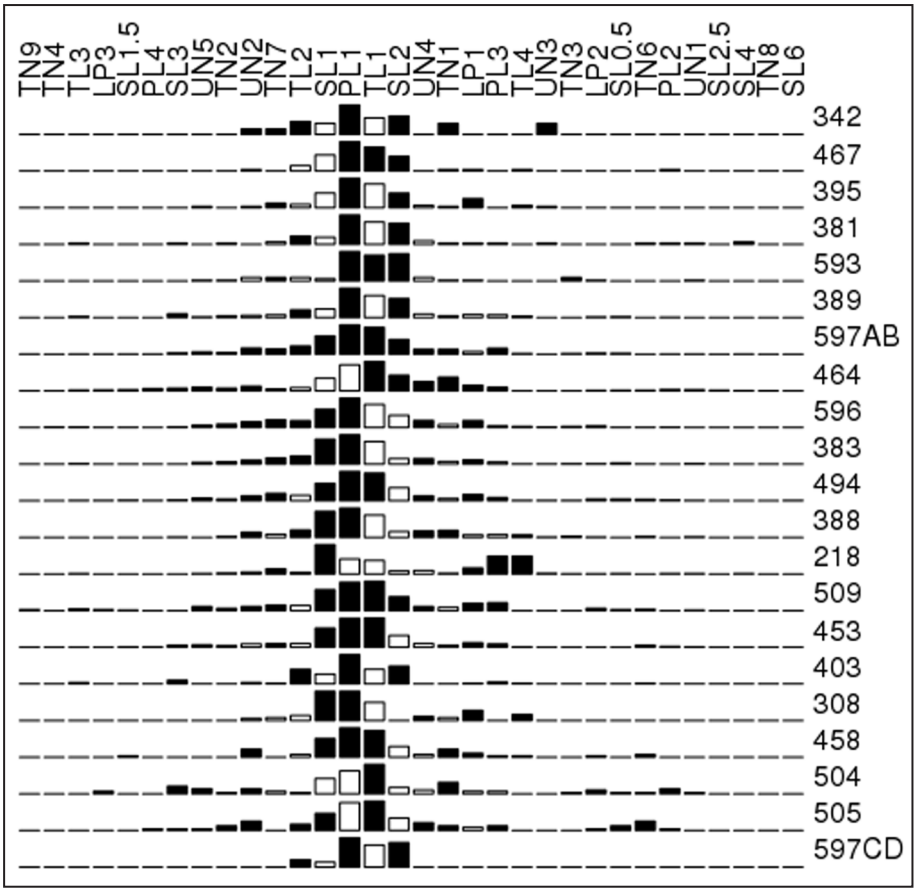

Figure 9. Seriation – Bertin plot (seriation of the studied features based on the variables describing the technique of execution of the linear ornament: miniaturized note (TN9), notch (TN4), three-line band (TL3), three lines under the rim (LP3), line width 1.5mm (SL1.5), irregular line cross-section (PL4), line width 3mm (SL3), notes in the middle of lines (UN5), oval note (TN2), notes at the ends of lines (UN2), semi-circular note (TN7), two-line band (TL2), line width 1mm (SL1), U-shaped line (PL1), simple line (TL1), line width 2mm (SL2), notes at the angles, intersections and ends of lines (UN4), circular note (TN1), one line under the rim (LP1), V-shaped line (PL3), band filled up with stabs (TL4), notes at meander tops and ends of lines (UN3), lenticular note (TN3), two lines under the rim (LP2), line width 0.5mm (SL0.5), triangular note (TN6), U-shaped groove (width > 3mm, PL2), independently placed notes (UN1), line width 2.5mm (SL2.5), line width 4mm (SL4), chevron note (TN8), line width 6mm (SL6)).

phases (for the grouping of the features in the area of the LBK settlement see Figure 10).

Cluster analysis – heat map (Wilkinson 2005)

A heat map is a colour image with a dendrogram added to the left side and to the top. Typically, reordering of the rows and columns according to some set of values within the restrictions imposed by the dendrogram is carried out. Larger values are represented by small dark-gray or black squares and smaller values by lighter squares.

The idea for joining cluster trees to the rows and columns of the data matrix originated with R. Ling (1973). He used typographical overstrike of printer characters to represent different shades of gray, one character-width per pixel[8]. We used the 'ade4', 'labdsv' and 'heatmap.plus' packages from R. In this way we reordered the distance matrix from the contingency table according to some set of values. We chose the heat map as an output from seriation (by Canberra distances) (Figure 11). In the dendrogram we can see that the individual pottery assemblages are arranged into two basic groups and four subgroups:

1. 308, 342, 395, 467, 597CD
2. 381, 403, 458, 504, 505, 593
3. 218, 383, 388, 389, 453, 494, 509, 597AB
4. 464, 596

[8] Taken from Wikipedia [online], [cit. 2011-01-14], URL: < http://en.wikipedia.org/wiki/Heat_map >.

We can interpret these clusters as LBK phases (for their grouping in the area of the LBK settlement see Figure 12). The first cluster corresponds to the LBK Ib. The features in clusters no. 2-4 represent the residues of settlement in LBK II. We think of the second cluster is LBK IIa and of the clusters no. 3-4 are two settlement phases from LBK IIb.

Variables describing the technique of execution of the linear ornament are arranged in a similar manner (Figure 11). The first cluster of features is characterized by chevron notes, miniaturized note and notches, U-shaped line, line width 1mm, 2mm, 2.5mm and 6mm and simple line. The second cluster of features is characterized by lenticular and triangular notes, irregular line cross-section, line width 0.5mm, 1.5mm, 3mm and 4mm, three-line band and a band filled up with stabs, separately placed notes and notes on meander tops and line ends and one or three lines under the rim. The third cluster of features is characterized by a circular note, semi-circular note, two-line band, notes either only at the ends or at the angles, intersections, and line ends and one line under the rim. The last cluster is characterized by oval note, V-shaped line and notes in the middle of the line.

Correspondence analysis – symmetric plots (Djindjian 1991; Greenacre 2007)

Our last example is a correspondence analysis with its classical output – the symmetric plot. It is a type of mathematical diagram using Cartesian coordinates to

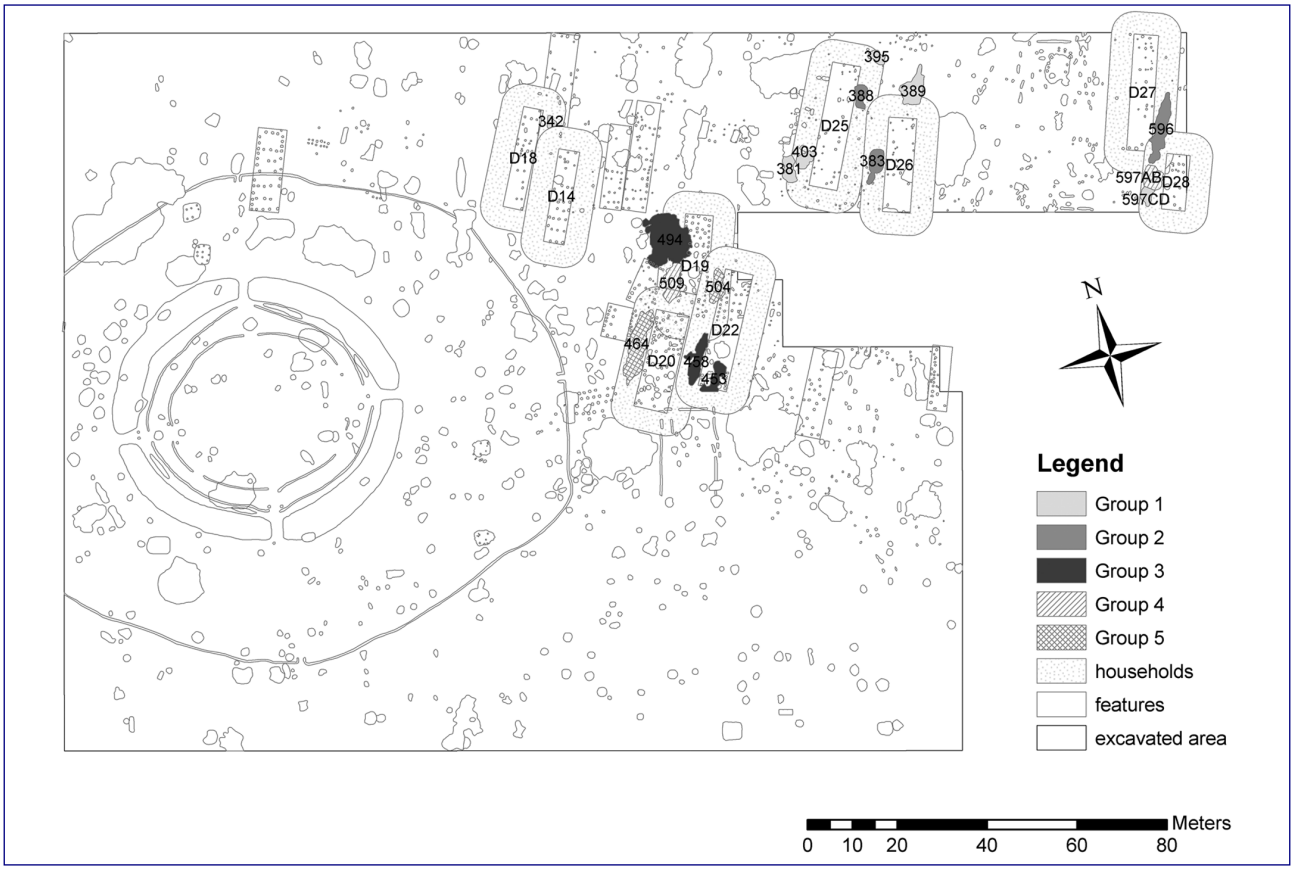

Figure 10. Grouping of the features in the area of the LBK settlement based on seriation.

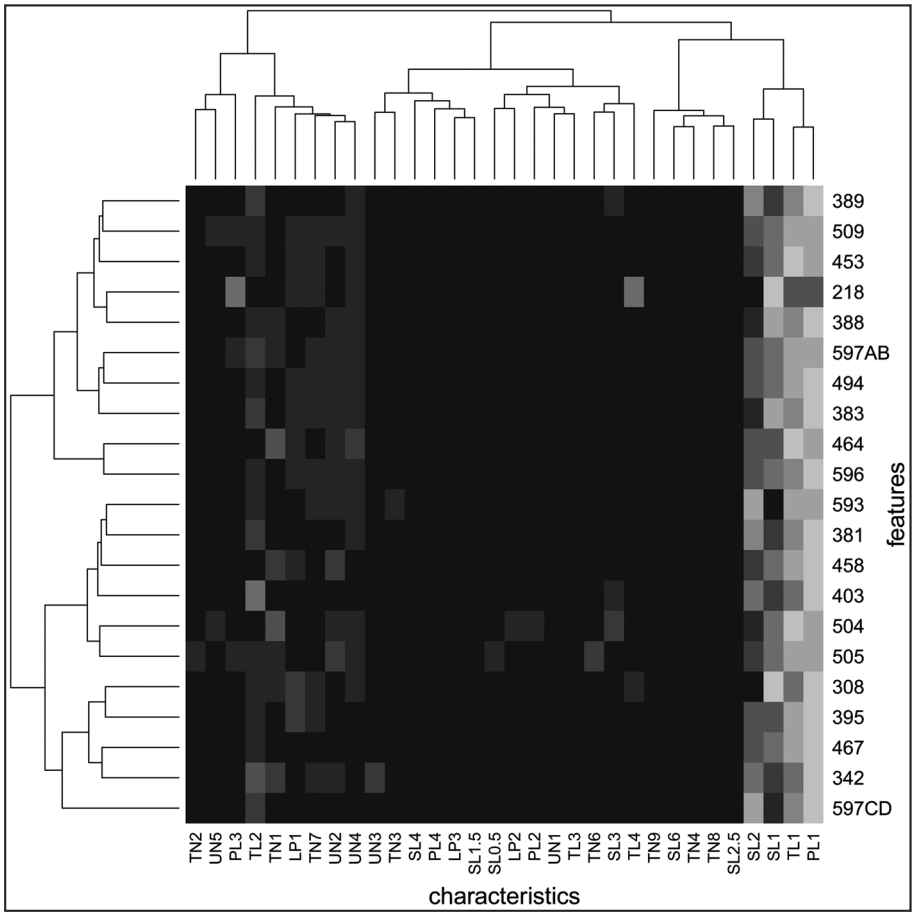

Figure 11. Cluster analysis – heat map arrangement of the studied features based on the variables describing the technique of execution of the linear ornament and the variables themselves: oval note (TN2), notes in the middle of lines (UN5), V-shaped lines (PL3), two-line band (TL2), circular note (TN1), one line under the rim (LP1), semi-circular note (TN7), notes at the ends of lines (UN2), notes at the angles, intersections and ends of lines (UN4), notes at meander tops and ends of lines (UN3), lenticular note (TN3), line width 4mm (SL4), irregular line cross-shape (PL4), three lines under the rim (LP3), line width 1.5mm (SL1.5), line width 0.5mm (SL0.5), two lines under the rim (LP2), U-shaped groove (width > 3mm, PL2), independently placed notes (UN1), three-line band (TL3), triangular note (TN6), line width 3mm (SL3), band filled up with stabs (TL4), miniaturized note (TN9), line width 6mm (SL6), notch (TN4), chevron note (TN8), line width 2.5mm (SL2.5), line width 2mm (SL2), line width 1mm (SL1), simple line (TL1), U-shaped line (PL1)).

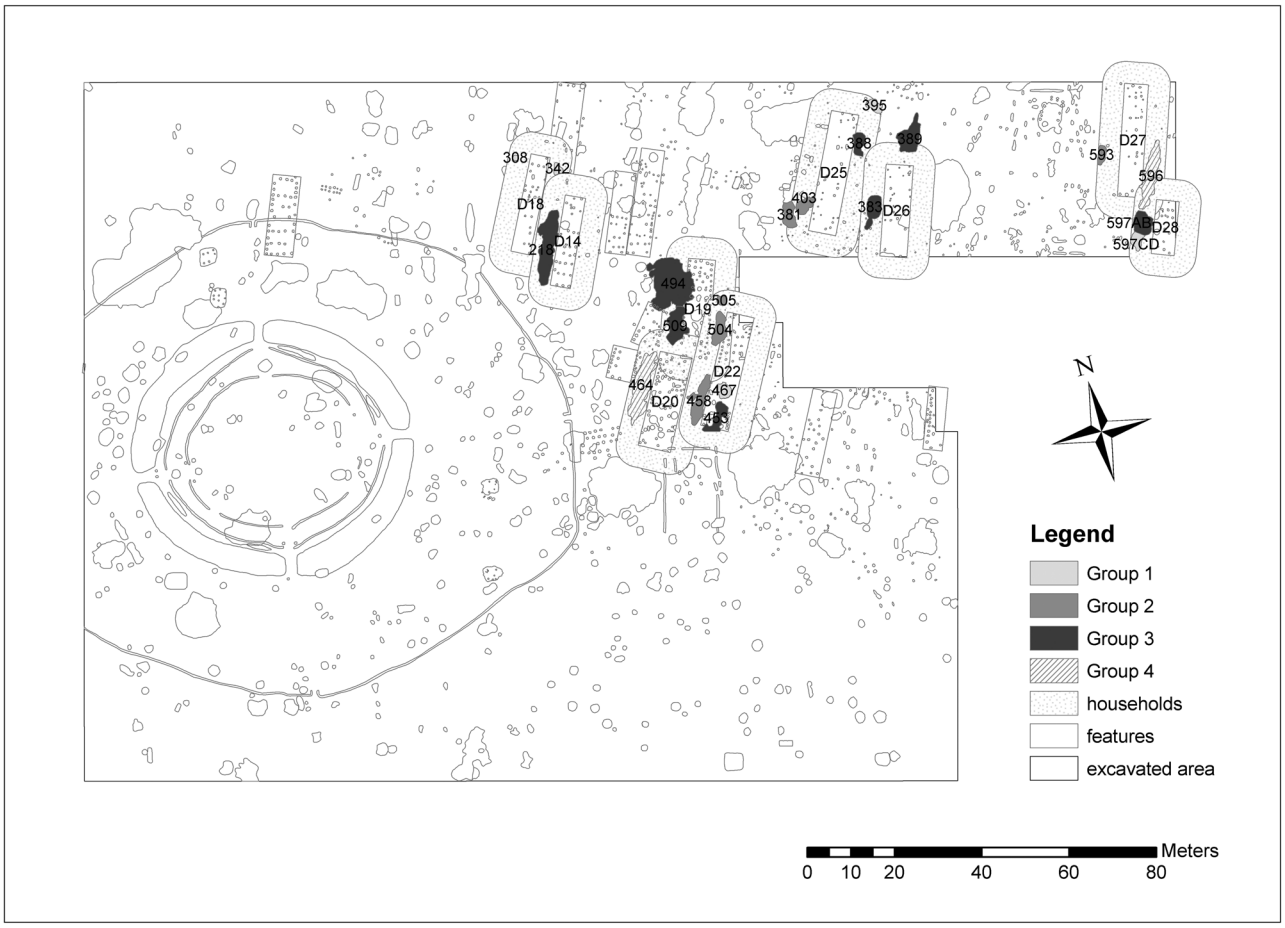

Figure 12. Grouping of the features in the area of the LBK settlement based on cluster analysis.

display values for two variables for a data set. The data are displayed as a collection of points, each having the value of one variable determining position on the horizontal axis and the value of the other variable determining position on the vertical axis. In R we used the 'FactoMineR' package and analysed features in two significant dimensions (Figure 13). We can see the main cluster in the centre of the symmetric plot and round about abnormalities and the disposition of extreme values (Figure 14). The main accumulation is created by features no. 381, 383, 388, 389, 395, 453, 458, 467, 494, 505, 509, 596, 597AB, the second by features no. 342, 403, 593, 597CD, and the third by features no. 464 and 504; whereas solitary features no. 218 and 308 are clearly outlying (their grouping in the area of the LBK settlement is shown in Figure 15). We think the main accumulation is LBK II and second accumulation corresponds to LBK Ib. Regarding the variables describing the technique of execution of the linear ornament, we can also observe two accumulations of characteristics. The main accumulation is created by notes at angles, intersections and ends of lines, line width 0.5mm, oval note, simple line, notes at the ends of lines, three-line band, one line under the rim, line width 2mm, two lines under the rim, miniaturized note, U-shaped line, semi-circular note and it corresponds LBK II. The second accumulation encompasses lenticular note and notches, line width 6mm and two-line band and it corresponds with LBK Ib. The third accumulation includes circular and triangular note, line width 3mm, the notes are positioned independently and in the middle of the lines and it corresponds more or less also with LBK II. The characteristics such as line width 4mm, V-shaped line and notes situated on meander tops and ends of lines are clearly outlying.

Conclusion

The aim of this contribution was to verify the chronological analysis of the LBK settlement in Těšetice-Kyjovice 'Sutny'. To this end we used formalized description and developed a descriptive system for the processing of Moravian LBK pottery. To evaluate the data acquired we employed the R statistical software and have presented data visualization options, the majority of which had not been used in archaeology before. Ternary diagrams, Chernoff faces diagrams and mosaic plots are suitable for depicting combinations of variables describing any property of pottery. The distribution of note shapes, vessel shapes, line width and note diameter correspond to the putative chronological model. Bertin plots, heat maps and symmetric plots enable us to evaluate the relations between pottery properties, and on that basis, the relations between individual features. In the latter case we found that cluster

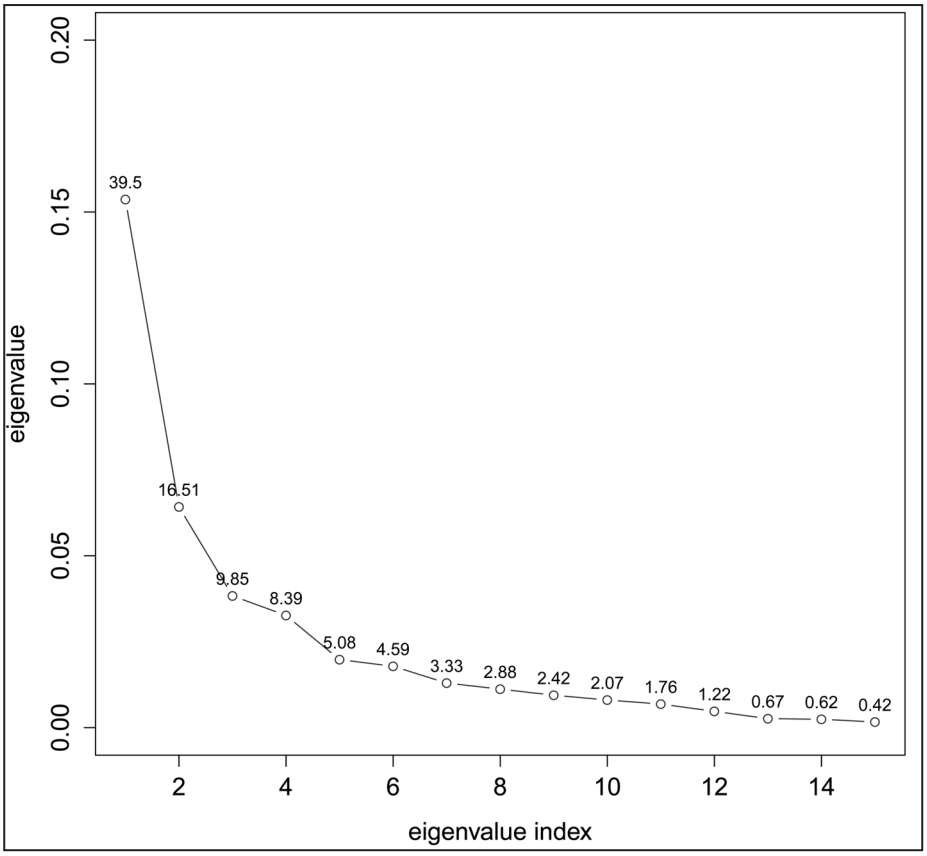

Figure 13. Correspondence analysis – scree plot.

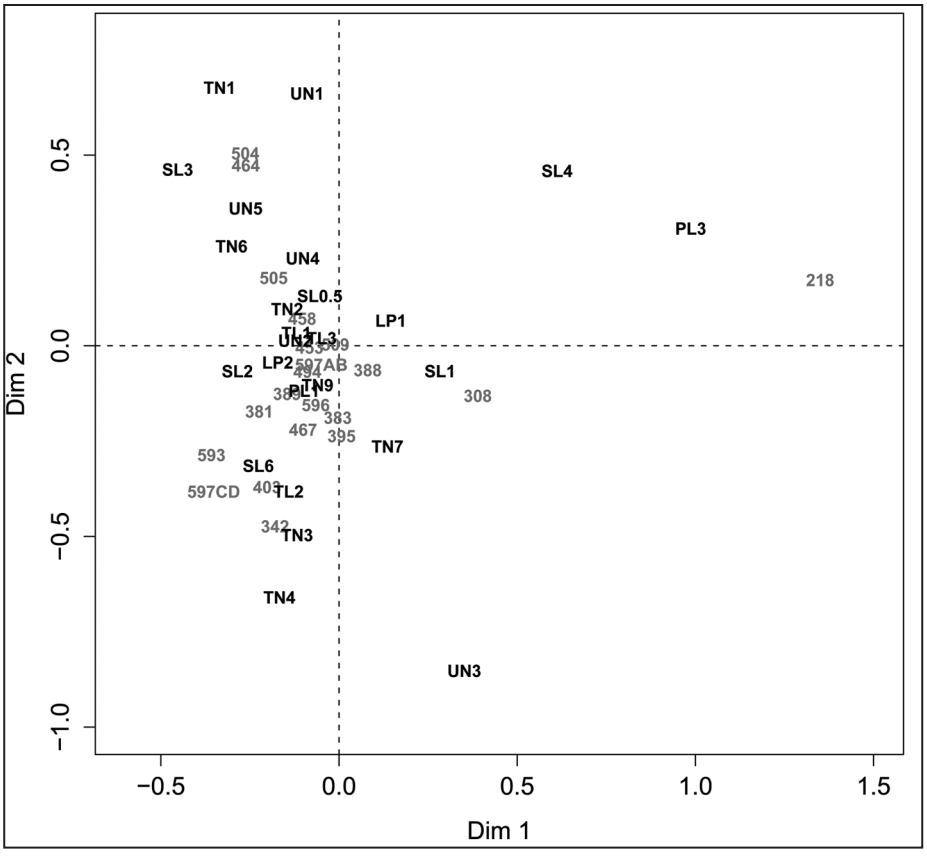

Figure 14. Correspondence analysis – symmetric plot (relations between the studied features and the variables describing the technique of execution of the linear ornament: circular note (TN1), independently placed notes (UN1), line width 3mm (SL3), notes in the middle of lines (UN5), triangular note (TN6), notes at the angles, intersections and ends of lines (UN4), line width 0.5mm (SL0.5), oval note (TN2), simple line (TL1), notes at the ends of lines (UN2), three-line band (TL3), one line under the rim (LP1), line width 4mm (SL4), V-shaped line (PL3), line width 2mm (SL2), two lines under the rim (LP2), miniaturized note (TN9), U-shaped line (PL1), line width 6mm (SL6), two-line band (TL2), lenticular note (TN3), notch (TN4), line width 1mm (SL1), semi-circular note (TN7), notes at the meander tops and ends of lines (UN3)).

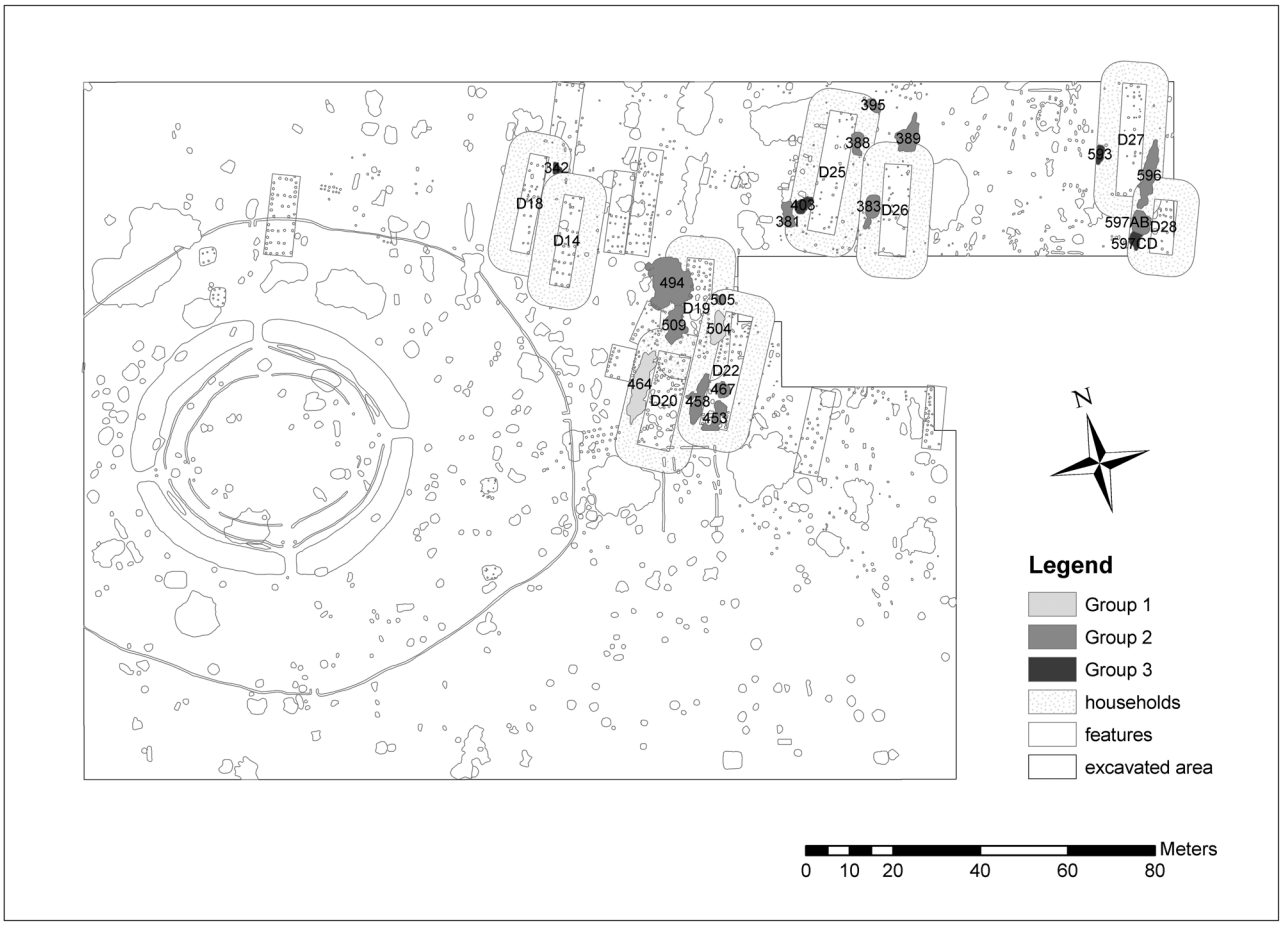

Figure 15. Grouping of the features in the area of the LBK settlement based on correspondence analysis.

analysis with output in the form of a heat map to be the most useful, since the clusters created could be interpreted as stages or, alternatively, phases of LBK. Also, the grouping of the variables describing the technique of execution of the linear ornament correlates relatively to the characteristics of the phases of the Moravian LBK culture. In principal, we managed to confirm the proposed hypothesis which presumes the chronological significance of the technique of execution of the linear ornament, and partly verify the results of the chronological analysis performed.

An essential problem that arose was the presence of several chronological components on the site. Although it is possible to include intrusions of LBK pottery from Lengyel features in the evaluation of the standard assemblage (and thus provide evidence, for example, for the existence of the original building pits of the LBK culture), the differential and unclear results of multivariate statistics are probably influenced by formative processes. The results may have been biased by the presence of pottery from several chronological phases of the LBK culture in the form of intrusions, which, given the extensive post-linear occupation and its impact on features of earlier chronological components, need not be obvious at first glance. This complicated situation requires the complex analysis of all finds and their spatial properties in the area of the LBK settlement (see Květina 2005; Pavlů 2010).

The contents of the features on the site are therefore not very suitable for addressing the problems related to the chronology of the LBK culture, as for analyses of this kind it is essential that only adequate and if possible homogenous assemblages are selected.

Despite the limited results from the analysis of the site we can state that the application of the formalized description method and the descriptive system developed for LBK pottery contribute to solving the problems of the development and relationships between the different communities with the LBK culture in Moravia. In future it will be necessary to extend the standardized descriptive system to include the other non-ceramic material of the LBK culture (see Květina and Pavlů 2007). It is the only way for us to ensure that from some point artefacts of the LBK culture within a given geographical region will be evaluated using the same method.

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