Variability in coiling technique in LBK pottery inferred by experiments and pore structure micro-tomography analysis

Variabilita výrobní techniky keramiky LBK ve světle archeologických experimentů a mikrotomografické analýzy struktury pórů

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The article aims at identifying the origin of voids left by burnt-out organic material within the ceramic paste of Neolithic pottery from the Czech Republic territory. In methodological terms, an experimental reference collection was created and compared with the original early Neolithic pottery from the sites of Bylany by Kutná Hora and Těšetice-Kyjovice. The key analytical procedure consisted in non-destructive 3D micro-tomography (uCT) analysis, which is especially well suited for the study of the internal spatial organization of voids and temper. It allows to determine whether it is possible to define different manufacturing techniques employed for vessel construction on the basis of internal distribution of voids. The research identified cow dung as the probable organic temper within the original LBK ceramic paste. The 'S'-forming technique, consisting in pressing the coil to the vessel wall, most closely corresponded to features observed at the Neolithic vessels.

forming techniques – coiling – Linear Pottery culture (LBK) – archaeological experiment – micro-tomography

Cílem článku je identifikování původu porozit, tj. stop po vyhořelé organické příměsi uvnitř hrnčířské hmoty, u neolitické keramiky (LBK) z území České republiky. Metodicky je práce založena na srovnání experimentálně zhotovených vzorků s originální keramikou staršího neolitu z lokalit Bylany u Kutné Hory a Těšetice-Kyjovice. Klíčovým analytickým postupem byla nedestruktivní 3D mikrotomografická analýza (uCT), která je přínosná právě pro studium vnitřní prostorové organizace porozit a příměsí. Umožňuje tak zkoumat, jestli je možné na základě vnitřního uspořádání pórů definovat odlišné výrobní techniky použité pro stavbu nádob. Výsledkem výzkumu bylo identifikování kravského hnoje jako pravděpodobné organické příměsi v keramické hmotě původní LBK. Jako utvářecí výrobní postup, který nejblíže odpovídal znakům pozorovaným na neolitických nádobách, byla určena tzv. technika „S", založená na přimačkávání válečku ke stěně nádoby.

technika formování nádob – válečková technika – kultura s lineární keramikou – archeologický experiment – mikrotomografie

Introduction

Despite the apparent uniformity in the shape and decoration preferences of pottery made by early farmers in Central Europe, which is known as LBK ceramics or Linearbandkeramik (e.g. *Modderman 1988*; *Rulf 1997*), not a lot is known about the technological preferences of makers of LBK vessels in Central-Eastern Europe. The assessment of variation in technology requires a combination of different analytical approaches. Among studies of LBK pottery technology, there is a predominance of archaeometric and raw-material studies, especially petrographic analyses of paste composition using thin sections. Studies of void morphology and its connection to potential variants of organic matter are one complementary approach, and their results provide information on organic material preferences in Central-Eastern Europe (*Franklin 1998*; *Kreiter 2010*; *Kreiter – Szakmány 2011*; *Kreiter – Pető – Pánczél 2013*; *Mecking et al. 2012*).

Studies dealing with organic matter usually prove the use of local clays combined with a non-specific organic temper, although sometimes the type of temper is evident, such as in the case of chaff (*Kreiter 2010*; *Kreiter – Szakmány 2011*; *Kreiter – Pető – Pánczél 2013*). Animal dung (*Franklin 1998*) and even wood and straw (*Hložek 2012*, 29) have been suggested as possible organic materials. Generally, the organic material got burnt out during the firing process, leaving voids with a specific morphology (e.g. *Maritan et al. 2006*; *Santacreu 2014*, 98–100). This enables the identification of the organic material itself. In addition, elongated voids aid the recognition of the inner structure of pottery. Because voids tend to orient themselves according to pressure, their spatial organization reflects different forming techniques (e.g. *Lindahl – Pikirayi 2010*; *Berg 2008*). Elongated organic tempering materials reflect the forming technique more than materials with round particles.

At the moment, technological studies of LBK pottery do not cover the whole distribution area of this archaeological culture. Despite being scattered all across Europe, however, their results show certain similar tendencies in technological processes. A description of the operational sequence (*chaîne opératoire*) for LBK pottery was included already in the synthesis of *J. Destexhe-Jamotte* (*1962*, 8–9). Besides other forming techniques he mentioned pinched coil and successive addition of coils on top of each other. *Bosquet et al.* (*2005*) described Belgian LBK ceramics from a single pit associated with an isolated house at the LBK site of Remicourt 'En Bia Flo' II (Liege prov.). They also described different forming techniques based on configurations in sherd cross sections and also pinched coils.

Complex technological studies are rare for the LBK period. An elaborate macroscopic study was conducted at the Cuiry-lès-Chaudardes site in the Aisne valley in France (*Gomart 2014*). Two dominant forming techniques were identified, and both technological groups are described as made of coils. A complex study of LBK pottery technology is underway at the Bylany site in the Czech Republic (*Neumannová et al. 2016*). The diagnostic marks of forming techniques are analysed according to different criteria: the morphology and position of sherd fractures, the microstructure that is visible on the edge of the sherd, the morphology of the surface, and wall thickness and its variability. Specific combinations of these attributes have been associated with complex categories.

Besides studies based on thin sections and the macroscopic approach, there are other, less common possibilities. One of them is micro-tomography (uCT), which has recently been tested in archaeological pottery studies. This method was developed for the visualization and analysis of inner structures. It enables the visualization of porous structures and calculates geometrical parameters such as total porosity, pore size distribution and pore shape (*Appoloni et al. 2004*). It has already been applied to the study of meso-neolithic pottery from northern Germany (*Kahl – Ramminger 2012*) and Early Neolithic pottery from the Low Don Basin (*Kulkova – Kulkov 2014*) with the aim to reveal different tempering materials and the orientation of pore structures indicative of vessel-forming techniques. Micro-tomography analysis can be used to infer the nature of organic temper even when all plant remains are completely burnt out during the firing process (*Machado et al. 2013*).

We took an experimental approach combined with uCT to examine the appearance of voids produced by different forming techniques. Our main aim was to identify the organic material used (1), the properties and spatial organization of voids left by burnt-out organic material within experimental samples (2), and to explore how different coiling techniques relate to different types of void structures and how to recognize them (3). The morphology and size distribution of experimental organic temper will be analysed to establish an analytical base usable for a comparison with LBK pottery samples. Original LBK samples were selected from assemblages of the prominent early farmers' sites Bylany and Těšetice – Kyjovice to illustrate the spatial variability or uniformity in early pottery technology. We hope to contribute to future comparisons of the forming techniques used by early farmers of the LBK pottery culture in Central Europe.

Material and experiment

We carried out several preliminary experiments combining different quantities and types of organic materials mixed with natural clay with the aim to find an appropriate organic temper that will form voids comparable to those found in LBK material. Experiments with straw and hay were inconclusive. The pores were too large and it was complicated to select a fine mixture of materials. Other organic residues were also tested, but they were not as easy to apply as animal dung. We made experimental pottery samples with different proportions of cow dung from a pasture. Once we found an appropriate temper for the experimental samples, we prepared a mixture of 30 % of cow dung and 70 % of natural clay. With this ceramic paste, we tested different types of coiling techniques.

Our main objective was to verify the variations in coiling technique and to examine differences in the inner organization of the pore structure deformed by the application of the coil to the vessel body in more usual ways. Before preparing the experimental samples, we carried out a series of preliminary experiments to analyse variation in inner structure resulting from different techniques of coiling. We used clay of a different colour for each coil to understand in detail what was happening inside the wall of each vase.

The most common techniques of coiling are generally described as the 'U' and 'N' technique. Coils are regularly joined in the horizontal direction. In cross section, they are either 'U-shaped' or in bevel position. Coils of the 'N' and 'U' type can be made in a very similar way, but the direction in which the coils are smoothed differs.

More specifically, coils in the 'U' technique are laid one on top of the other (*fig. 1: 1*, first row), without any important inner deformation during the joining (*fig. 1: 2*, first row). The coils were smoothed superficially using a rib (*fig. 1: 2*, first row), both sides in the same direction. This technique produces a 'U' shaped distortion of the coils (*fig. 1: 3*, first row).

In the 'N' technique, coils are also laid one on top of the other as in for the 'U' coil technique (*fig. 1: 1*, second row). They are also superficially smoothed using a rib, but in the opposite directions from the inner and outer surface of the wall. (*fig. 1: 2*, second row). This variant produces a bevel-shaped (N) distortion of the coils (*fig. 1: 3*, second row).

Pinched 'S' coils are stacked alternately, inclined towards the inner and outer side of the vessel (*fig. 1: 1*). They are joined by pinching, which deforms considerably the inner structure of the coil (*fig. 1: 2*). The coils are crushed by a rhythmic gesture, which also produces

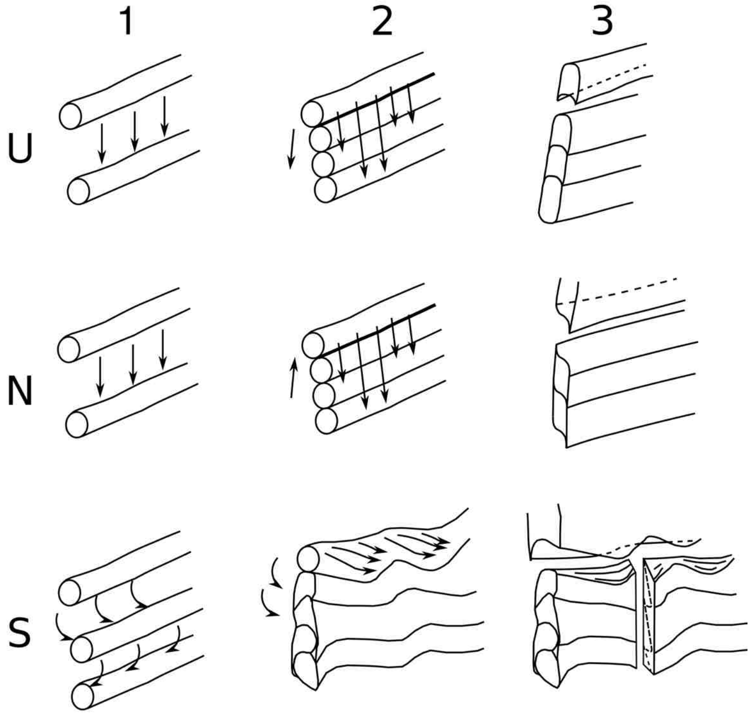

Fig. 1. Scheme of techniques reconstructed for uCT analysis of experimental samples. The position of the adjunction of coils, the type of joining and marks on fractured sherds are presented for the three selected techniques. The different techniques used to manufacture the experimental samples can be explained in three steps. First (column 1) is the position of joining of the coils, second (column 2) is the mode of the joining, and third (column 3) is the general characteristics of fractures in joins of coils. The first row illustrates the 'U' technique, the second row illustrates the 'N' technique, and the third row illustrates the pinching 'S' technique.

the inner rotation of each coil (*fig. 1: 2*). The rhythmicity and distortion of the coils are indicated by irregularities on the wall surface even on the joins of coils (*fig. 1: 3*).

We also tested the pinched coil technique, attempting to reproduce the diagnostic traces of LBK sherds as closely as possible (referred to herein as 'S' coils). Our experiments with this technique were inspired by ethno-archaeological examples, especially the unfinished vases from the collections of *Alexandre Livingstone Smith* (*2001*). Further pre-experiments were necessary to experience this forming technique. We aimed to obtain marks that would correspond to LBK pottery, in which a specific rhythmicity of the pinching of the coils is clearly visible.

The main advantage of these experiments lay in the fact that we could control the details of the technological process of fabricating the experimental samples. This allowed us to test our hypotheses about the origins of the raw materials and their organization, depending on the forming technique. Our methodological strategy for the future is to compare original artefacts with experimentally produced samples and thereby test our hypotheses about the technological processes used by LBK potters.

Method of uCT analysis

The porosity of the samples was determined by X-ray micro computed tomography (micro CT). Micro CT measurements of samples were performed using the laboratory system GE phoenix v|tome|x L 240 equipped with a 240 kV / 300 W maximum-power nanofocus X-ray tube and a high-contrast flat panel detector DXR250 with 2048 × 2048 pixels and 200 × 200 μm pixel size. Tomographic measurements were performed at the temperature of 21 °C. The parameters of the tomographic measurement were adjusted according to the size and morphology of the specimens. *Table 1* shows the parameters of each specimen.

The tomographic reconstruction was realized using GE phoenix datos|x 2.0 3D computed tomography software. The visualization of samples and the porosity analysis were performed in VG Studio MAX 2.2 software. The segmentation of pores was based on the simple thresholding procedure, and the automatic tool of VG Studio was used for threshold determination. This tool determines the background peak and the material peak in histograms for all slices and then calculates the grey value of the material boundary. Most micro cracks were not included in the pore analysis, because their dimensions were below the voxel resolution.

An alternative approach to study void structures is based on carbon coatings (see *fig. 2*) produced on the inner surface of voids by residues of organic matter remaining on the surface of ceramic voids (*Hanykýř – Kutzendörfer 2002*, 95). It was possible to reveal this coating by adjusting the visualised spectra.

LBK ceramic sherds

The samples examined in thus study come from two important LBK sites: Bylany in central Bohemia (excavated by the Czech Academy of Sciences) and Těšetice in Moravia (excavated by Masaryk University in Brno), both long-term excavations. Both LBK settlements cover the interval of c. 5350–4900 cal BC (*Kuča et al. 2012*; *Pavlů ed. – Zápotocká 2007*, 27–31).

Specimen	Bylany	Těšetice	N' coil technique	U' coil technique	S' coil technique
Acceleration voltage [kV]	170	150	150	150	150
X-ray tube current [uA]	100	100	100	100	100
Exposure time [ms]	500	333	300	300	300
Number of projections	2000	2000	2400	2400	2600
Linear voxel size [um]	60	34	25	25	25

Tab. 1. Technical specifications of uCT analyses of the pottery samples.

Site	Sample No.	Inventory No.	Feature	Context	Original shape
Bylany	B1	278 389	2164	house no. 2209	undetermined
Těšetice-Kyjovice	IV 76	96.254	464	house no. D20	storage vessel
Těšetice-Kyjovice	MH 10	K96254/3	225	irregular pit	globular vessel

Tab. 2. Essential information concerning the archaeological samples choosen for the uCT analysis.

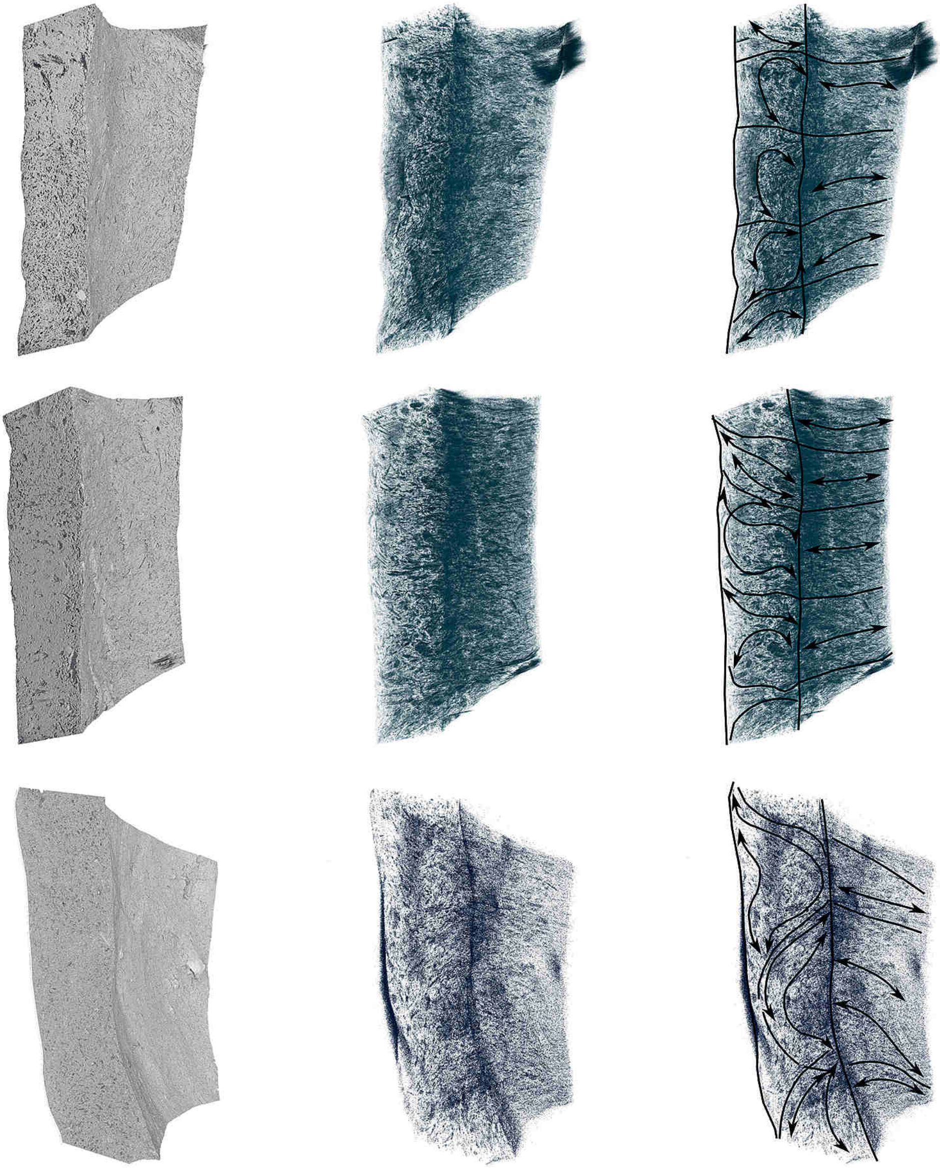

Fig. 2. Segments of experimental samples visualised using adjusted spectra to reveal the carbon coating of voids. It shows the void orientation and approximate joins between coils in experimental samples prepared using different forming techniques.

The Neolithic settlement area at Bylany was discovered in the 1950s by Bohumil Soudský. Large-scale archaeological excavations were undertaken here between 1955 and 1967. Seven hectares of Linearbandkeramik settlement (LBK, linear pottery culture) and subsequent Stichbandkeramik settlement (STK, stroked pottery) were excavated and explored.

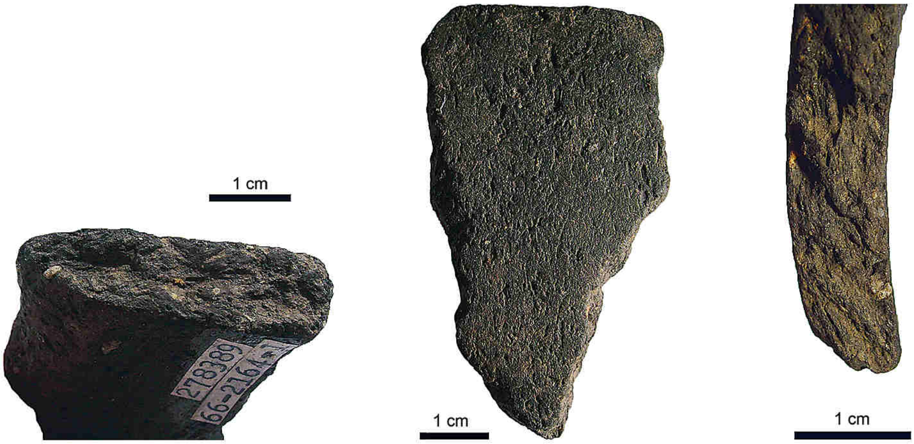

Fig. 3. Bylany sample B1 and macroscopic traces, join of coils (upper part and detail in the bottom left corner) and the elongation of the structure on the section (top right corner). Authors K. Neumannová and K. Kleinová.

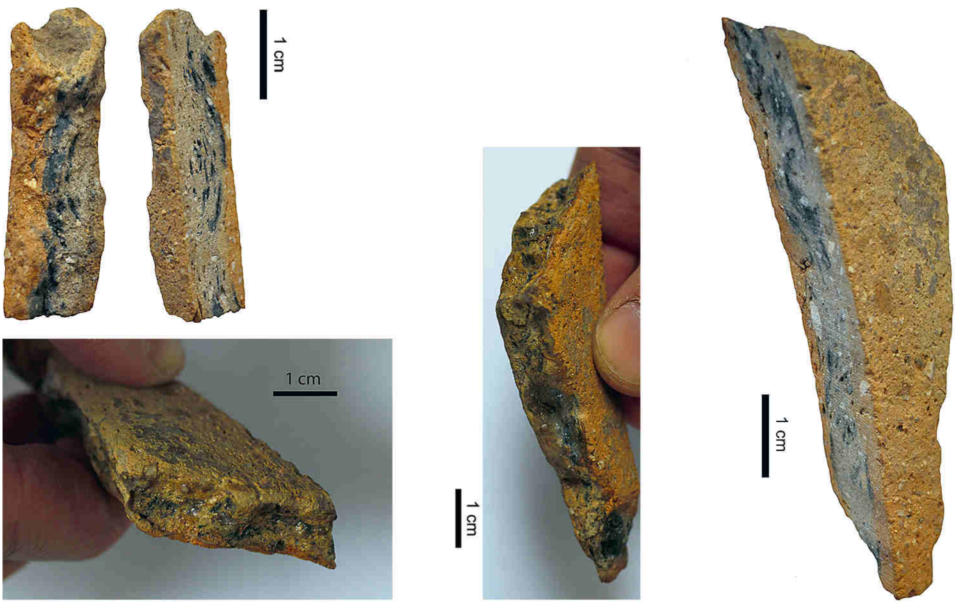

Fig. 4. Těšetice sample MH10. Burnt-out organic material facilitates the recognition of the structure. On the section there is a C-shaped organization of pores (detail on the left, upper photo), join of coils (detail on the left, photo below). Authors K. Neumannová and K. Kleinová.

The site is one of the most important excavations of Neolithic settlements in Europe (*Pavlů et al. 1986*, *Květina – Pavlů 2007*). The excavations revealed a characteristic picture of LBK settlement residues, comprising ground plans of timber pole long-houses surrounded by a large number of pits.

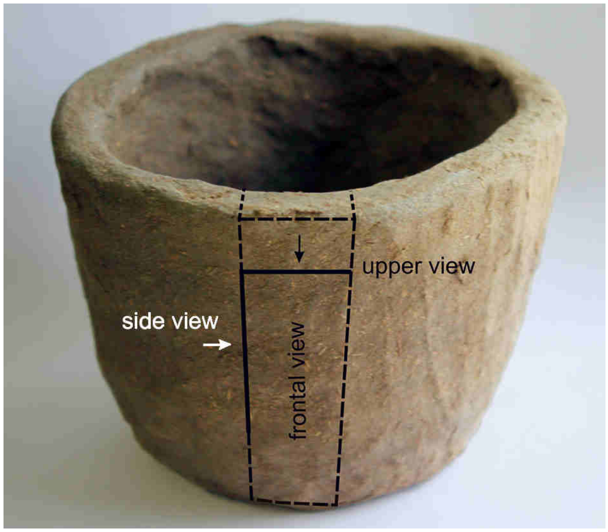

Fig. 5. Example of the experimental vessel with the depiction of views used for the uCT analysis visualisations.

The Těšetice-Kyjovice site is situated in the district of Znojmo. Systematic excavation has uncovered a multi-period site with settlement remains from the Neolithic to the Iron Age. The LBK settlement is concentrated in the north-east section of the excavated area, where over 120 features were uncovered together with 20 not well preserved outlines of post-hole houses and 11 inhumation burials (*Vostrovská – Prokeš 2012*). A geophysical survey ascertained that the settlement extends further towards the north-east, and 80–130 other construction complexes (longhouses with longitudinal pits) arranged in several rows can be identified here (*Milo 2013*).

Micro-tomographical samples and their contexts are presented in *table 2*. Sample selection was based on macroscopic observation of technological traits typical of burnt-out organic material and associated with different coiling techniques. We chose two samples from each side that macroscopically correspond to our hypotheses concerning the 'S' coil technique and one from the site Těšetice-Kyjovice (IV 76), in which we attempted to identify the inner structure, which is not macroscopically visible.

Results

Segments of experimental vessels are visualized in *fig. 2* (left column), using the adjustment of spectra on the carbon coating of voids. It shows the voids' orientation and approximate joins of coils for different forming techniques on experimental samples. The arrows indicate the dominant void orientation (*fig. 2*, central and right columns). The visualization of voids in front view, side view and upper view offers much more detailed insights into the complexity of the spatial organization of voids associated with different forming techniques (*fig. 6*).

'U' coil technique: Front view (*fig. 6*, first row, first column): There is no visible join of coils in front view. Voids are oriented horizontally, parallel. Occasionally, the orientation

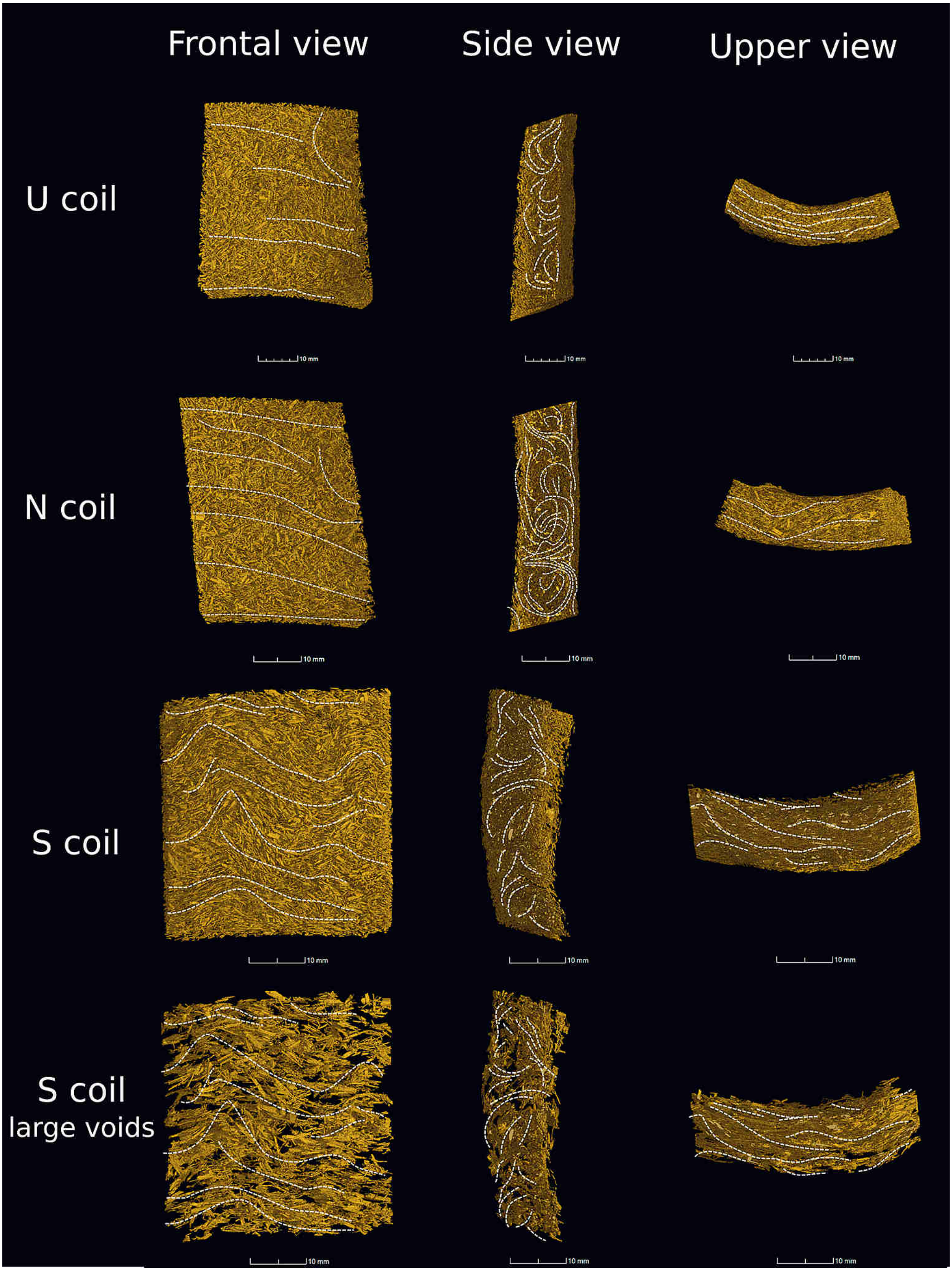

Fig. 6. Visualization of voids in front view, side view and upper view. White lines illustrate the dominant orientation of voids.

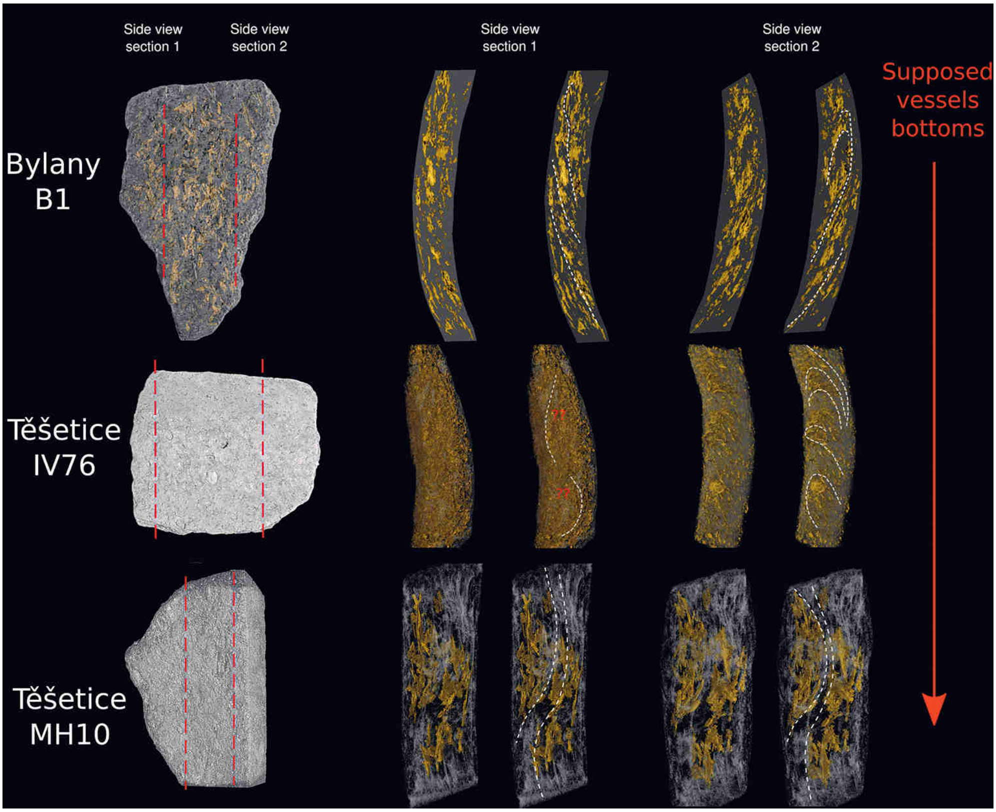

Fig. 7. Samples from the sites Bylany and Těšetice. Variability in the coil deformation is clearly visible if different side-view cross-sections are directly compared. White lines illustrate the dominant orientation of voids.

is deformed around mineral grains into a fluidal texture. Side view (*fig. 6*, first row, second column): Elongated voids are oriented into concentric structures. A typical 'U' shape is visible if the elongate voids close to the surface are oriented towards the vessel bottom. The structure matches well the original position of the coils, the margins of which are clearly recognizable. The shape of coils is similar in different side-view cross-sections. Upper view (*fig. 6*, first row, third column): Voids are parallel to the coils and rim of the vessel.

'N' coil technique: Front view (*fig. 6*, second row, first column): The structure of voids in front view is similar to the 'U' coil sample. There is no visible join of coils in front view. Elongate voids are horizontal and parallel as the 'U' coil sample in front view.

Side view (*fig. 6*, second row, second column): Elongate voids are oriented into concentric structures in the central part of coils. Their orientation is inverse close to opposite surfaces of the vessel walls. The inverted orientation around opposite sides is typical for 'N' coil technique. The shape of coils is similar in different side-view cross-sections. Upper view (*fig. 6*, second row, third column): Voids are parallel to the coils and rim of the vessel. The visible discontinuity is probably related to a joining of two different coils (*fig. 6*, second row, third column).

'S' coil technique: Front view (*fig. 6*, third row, first column): There is no visible join of coils in front view. The voids are parallel, but not horizontally oriented. The orientation of voids orientation is deformed into wavy or folded structures. Side view (*fig. 6*, third row, second column): Elongate voids are oriented according to the intensity of deformation in different parts of the vessel wall. Less deformed zones contain concentric structures similar to what could be caused by the 'U' technique. More deformed zones contain drop-like irregular structures. Coils are occasionally connected into continuous 'S' joins. Upper view (*fig. 6*, third row, second column): A rhythmic variation of slightly parallel and more deformed parts is visible in upper view.

Method of uCT analysis of LBK artefacts from the sites Bylany and Těšetice: LBK samples from the sites Bylany and Těšetice were selected for consequent comparison with experimental samples. Variability in the coil deformation is clearly visible if different side-view cross-sections are directly compared (*fig. 7*). Side-view sections 1 show the more deformed zones of both artefacts. Coil joins are not visible at all in these cross-sections. Side-view sections 2 run through the less deformed part of both artefacts. Coils are clearly visible. uCT sections exhibit variability of coils in space and transitions between less and more deformed zones in samples Bylany B1 and Těšetice MH10. In sample Těšetice IV76, no zone with clearly visible structures indicating less deformed coils could be identified. It could be caused by a different size and shape of the original organic temper and by a different forming technique, which does not directly correspond to our experimental model. On the other hand, there is an overall similarity to the more deformed zones of samples Bylany B1 and Těšetice MH10. The inner structure of sample IV76 does not fit into our experimental models. Perhaps this sample is more difficult to interpret than the others, which were selected due to well visible macroscopic marks. On a limited number of samples, we tested whether uCT analysis can aid the interpretation of sherds that are difficult to identify. The results support our conclusions based on the application of other methods of technological analysis.

Discussion

An important part of our experiments was the testing of different organic materials suitable for uCT analysis. Experiments with straw and hay were inconclusive. Even the finest particles of hay we found produced pores that were too large for our purposes. It was a complicated and time-consuming task to select a fine mixture of these materials. The first closer look at cow dung answered some of our questions that arose during the macroscopic study of organic residues in Neolithic pottery. Most notably, the use of dung may explain the infinitely variable shapes of very tiny particles resembling the remains of grains and parts of plants. Furthermore, dung is perfectly suited for mixing with clay in contrast to sharp and rough particles we tried to use before. It influences the workability of clay, but not as much as other materials.

The proportion of cow dung and clay was only approximate, although we strived to be as exact as possible. The volume to weight ratio of both materials depends on their moisture content. Anyhow, it does not reflect the final proportion of pores and clay, because cow dung also consists of a fine material that gets incorporated in the clay. For the uCT analysis, we settled on a mixture containing 30 % of cow dung, but the final amount of pores is probably higher than within original artefacts. Our experiments with variation in the proportion of organic matter have also brought other useful information, for example on the limits of macroscopic resolution (around 10 % of cow dung) and how it influences the solidity of pottery. Our experiments also included the crushing of experimental pots and the study of macroscopic marks of different coiling techniques.

For our study, we focused on three types of coiling techniques, which of course do not cover the whole range of possible techniques. Our aim was to produce experimental pottery that matches LBK pottery as closely as possible to enable comparisons with original sherds and to touch on questions that arose during the macroscopic study of LBK assemblages. Experiments with forming techniques demand considerable experience in pottery making. Even though we performed a series of preliminary experiments, there were still differences in the quality and regularity between the 'U' coil technique sample and the other ones, which required the experimenter to adjust their modus operandi. The 'S' coil technique requires the fine tuning of motoric skills and a regular rhythmicity.

The most significant marks of the 'U' coil technique are visible in the side view. The structure matches well the position of the coils, the margins of which are clearly recognizable. The coils are continuous in side-view cross-sections. A typical void orientation in vessels made by the 'N' coil technique is also visible in side view. The orientation of the voids is approximately parallel along the opposing surfaces of the vessel walls, forming a stretched 'N' shaped pattern. Another difference in comparison to the 'U' coil technique resides in the symmetrical cores of the coils. The appearance of the inner structure is similar to the 'U' coil vessel: horizontal and parallel. The void orientation in side view is similar to 'U' technique vessels in some side-view sections: slightly concentric to slightly parallel to the vessel wall surfaces, but the pattern is irregular and the most pinched parts cause 'S'-like structures in side view. It is caused by the alternation of more or less deformed zones. In front view, voids are parallel but deformed into wavy or folded structures. The technique we call 'S' coil, which we designed to reproduce the technique observed on LBK pottery, represents only one of many variants of pinched-coil techniques. Pinching produces irregularities in the wall structure, which may constitute many of more or less visible sub-variants.

Beside the spatial organization of voids, we also documented their morphology. The size and shape of voids produced by the use of dung is very specific. The bovine digestive tract causes the fragmentation of grass tissues into angular pieces of variable size. Void size distribution seems to be a possible marker of different organic materials used as temper.

The results of our experimental reconstruction of the 'U', 'N' and 'S' techniques only partly matched what has been identified in archaeological finds. In Remicourt 'En Bia Flo' II, the configurations are called 'C', 'O' and 'S', but all of these configurations correspond to the pinched coil technique (*Bosquet et al. 2005*, 110). The configurations are richly illustrated, but not interpreted in detail. Configuration 'C' (see *Bosquet et al. 2005*, 109) seems to correspond with the 'S' technique, but this would require a closer comparison. At Cuiry-lès-Chaudardes in France, the techniques are characterized more precisely. The first group (CCF1) is described by specific diagnostic marks (*Gomart 2014*, 63): In cross sections, voids can be distinguished at regular distances. Between these voids, pores and particles are oriented sub-circularly. The voids are inclined in alternating directions, which correspond with the orientation of the porosity. It is called the 'S' or 'Z' configuration. This method of manufacture can be recognized also by longitudinal indentations on the interior of vessels left by the pressure of the potter's fingers (*Gomart 2014*, 63).

These technological marks have not been interpreted in detail (*Gomart 2014*, 63). One of the mentioned variants is pinched coil pottery. *Alexander Livingstone Smith* (*2001*, 121) described the correspondence of these macro-traces with the pinched coil technique in ethno-archaeological material from Africa. The second main technique (CCF2) corresponds with the 'U' coil technique, in that study referred to as 'C/O'. It is described as thin coils that were only superficially deformed during the forming of the vessel. Signs of these two techniques were identified also at other sites in France and Belgium, but not at all of them (*Gomart 2014*, 280, see tab. 81).

At the Bylany site in the Czech Republic, signs of the 'S' technique have been observed systematically (*Neumannová et al. 2016*), besides other techniques, as a less pronounced variant of coiling, which can be associated with the 'U' technique or a better smoothed and drawn variant reshaped during secondary forming. Similar tendencies were randomly observed also at other sites in the Czech Republic, for example, Těšetice in Moravia and Nové Dvory (see *fig. 6*), which is situated in the close vicinity of the Bylany site (*Neumannová et al. 2016*). Macroscopic studies show similar trends in technological processes across different regions of Europe. The coiling technique is predominant. Macroscopic studies also provide details on the methods of joining coils and some data on the composition of ceramic paste.

Comparison of our uCT results for experimental samples and selected LBK samples shows similar signs in the 'S' technique experimental sample and in LBK artefacts. There is clearly visible variability in the deformation of coils.

Conclusion

A closer analysis of LBK artefacts will be the subject of a follow-up study. The method of uCT analysis seems to be suitable for this purpose. It allows to visualize the spatial orientation of pore structures in experimental pottery in relation to deformations caused by the pinched coil forming technique.

Rhythmic irregularities in wall structure caused by the pinching technique pose difficulties for thin-section and similar one-dimensional section analyses. This non-uniform and dynamic phenomenon in the structure of ceramic sherds requires the consideration of different perspectives and scales (macro/micro). Deeper insights into the topic will require the application of multiple approaches.

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