Edited by:
MICHELA SPATARO, MARTIN FURHOLT

Detecting and explaining

# TECHNOLOGICAL INNOVATION IN PREHISTORY

**SCALES OF TRANSFORMATION** IN PREHISTORIC AND ARCHAIC SOCIETIES | 8

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# Preface of the editors

With this book series, the Collaborative Research Centre *Scales of Transformation: Human-Environmental Interaction in Prehistoric and Archaic Societies* (CRC 1266) at Kiel University enables the bundled presentation of current research outcomes of the multiple aspects of socio-environmental transformations in ancient societies. As editors of this publication platform, we are pleased to be able to publish monographs with detailed basic data and comprehensive interpretations from different case studies and landscapes as well as the extensive output from numerous scientific meetings and international workshops.

The book series is dedicated to the fundamental research questions of CRC 1266, dealing with transformations on different temporal, spatial and social scales, here defined as processes leading to a substantial and enduring reorganization of socio-environmental interaction patterns. What are the substantial transformations that describe human development from 15,000 years ago to the beginning of the Common Era? How did interactions between the natural environment and human populations change over time? What role did humans play as cognitive actors trying to deal with changing social and environmental conditions? Which factors triggered the transformations that led to substantial societal and economic inequality?

The understanding of human practices within often intertwined social and environmental contexts is one of the most fundamental aspects of archaeological research. Moreover, in current debates, the dynamics and feedback involved in human-environmental relationships have become a major issue, particularly when looking at the detectable and sometimes devastating consequences of human interference with nature. Archaeology, with its long-term perspective on human societies and landscapes, is in the unique position to trace and link comparable phenomena in the past, to study human involvement with the natural environment, to investigate the impact of humans on nature, and to outline the consequences of environmental change on human societies. Modern interdisciplinary research enables us to reach beyond simplistic monocausal lines of explanation and overcome evolutionary perspectives. Looking at the period from 15,000 to 1 BCE, CRC 1266 takes a diachronic view in order to investigate transformations involved in the development of Late Pleistocene hunter-gatherers, horticulturalists, early agriculturalists, early metallurgists as well as early state societies, thus covering a wide array of societal formations and environmental conditions.

The publication on detecting and explaining technological innovation in prehistory includes interdisciplinary research, with case-studies from Europe, the Indus Valley, Iran, and Mexico. We are very thankful to the editors of the workshop proceedings Michela Spataro and Martin Furholt and to graphic illustrator Carsten

Reckweg for their deep engagement in this publication. We also wish to thank Karsten Wentink, Corné van Woerdekom and Eric van den Bandt from Sidestone Press for their responsive support in realizing this volume and Hermann Gorbahn and Katharina Fuchs for organizing the whole publication process.

*Wiebke Kirleis and Johannes Müller*

# Contents

# Preface

For the last quarter of 2017, I was a Mercator Fellow at Kiel University, Germany, within the Collaborative Research Centre 1266 “Scales of Transformation”, which is funded by the German Research Foundation (DFG). The fellowship was part of subproject F5 “Social Dimensions of Technological Change”, whose PIs were Martin Furholt, Johannes Müller (Kiel University) and Berit Eriksen (Centre for Baltic and Scandinavian Archaeology, Schleswig, Germany).

As part of the fellowship, hosted by Kiel University’s Institute of Pre- and Protohistory, I carried out research on technological choices and variations in pottery technology in the Balkans, studying early Neolithic ceramics from one site in the Romanian Iron Gates region and another in Bulgaria. At the Institute, I particularly appreciated discussing archaeological topics with Johannes Müller, Martin Furholt, Robert Hofmann, Martin Hinz, and Henny Piezonka. With the support of Petra Herms, Peter Raase and Romain Bousquet of Kiel University’s Department of Petrology and Geodynamics, I was able to continue petrographic analysis of these materials, and I enjoyed many helpful discussions of geological aspects.

The main task of the fellowship was the organisation of a workshop, entitled *Detecting and explaining technological innovation in prehistoric Europe*. The workshop, which took place at Kiel University on 23-24 November 2017, focused on the definitions of innovation, detecting the initial appearance of innovation, adoptions and diffusions of innovation, transmission of technical skills and factors promoting innovation. I would like to thank everyone who helped to make the workshop a reality at such short notice, particularly Katharina Fuchs, Angelika Hoffmann, and Carsten Reckweg. This book is the product of that workshop. I would like to thank all the workshop participants, the authors and co-authors of all the papers in this volume, and in particular all the reviewers, some of whom also contributed papers, and carried out this work within a tight time-frame. I would also like to thank Jude Secker for proofreading the finished papers and Sidestone Press for the professional publication.

*Michela Spataro*

# Detecting and explaining technological innovation in prehistory – an introduction

*Michela Spataro[1], Martin Furholt[2]*

*Keywords: technology, innovation, invention, tradition, chaîne opératoire, knowledge acquisition, knowledge transfer, Neolithic, Bronze Age, Iron Age, ethnography, ceramic, metal, bone*

## Concepts

Technology is a broad concept that permeates virtually all areas of human life. By definition, technology refers to standardised, repetitive procedures, involving the use of physical material, which makes it a concept especially suited for exploring social traditions, mechanisms of social learning, and culturally specific habitual, embodied practices, using archaeological finds. It is thus a unifying conceptual framework which gives, from a specific perspective, meaning to all artefacts, irrespective of period, region or form of social organisation. Technology, as a topic in archaeological research, attracts a diverse audience: craft practitioners, ethno-archaeologists, theoretical archaeologists, archaeological scientists, and field archaeologists. It informs us about artisans' skills, about ways and modes of knowledge transmission, as well as about the stability of traditions, or rates of change.

Innovation, as the second main concept in our volume, is a more problematic term, as it is often used in a superficial way, and carries normative baggage. Firstly, it is often not very well defined when used. It is most widely applied in economics, where it is bound up with ideas about profit-generating inventions, and often this kind of mindset follows innovation into archaeological debates. An innovation is thus seen as an improvement within a framework of utility-maximizing, competitive individuals or societies. Using the term thus risks introducing a long-overcome, teleologic, or maybe rather neo-colonial belief in progress as defined by western rationality. In the light of this, it is important to remind ourselves that the classic definition of innovation by Joseph Schumpeter does not even mention improvement, profits or anything of these normative connotations. He rather emphasized the novelty aspect; innovation is, according to Schumpeter: "*…the doing of new things or the doing of*

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*things that are already being done in a new way* (Schumpeter 1947)". What is interesting here is, firstly, the mentioning of both new things, and things done in new ways, and secondly, the emphasis on the *doing* of things. Of course, one does not have to follow this definition, but it actually seems to be a good way of thinking about innovation. An innovation is not just any new item or thing, but something becomes an innovation when new things are *being done* (or already known things are *being done* in a novel way). This interpretation indicates that innovations are defined by having a real effect on human practices. As soon as they are acted out, and start changing things, then novelties become innovations. This is obviously a pragmatic perspective, and such a perspective helps to make the important distinction between novelty – which could mean virtually everything that is new in any thinkable way – and innovation. An innovation has to have a tangible effect on peoples' lives.

Things change all the time. Humans might have the tendency (as at least many people believe, even if it cannot be justifiably generalised), to try to create or maintain more stable lifeworlds, but there is a threshold beyond which a novel practice has such tangible effects that it effectively and perceptibly changes things. It seems that this is more or less what archaeologists who use the term 'innovation' are thinking about, much more so than in terms of the maximisation of profits. Most archaeologists – including the contributors to this volume, use the term innovation to refer to a novelty of practices, which has a tangible and lasting effect on routines or technologies involved. While there remains a kind of conundrum of how to actually draw a limit to when something is tangible or not, it is still a workable definition.

One of the first volumes dedicated to technological innovation in the past was published in 1971, when *World Archaeology*, in its third year, dedicated an issue to *Technological Innovations*. Contributors generally considered technological innovation/change as the outcome of population growth, market and political changes (*e.g.* social centralisation, see Collis 1971), but also considered the role of itinerant artisans or gifted individuals.

In the opening article, Bordes (1971) briefly discussed the parallelism between physical and technical evolution, suggesting that two factors are essential to technological evolution/change. First, focussing on early prehistory (Palaeolithic), he suggested a relationship between brain size and the complexity of the techniques used by humans. However, the author also stressed that innovation seems to take place during the phases of physical evolution (Bordes 1971, p.5). The second factor is the relationship between technical progress and population growth (*e.g.* finding better ways to preserve foods) "*and an application of the new brain power to better communication and storage of knowledge*" (op. cit., p.5).

In the same volume, Peltenburg (1971), discussing vitreous materials, stressed how movement of craftsmen is critical to the diffusion of techniques (*e.g.* glazed pottery in Etruria; see also the problem of tin in Dayton 1971), but also the idea that "*the materials, and sometimes the methods, [..] were at hand long before they were 'invented'*" (*e.g.* polychrome faience was discovered after having been used in glass production) (Peltenburg 1971, p.10). Discoveries often require more than a single cause, and in some cases, they appear at the same time in two geographically distant areas with no apparent association (*e.g.* independent glaze invention in Mesopotamia and Egypt) (op. cit., p.10).

Nicklin (1971), considering ethnographic case studies (*e.g.* Chowra in Great Nicobar, Aegean and Mexico), discussed how some communities may depend on trade of pottery, whereas others export this commodity over long distances. She noted that changes can also be due to artisans with special skills: "*Despite the proverbially inherent conservative nature of the craft of pot-making, and the disposition of potters, the factors which seem to propagate stability in such aspects of pottery as materials, techniques, and forms are endangered by static economic and other conditions. Changes in these conditions often give rise to changes in the aspects of pottery manufacture referred to above*" (Nicklin 1971, p.47).

Schiffer and Skibo's (1987) approach to technological change put a strong emphasis on function and society, recognising three components of technological knowledge: recipes for actions (types of raw materials, tools, the different steps of the chaîne opératoire and rules to solve possible problems that the artisan might encounter), knowledge which is intergenerationally transmitted, and techno-science (scientific principles at the basis of the technological activity). They made an important statement, which underpins the current volume, that "*without substantial foundation of modern science for identifying techno-science, archaeologists can scarcely hope to explain technological variability and change*" (op. cit., p.597), and suggested that the principal driver of technological change lies in the 'functional field', the set of techno- socio- and ideo-functions, "*that the artefacts in a society have to perform*" (op. cit., p.598). Aspects favouring innovation include demand for new functionality, feedback and experiments to improve the function of a tool, and 'producer pressure' (*i.e.* competition between artisans). Schiffer and Skibo (1987, p.601) suggested creating a 'performance matrix' for each artefact to explain technological change, where all the characteristics of the object, from its production to its use and maintenance are described.

More recently, Sanchez (2012, pp.31-32) summarised models to explain change – starting with alteration of the social, economic, environmental system resulting in the modification of the artefacts (Binford and Binford 1968; Flannery 1968), to the agency of people (Giddens 1979), to the more recent interpretation of material culture as an agent of change (Gosden 2006).

# Detecting technological innovation

## Methods of analysis

To detect technological innovation, transfer and adaptation, the entire sequence of activities carried out by the artisan (the chaîne opératoire) needs to be studied. To do so, a wide range of analytical methods is required, from macro-examination to the use of archaeometric techniques. Ideally, these approaches should be used in tandem, as they are complementary. Macro-analyses focus on distinguishing different reduction techniques, in the case of lithics and bones, and forming techniques for ceramics. As well as the chaîne opératoire, function might be a motive for innovation, and another important observational technique is use-wear analysis, which is widely applied to lithics but is less so for pottery (see Vieugué 2014; Vuković 2010).

For ceramics, macro-analyses usually include a preliminary description of the ceramic paste (fabric). For a more detailed study of fabrics, thin sections are analysed using a polarised microscope to determine the type of clay (matrix), any addition (temper) or removal of inclusions to make the clay less plastic or finer, any surface treatment (*e.g.* slipping, painting, polishing), and the firing temperature, for example detecting whether the pot was fired below or above vitrification point (see Rice 1987, pp.334-335). To quantify the chemical composition of the clay or mineral inclusions, scanning electron microscopy with energy dispersive X-ray analysis (SEM-EDX) measures the concentrations of major and minor elements (sodium to iron), and with its high magnification images it helps to better understand the fabric, *e.g.* the degree of vitrification (see Tite and Maniatis 1975). If the fabric is very fine and we need to quantify trace elements (concentrations *e.g.* < *c.* 0.1%, usually expressed in parts per million – ppm), neutron activation analysis (NAA), inductively coupled plasma mass spectrometry (ICP-MS) or inductively coupled plasma atomic emission spectroscopy (ICP-AES) are used to detect variations in clay matrix composition, which reflects the local geological background at the clay source, and may therefore reveal artefact exchange over short or long distances (*e.g.* Bruno *et al.* 2000). X-ray diffraction (XRD) is useful for clay mineral identification and estimating firing temperatures on the basis of the presence or absence of specific minerals (Štubňa *et al.* 2012); it can also be used quantitatively. Ideally, a range of scientific techniques should be used together (see for example, the interdisciplinary case study of Egyptian and Greek-style pottery found in the Nile Delta, Spataro *et al.* 2018).

Biomolecular methods are also relevant to artefact studies. To study vessel uses, and possibly fabric and function correlations, organic residue analyses may be undertaken, using techniques such as gas chromatography-mass spectrometry (GC-MS), which enables identification of the organic compounds and gives a biomolecular fingerprint, and gas chromatography-combustion-isotope ratio mass spectrometry (GC-C-IRMS), which measures stable isotope values in individual fatty acids (Historic England 2017, p.6; Roffet-Salque *et al.* 2017). To identify animal species used to make bone/antler tools, ZooArchaeology by Mass Spectrometry (ZooMS) can be used, although extraction and analysis of ancient DNA (aDNA) is necessary to distinguish closely related taxa, such as aurochs and domestic cattle (see Buckley *et al.* 2009).

In this volume, authors applied a wide range of techniques, including macro-examination (*e.g.* of forming methods [macro- and micro-traces]), in both archaeological and ethnographic case studies (see Arnold, Gomart *et al.*, Vidale, Vitezović, Vuković), but also in syntheses (see Arnold, Hofmann, Kadrow and Miller) and experimental archaeology (see Botwid). In some cases, macro-examination is combined with scientific techniques, such as thin section petrography, LA-ICP-MS, SEM-EDX, XRD, and X-ray fluorescence (see Czifra *et al.*, Rauba-Bukowska and Czekaj-Zastawny, Vidale).

## Change which constitutes innovation

Although a suite of methods can be applied to detect innovation, more importantly, innovations need to be detected in the archaeological record, which means recovering and selecting relevant samples, and investigating the sites where innovation occurred (see limits of sample identification in Vitezović this volume). In the process of innovation, many novelties can fail, or only appear for a short period of time, and will therefore not be detected, or not be recognised as innovations. Archaeologists mainly detect innovations which have had a long period of use (*e.g.* see the reduction techniques used in the Mousterian, *e.g.* Bordes 1971), but short-lived precursors should be looked for.

Another issue in detecting and explaining change in the chaîne opératoire for the production of ceramic, lithic and organic artefacts is knowledge of *when* the action/artefact changed (see Spataro 2018). If the aim is to observe the process of innovation, from the initial appearance of new technologies to their adoption and diffusion, we also need to be guided by the datability of archaeological assemblages. Furthermore, the spread of any change needs to be mapped to reveal its geographical scale.

There should be equivalent data from the appearance of an innovation and from the previous tradition. Explaining technological change requires analysis of artefacts *before* and *after* the change, and in order to be able to describe why it happened, it is important to recognise the qualitative aspects of change and the tempo at which change takes place. In doing so, we address the concepts of success and failure of innovations (which technological changes becomes permanent).

Some innovations are inevitably more difficult to detect, *e.g.* changes in the organisation of production, as the final product might appear to be the same. Often these changes cannot be detected by scientific methods. In other cases, however, we might observe a change in the artefact itself, without any innovation in the chaîne opératoire or in the function of the object produced. For example, changes in settlement patterns and shifts in the subsistence economy might change the types of raw materials available (*e.g.* in the Serbian early Neolithic the Starčevo communities replaced some of their osseous tools and started using bones from domestic animals, see Vitezović this volume).

# Explaining technological change

## Economic factors

In the modern world, innovation is usually seen as being driven by economic factors such as scarcity and competition. The same template has often been applied to prehistoric technology (*e.g.* Nicklin 1971 on pottery), and it is easy to assume that innovations which solve existing problems and increase productivity will be more readily adopted. Changes often imply trial-and-error efforts by artisans to solve specific problems (see Schiffer and Skibo 1987). Nevertheless, we need to be careful about applying modern interpretations to past societies, as we might use values and rules which are not applicable. Historically, innovations solve existing problems and therefore are easily adopted; an example is the use of larger and more efficient kilns (see the Tripolye culture in Ukraine or the dragon kilns made for porcelain production in China). Economically, in order for a technological innovation to take off, there is the need for a critical mass of consumers, which spreads knowledge of and demand for the new product (see Lechman 2015). Spataro (2018) and Hofmann (this volume) argue that innovations occur in the context of increasing consumption and less egalitarian societies.

## Intercultural contact and hybridisation

One of the oldest explanations for technological change is in terms of immigration of newcomers, who replaced previous people and/or their technologies; however, historical sources and ethnoarchaeology often reveal a more complex situation, *e.g.* of an existing community accepting or adapting the ideas of newcomers. An example is the work of Sanchez (2012), who discusses the effects of the Spanish conquest on daily life in central Mexico. Indigenous people had to interact with the colonisers and this led to new social systems, technologies and art. Indigenous people had an active role in the creation of colonial society (Sanchez 2012, p.1), maintaining old cultural elements (technology and style) and introducing new ones. This can be seen in ceramic production, where some manufacturing processes, shapes and decorations disappeared, others were kept, and new ones were introduced in response to new techniques and ways of consumption.

Intensive interaction, leading to a new material culture, can be described as hybridisation, and must have occurred in prehistoric contexts as well. For example, Vuković (2017) observes changes in the chaîne opératoire, mixing traditions which were not allowed before within the conservative learning framework of cultural transmission. In this volume, Vuković presents the case of Pavlovac-Čukar in southern Serbia, where pots made with typical early Neolithic Starčevo fabrics and surface treatments are morphologically typical for late Neolithic Vinča assemblages, and vice versa. Vuković argues that hybridisation reflects changes in learning frameworks, suggesting freedom from social pressure.

Other technological innovations can best be explained in relation to contacts between groups/communities. Vitezović (this volume) stresses the importance of contacts with Anatolia and south-eastern Europe in the adoption in Serbia of selected new techno-type osseous artefacts, and also the use of abrasive techniques to make them. Rauba-Bukowska and Czekaj-Zastawny (this volume) discuss the influences on ceramic production in the Linearbandkeramik (LBK) communities of Poland and Slovakia by communities of the Bükk culture to their east. Kadrow (this volume) also stresses the importance for ceramic changes in south-eastern Poland LBK communities of contacts with the Alföld Linear Pottery culture from the northern Carpathian Basin. Although archaeological evidence is available for these contacts, the nature of the contact is still difficult to address.

## Circulation of knowledge

Successful innovation requires that ideas are implemented and become dominant. In prehistoric societies, the spread of an innovation would generally have been accompanied by the spread of knowledge necessary for its production, and researchers have therefore been interested in how easily knowledge could have circulated. For example, Hofmann (this volume) focusses on communication networks. Increasing connectedness between communities, attested by the frequency of common traits, could be expected to facilitate innovation by increasing human interaction and circulation of technical knowledge.

Even at a more local level, Courniquet (2011) stressed that the sharing of frames of practice in Niger, such as the persistent use of an extraction site and a market, leads to a 'share of practice', *e.g.*, vessels being made following the same recipe in the same village, or improvements in techniques and practices.

Pottery has always been one of the preferred artefacts to study change, as it is often assumed that style, shape and forming techniques reflect the cultural identity of the community who produced them. Ceramics can be found in various contexts, domestic and ritual. From this we assume that these artefacts reflect a wide variety of aspects of daily, social and ideological life. Traditionally, archaeological attention focused on fine and decorated ware, and little attention has been paid to coarse domestic utilitarian pottery; this perspective has changed in the last decades (see Mee and Renard 2007; Villing and Spataro 2015 and references therein).

Prehistoric pottery making was probably a daily activity in specific seasons. Pottery making follows conservative methods, transmitted intergenerationally; this implies that any technological changes occur for important reasons, which reflect important changes in daily life that are more difficult to detect in the archaeological record, such as changes in values, thoughts and beliefs (see Foster 1962).

## Social dimension and collaboration

Another question is whether innovations are more likely to be introduced by a single skilled artisan, or by a collaborative group. Archaeologically it is extremely difficult to detect whether collaboration was itself a factor which promoted innovation, or whether innovations appear simultaneously due to copying by individual artisans (*e.g.* see the discussion on talc-faience objects in the Indus Valley, Miller this volume).

In a sense, all innovation has a social dimension, due to the social milieu in which artisans work, and the receptivity of society to innovation. Gosselain (2000, p.191) argues that different stages of the chaîne opératoire reflect different social interactions, which affects their variability. Forming vessels is a very conservative method (usually learned during childhood), whereas potters are more likely to change their clay selection, extraction, processing and firing. Gosselain argues that these stages reflect changes in their interaction networks (Gosselain 2000, p.192).

The social significance of known artefact types and established preferences of consumers can be viewed as factors which might discourage innovation. On the other hand, the social status of the artisan might be a factor promoting innovation. In their ethnoarchaeological study, Stark and Longacre (1993) stress that innovations among *e.g.* Ashanti wood-carvers can appear from top-down or bottom-up, as high-status artisans are able to innovate because they can afford to take risks, whereas some low-status artisans may innovate because they have little to lose. Differences in status between artisans might therefore encourage innovations, whereas similarities in status might discourage it.

## An interdisciplinary case-study: Vinča technological take-off

In 2018, Spataro published the results of a case-study on Vinča pottery (*c.*5200-4800 cal BCE) from Vinča-Belo Brdo in Serbia, where a combination of economic factors, knowledge circulation and social change can be credited for a surge of technological change during Vinča phase B. A detailed archaeometric study of ceramics from Vasić's old excavation, dated by typology and provenance to Vinča phases A-C, showed an increase in firing temperature, more thorough clay processing, and an almost complete replacement of fabric types during phase B, following the appearance of black burnishing and the use of different recipes for the production of fine and coarse wares during phase A. Comparison with the absolute timescale obtained by Tasić *et al.* (2016), by dating bones from the same excavation sequence, shows that the period of technological take-off (Lechman 2015) lasted several generations, and allowed the evidence of innovation to be synchronised with developments taking place elsewhere in the Vinča world. Phase B coincides with the 'connectivity peak' suggested by Whittle *et al.* (2016), when Vinča settlement density peaked (Spataro 2018).

## The workshop

The workshop 'Detecting and explaining technological innovation in prehistoric Europe' took place in Kiel on 23-24 November 2017. Its origin was the concept that it is not enough to map which innovations were diffused rapidly across cultural boundaries, or which societies were more conservative and which were more receptive to innovation. We need to understand the social context and historical circumstances before attempting to explain these patterns. In particular, we need to think about how technical skills are transmitted and reproduced. One of the aims was to gain a better understanding of the factors promoting innovation in prehistoric societies. Invited researchers from a variety of backgrounds (field archaeology, anthropology, archaeometry, ethnoarchaeology and experimental archaeology) discussed evidence of innovation in the production of different artefact types (pottery, lithic, bone and metal).

One main focus was the conditions under which innovation is taken up, from the perspective of the individual producer. Dean Arnold used his experience as a field researcher in Yucatán to explore how the acceptance of technological innovations by potters is dependent on multiple factors, among which he especially highlighted the conditions of learning in a household context, but also the role of the constraints of existing production technologies and raw materials. Katarina Botwid also started from the perspective of the artisan, and focussed on differential skills as a driver of innovation and adoption of innovation. She also explored the transfer of knowledge between workers of different materials, *e.g.* pottery and bronze, drawing on the Scandinavian Bronze Age as a case study.

During the workshop, Åsa Larsson contributed with her systematic review of factors of change affecting different stages of the chaîne opératoire of pottery making, based on anthropological literature. She identified factors resisting change (tradition, norms and conformism, peer pressure, embodied practices, motor skills), and agents likely to cause change (influential individuals, individual experimentation, new practices, relocation to a new community). She identified those parts of the manufacturing process which are easy to change (vessel shape, surface treatment, decoration) and those who are much harder to alter (clay selection, tempering, firing, less so primary shaping techniques and secondary shaping, *e.g.* rim-forms, handles, see Larsson 2009). This corresponds very much with Dean Arnold's contribution, even though her case study dealt with the southern Scandinavian Middle Neolithic.

How innovations are interlinked with social conditions and political developments was discussed by Robert Hofmann, in his case study on Late Neolithic pottery from central Bosnia. He argued for a decisive role being played by innovation to foster and cement social inequality, in a process of competitive behaviour between households in a context of increasing resource scarcity. Drawing on a number of other Late Neolithic sites and regions, Hofmann argued for the central role of demography, especially population numbers and concentration, and relations of centre and periphery driving the rate and acceptance of innovation. His model of a south-eastern European centre-periphery system sees the central Balkan region, with communities connected to Vinča, as the main motor of innovation, due to its higher population density and degree of specialisation.

This is confirmed by Jasna Vuković, who discussed how technological innovations are at least partly responsible for what is traditionally referred to as cultural change. One important example here is the transition from Starčevo-Criş to Vinča, where Vuković could point to a visible standardisation of production during the Vinča sequence. This she attributed to at least partial specialisation of pottery production. Selena Vitezović gave a parallel account for the osseous technologies in the same period and region, noting greater standardisation in raw materials, *i.e.*, increased use of antlers, metapodials and ribs compared to other bones, while the typological repertoire became more diverse.

Anna Rauba-Bukowska and Agnieszka Czekaj-Zastawny sketched out a parallel and contemporary model for the Polish later LBK period, as did Kadrow. They discussed the relatively uniform clay recipes for LBK pottery, which changed markedly during the Želiezovce phase (starting around 5200 BCE). This change was attributed to closer contact to people producing the more sophisticated and probably more specialised Bükk pottery, located in eastern Slovakia and north-eastern Hungary, and who were associated with Carpathian obsidian sources. This attractive raw material is regularly associated with Bükk pottery finds in LBK contexts, as well as with local attempts to copy some of the characteristics of Bükk pottery. Kadrow made more explicit how innovations in pottery technology can be seen as indicators for wider societal developments. He sees pottery production mainly as a non-discursive, habitual practice, and thus as a good indicator for overall change, which is more effectively visible in other domains of social life.

Gomart *et al.* followed a similar strand and interpreted pottery manufacture sequences (in the sense of chaîne opératoire) as embodied practices, the result of a joint social learning among potters, which reflect intensive contacts between teacher and apprentice in communities of practice. They studied the stylistically mixed assemblages of four Neolithic settlement contexts in the Carpathian Basin from the late Körös and early LBK periods. They observed locally distinct patterns of pottery manufacture, some of which can be traced back to the early Neolithic of the Struma Valley in Bulgaria, while others have not been found before. Also, they found the co-existence of several different communities of practice in single settlements, a pattern also encountered in several early Neolithic sites. Although the authors find a continuity of schemes of pottery production from the Balkans to Belgium and eastern France, they also see a diversification, and mixing of different traditions in the same settlements. The eastern Hungarian Alföld Linear Pottery stands out as a possible innovator area, as here we find a totally new technique. This seems to correspond well with the strongly related, later Bükk pottery which is also connected to more innovative communities. Gomart *et al.* studied the role of different clay building techniques at the transition from the Balkan Neolithic to the Central European LBK, and differentiated between local innovations and the role of newcomers to settlement communities.

At the workshop, Attila Kreiter provided insights into several examples of a co-existence of stylistic groups, which are traditionally viewed as characterizing distinct 'archaeological cultures', at individual settlements in Transdanubia. At Tolna-Mözs, Starčevo, Vinča and LBK pottery co-occurs, while at Szederkény, Starčevo, Vinča, Sopot and LBK pottery was found in houses resembling the LBK type. Together with the Gomart *et al.* paper, this suggests that southern and eastern Hungary should be seen as a melting pot of differential stylistic and technological traditions during the formation of the Central European early Neolithic (the LBK) in the second half of the 6th millennium BCE.

An important contribution to the workshop was provided by Valentine Roux, who discussed the question of what social structure favours the adoption of new techniques. She used a case study of innovations in ceremonial objects in 5th millennium BCE Levant, in relation to social structure and the social composition of communities, exploring the question of which kinds of network structures would favour innovation and its adaptation (see also Roux *et al.* 2017; Roux *et al.* 2018).

The overall topic of the broader social factors at work in the innovation process was also examined by Massimo Vidale, albeit from a very different angle. He explored the prehistory of the potter's wheel and argued for its Chalcolithic origin in the Middle East. He used the concept of *latent knowledge*, how several elements of technological skill and expertise might be available and combined in different ways over longer periods, before they are fused together into a new innovative technology. He revisited the traditional ideas of cognitive links between different sources of rotatory motion and the treatment of clay, which were present since the Neolithic period. Szabolcs Czifra *et al.* traced the introduction of the potter's wheel into the Carpathian Basin during the Iron Age. They could draw on new archaeometric investigations from their working area, and demonstrate that the adaptation of this innovation was connected to complex processes, involving contemporaneity of diverse techniques and variants of the same principles.

Using the example of the talc-faïence complex in the context of the Indus culture in Pakistan, Heather Miller discussed the concept of innovation as a process involving different practices, like invention, adoption, and rejection, and how these are differently connected to the producer and consumer side of production.

Igor Manzura discussed the significance of technological innovations in flint tools at the interface between the Balkans and the eastern European steppe, using as case studies assemblages from Orlovka-Kartal in Ukraine and Cealic in the Republic of Moldova. Maria Ivanova made the point that specific technological innovations of farming tools – sickles – enabled the expansion of farming from the Near East to different ecological regions. While Near Eastern Epi-Palaeolithic and Pre-Pottery Neolithic A sickle blades are straight and simple, during the Pre-Pottery Neolithic B and the establishment of farming, more complex, but also more efficient forms were invented (*e.g.* curved shafts, obliquely inserted blades). While such more complex and more efficient tools are common in western European Neolithic, in Central Europe there seems to have been a return to simpler, less efficient forms. She explained this divide by climatically induced strategy differences. In regions in which the climatic and environmental setting only allows for low production levels, simple artefacts with lower efficiency, which are easier to manufacture and replace, are more appropriate. In turn, regions allowing for higher production rates would favour the use of more elaborated toolkits. She also made the same argument for quern-stones in different regions of Europe.

Berit Valentin Eriksen discussed the aesthetic dimension of technological change, using the case study of the Beuronian flint tools, where, she argued, heat treatment of flint tools was regularly applied to gain the specific rose colour.

Overall, the workshop showed a wide spectrum of approaches to explaining technological innovations and their adaptation. Ecological factors (Ivanova, Manzura) and demography (Hofmann) were represented, while more emphasis was put on exploring the social structure and the organisation of production as a main factor enabling or hindering innovation (Roux, Hofmann, Gomart *et al.*, Miller). This was accompanied by agent-centred approaches, where the actions and possibilities of artisans were at the centre of analysis (Arnold, Larsson, Botwid). Here, also the material basis for production, the properties of raw materials (Eriksen, Arnold, Botwid) and the availability of latent knowledge of technological elements, which can be recombined (Vidale, Botwid), were discussed. Another group of papers came from a culture-historical tradition, which focussed on the issue of innovation transmission from one community to the other in terms of transregional networks and human mobility (Kreiter et al., Gomart *et al.*, Kadrow, Rauba-Bukowska and Czekaj-Zastawny, Czifra *et al.*). Vuković, Vitezović and Spataro used the perspective of technological change to – at least partly – deconstruct the culture-historical version of prehistory, by identifying technological innovation as the main reason for what is traditionally spoken of as 'culture change' (*i.e.* the transition from early Neolithic Starčevo to late Neolithic Vinča 'cultures').

We view this breadth of approaches not as eclecticism, but rather believe that all these factors are actually valid and necessary perspectives if we want to explain technological innovation and its role in social reality. For example, the engagement with network structures being connected to different susceptibility to innovation can potentially help to better understand how innovative technologies are transferred from the Bükk region to the southern Polish LBK. The perspective of the artisan's abilities and possibilities might inform the evaluation of social structure and population densities as conditioning innovation rates, as will an evaluation of the ecological and environmental constraints as favouring or hindering factors.

Most of the workshop presentations are published for the first time in this volume. We hope that their joint publication can help to create synergy between the different, yet compatible perspectives proposed.

## References


Bordes, F. 1971. Physical evolution and technological evolution in man: a parallelism. *World Archaeology. Technological Innovations* 3 (1), 1-5.

Bruno, P., Caselli, M., Curri, M.L., Genga, A., Striccoli, R., Traini, A. 2000. Chemical characterisation of ancient pottery from south of Italy by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES): Statistical multivariate analysis of data. *Analytica Chimica Acta* 410, 193-202.

Buckley, M., Collins, M., Thomas-Oates, J., Wilson, J.C. 2009. Species identification by analysis of bone collagen using matrix-assisted laser desorption/ionisation time-of-flight mass spectrometry. *Rapid Communications in Mass Spectrometry* 23 (23), 3843-3854.

Collis, J.R. 1971. Functional and theoretical interpretations of British coinage. *World Archaeology Technological Innovations* 3 (1), 71-84.

Courniquet, C. 2011. Frameworks of practice and the circulation of Knowledge among the potters of Arewa (Niger). *Cahiers d'études africaines* 2011/1 (No 201), 87-114.

Dayton, J.E. 1971. The problem of tin in the Ancient World. *World Archaeology Technological Innovations* 3 (1), 49-70.

Foster, G.M. 1962. Traditional cultures: and the impact of technological change. New York & Evanston: Harper & Row.

Giddens, A 1979. Central problems in social theory: action, structure and contradiction in social analysis. Berkeley: University of California Press.

Gosden, C. 2006. Material culture and long-term change, in: Tilley, C., Keane, W., Küchler, S., Rowlands, M., Spyer, P. (eds), *Handbook of material culture.* London: Sage Publications, 42-42.

Gosselain, O. 2000. Materializing identities: an African perspective. *Journal of Archaeological Method and Theory* 7: 187-217.

Historic England 2017. *Organic Residue Analysis and Archaeology Guidance for Good Practice*, Historic England.

Larsson, Å.M. 2009. Breaking and making bodies and pots: material and ritual practices in Sweden in the third millennium BC, Aun 40. [Doctoral Thesis], (Uppsala 2009).

Lechman, E. 2015. *The 'technological take-off' and the 'critical mass'. A trial conceptualization*. Gdańsk University of Technology. Working Paper Series A (Economics, Management, Statistics) 1(2015, 26). http://ssrn.com/abstract=2517019

Mee, C. and Renard, J. (eds) 2007. *Cooking Up the Past. Food and Culinary Practices in the Neolithic and Bronze Age*. Oxford: Oxbow Books.

Nicklin, K. 1971. Stability and innovation in pottery manufacture. *World Archaeology Technological Innovations* 3 (1), 13-48.

Peltenburg, E. 1971. Some early developments of vitreous materials. *World Archaeology Technological Innovations* 3 (1), 6-12.

Rice, P.M. 1987. *Pottery Analysis. A Sourcebook*. Chicago and London: The University of Chicago Press.

Roux, V., Bril, B., Cauliez, J., Goujon, A.-L., Lara, C., Manen, C, de Saulieu, G. and Zangato, E. 2017. Persisting technological boundaries: Social interactions, cognitive correlations and polarization, *Journal of Anthropological Archaeology* 48, 2017, 320-335.

Roux, V., Bril, B., Karasik, A. 2018. Weak ties and expertise: crossing technological boundaries, *Journal of Archaeological Method and Theory* 25 H. 4, 2018, 1024-1050.

Roffet-Salque, M., Dunne, J., Altoft, D.T., Casanova, E., Cramp, L.J.E., Smyth, J., Whelton, H.L., Evershed, R.P. 2017. From the inside out: Upscaling organic residue analyses of archaeological ceramics, in: Spataro, M., Tomber, R. (eds.), *Contextualising science: advances in ceramic production, use and function.* Special issue of *Journal of Archaeological Science: Reports* 16, 627-640.

Sanchez G.H. 2012. *Ceramics and the Spanish Conquest. Response and continuity of indigenous pottery technology in Central Mexico*. Leiden and Boston: Brill.

Schiffer, M.B., Skibo, J.M. 1987. Theory and experiment in the study of technological change source. *Current Anthropology*, 28 (5), 595-622.

Spataro, M. 2018. Origin of specialization: the ceramic chaîne opératoire and technological take-off at Vinča-Belo Brdo, Serbia. *Oxford Journal of Archaeology* 37(3), 247-265.

Spataro, M., Mommsen, H., Villing, A. 2018. Making pottery in the Nile Delta: ceramic provenance and technology at Naukratis, 6th-3rd centuries BC. *Archaeological and Anthropological Sciences*. https://doi.org/10.1007/s12520-017-0584-4

Stark, M. T., Longacre, W. A. 1993. Kalinga ceramics and new technologies: social and cultural contexts of ceramic change, in Kingery, W. D. (ed.), *The Social and Cultural Contexts of New Ceramic Technologies.* Westerville: The American Ceramic Society, 1-32.

Štubňa, I., Trník, A., Podoba, R., Sokolář, R., Bačík, P. 2012. Elastic properties of waste calcite-clay ceramics during firing. *Journal of the Ceramic Society of Japan* 120(9), 351-354.

Tasić, N. N., Marić, M., Bronk Ramsey, C., Kromer, B., Barclay, A., Bayliss, A., Beavan, N., Gaydarska, B., Whittle, A. 2015. Vinča-Belo Brdo, Serbia: the times of a tell. *Germania* 93, 1-75.

Tite, M.S., Maniatis. Y. 1975. Examination of ancient pottery using scanning electron microscope. *Nature* 257(5222), 122-123.

Vieugué J. 2014. Use-wear analysis of prehistoric pottery: methodological contributions from the study of the earliest ceramic vessels in Bulgaria (6100-5500 BC). *Journal of Archaeological Science* 41, 622-630.

Villing, A., Spataro, M. 2015. Investigating ceramics, cuisine and culture – past, present and future, in: Spataro, M., Villing, A. (eds.), *Ceramics, Cuisine and Culture: the Archaeology and Science of Kitchen Pottery in the Ancient Mediterranean World.* Oxford: Oxbow, 1-25.

Vuković, J. B. 2010. Neolithic fine pottery: properties, performance and function. *Journal of the Serbian Archaeological Society* 16, 7-23.

Vuković, J. 2017. Erasing boundaries or changing identities? The transition from Early/Middle to Late Neolithic, new evidence from Southern Serbia, in: Gori, M. and Ivanova, M. (eds.), *Balkan dialogues: Negotiating Identity between Prehistory and the Present*. London: Routledge, 240-253.

Whittle, A., Bayliss, A., Barclay, A., Gaydarska, B., Bánffy, E., Borić, D., Drașovean, F., Jakucs, J., Marić, M., Orton, D., Pantović, I., Schier, W., Tasić, N., Vander Linden, M. 2016. A Vinča Potscape: formal chronological models for the use and development of Vinča ceramics in South-East Europe. *Documenta Praehistorica* XLIII, 1-60.

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# Understanding the acceptance of innovative technical skills across time. Ethnographic and theoretical insights from Latin America

*Dean E. Arnold*

## Abstract

Using a perspective of more than forty years of study and reflection about pottery production and its changes in Ticul, Yucatán, México, this paper presents insights helpful in understanding the acceptance and rejection of innovations in the past. Using theoretical perspectives such as engagement theory, the chaîne opératoire, feedback, and technological choice, it will show some important reasons why some innovations are accepted, and others are not, and how that acceptance/rejection relates to larger issues of the engagement of the potter with the agency of the constraints of raw materials, the fabrication technology and the motor and postural patterns in light of learning in a household context. It is argued that the acceptance of innovative technological skills needs to be understood within a larger context of diverse sources of agency, the social reproduction of how skills are transmitted, and how these skills affect this reproduction with the opportunities and constraints of fabrication technologies given the physical properties of the local clay.

*Keywords: pottery, forming techniques, innovations, wheel, turntable, moulding*

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## Introduction

What are those factors that lead to the adoption of a technological innovation, and what are its effects upon a society? Why are some innovations adopted and others rejected, and how do they affect society and its social and technological evolution?

This paper lays out some explanations of how and why innovations were adopted or rejected using some examples from Ticul, Yucatán Mexico over roughly six decades from the work of Raymond Thompson (1958) in 1951 through my own research there from 1965 to 2008. Such a longitudinal study has allowed me to see the overall affect that these innovations have made in pottery production in ethnographic "deep time".[1]

## Some conceptual baselines

As I have stated in *Ceramic Theory and Cultural Process* (Arnold 1985), one place to look for cross-cultural commonalities between the present and the past is to look at the basic sequence of pottery production (now called the chaîne opératoire) and discover those patterns affected by the unique characteristics of ceramic raw materials, their distribution and access, the pottery production sequence, and their interaction with the environment before trying to discern those patterns unique to the group, society, or area under consideration.

The advantage of ethnographic study of pottery technology, for example, is that it is possible to understand those patterns that are the result of the agency of raw materials used and the effect of the overall chaîne opératoire that are isomorphic (but not identical) with ancient production and distinguish them from those aspects of the chaîne opératoire that result more from social agency. Consequently, careful analysis of the chaîne opératoire of the technology in a local environmental or social context can identify those features of production in a modern context that have relevance to the past and those that do not. Besides *Ceramic Theory and Cultural Process* (Arnold 1985), this approach was applied in Arnold (1975; 1993; 2008; 2018) which proposed specific analogies between the present and the past.[2]

## Engagement Theory

For those of us who have spent our entire professional careers studying potters and their craft, it is obvious that technology does not just consist of "things", such as pots and their associated artefacts, but also mental constructs, muscular and postural patterns, and the social, material, and environmental context of production. Pottery making, like all technology, further involves the engagement of the potter with the raw materials, the pottery making process (the chaîne opératoire), and, of course, the potters' choices.

This engagement of the potter with the material world can be usefully described in terms of engagement theory (Arnold 2018). As formulated by Colin Renfrew (2004), and Lambrous Malafouris (2004; 2013), engagement theory concerns the relationships between humans and the material world that stresses the knowledge-based nature of human action, and the reflexiveness that the material world exerts on the mind.[3] The potter comes to the pottery making process with some mental construct, but this construct is not just restricted to the brain, but extends

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1 This brief paper is a superficial distillation of many other publications, especially Arnold (1999; 2008; 2015; 2018), Arnold, *et al.* (2007), and Ralph and Arnold (1988). References point to information from those works and interested readers will find more elaborate and detailed information there.

2 My research methodology largely utilized participant observation. This approach has given me a deep knowledge of informants, their social context, and their craft. Relationships with my informants often resulted in informal, unstructured, spontaneous, and unsolicited oral histories that were often corroborated by my own experience, observation, and/or verified during another visit by either the same or different informants. On occasion, I used informal, but structured behavioural surveys that were not dependent upon informant's statements, but upon my observations of the potters' craft and the composition of the production units visited. In addition, using the potters' language of Yucatec Maya I was able to discover their deep knowledge of raw materials, and their perceptions of the resource environment and the basic chaîne opératoire of pottery making (Arnold 2018).

3 Malafouris's theory is much more complex than that which is described and applied here. Considering the lexical elaboration that Malafouris uses in his book, this presentation only engages that theory generally and superficially. I have applied his theory to my own field work experience elsewhere (Arnold 2018), but without the elaborate lexical semantics.

beyond it to the body and to the external world. For innovations, potters' engagement with them has reflexive effects on their adoption or non-adoption.

In this paper I focus largely on only one of the aspects of the chaîne opératoire of pottery production in Ticul: forming techniques. There are many other aspects of the chaîne opératoire of pottery technology in Ticul and their social and organizational context. A description of potters, their households, their organization and the variability of their choices of production, distribution, and consumption occupy hundreds of pages (such as Arnold 1999; 2008; 2015; 2018; Arnold *et al.* 2008). For this paper, however, I want to answer the question: What are some of the factors that influence potters to accept some innovations in forming technology and reject others?

## The social context of learning

Making pottery, like engaging in all technology, results from learning that takes place in a social context. Learning the skills and transmitting those skills across space and time requires sustained social contact. Furthermore, learning the semantic categories for obtaining and engaging raw materials and the technical skills necessary to turn those materials into a pot requires enough time in a social context for neophytes to learn them. The greater the skill necessary to make pottery, whether by imitation, observation and/or verbal instruction, the longer the amount of time necessary to become a viable potter.

Since 1965, pottery production in Ticul has undergone massive social and technological evolution including changes in acquiring raw materials, and in the modification of paste recipes, vessel shapes, decoration, and the distribution of pottery (see Arnold 2008). Nevertheless, the most remarkable aspect of this evolution is that despite this massive change, production units largely consisted of the same households and their descendants[4] that have perpetuated and sustained the craft generation after generation. The most frequent category of potters in production units during this period were members of the nuclear family, with no significant change in the trend lines of their frequency over time (Arnold 2008, 38-91; 2012; 2015, 57-190).

As a consequence of the embeddedness of pottery production in the household, I found that the transmission of pottery production parallel those same processes that perpetuate the household: procreation, the inheritance of learning space (that is, the house lot) and pottery making equipment (such as the kiln and objects for forming), and post-nuptial residence behaviours that bring a spouse (usually, but not always, a woman) into the household. Inheritance of household land may bring with it affinal or collateral relatives such as widows and single and abandoned women (with children) already in the household that may also serve as mentors for others to learn the craft. Unlike the processes of household perpetuation, however, learning to be a potter does not strictly follow these behavioural patterns because the number of potters that continue the craft through time is always smaller than the number of potters in the household. Rather, the household merely provides a pool of potential learners. Not all relatives within this pool choose to learn and make pottery and a variety of mechanisms select for or against becoming a potter in adulthood. For example, the poor and women who have no other means of support (such as widows and single women with children) sometimes turn to making pottery as adults to support themselves, and this behaviour selects for the ongoing practice of the craft whereas education tends to select against it (Arnold 2008, 31-91; 2015, 57-190).

Learning the knowledge and skills to make pottery are most effectively learned during childhood while muscles and motor habit patterns are developing (Arnold 2008; 2015; Hayden and Cannon 1984, 328). Children's residence in their parents'

4 Ticul potters were largely clustered in eleven extended families (Arnold 2015).

household is long enough for them to learn all that is necessary to make pots, and the indigenous semantic categories and muscular patterns can be reinforced during the years before adulthood. If children begin learning the craft at a young age, they will know how to make pots by the age of ten or eleven. Adult learners that reside in the household because of post-nuptial residence on the other hand tend to learn less than children who learned the craft growing up in a pottery making household.

Learning in a household context is important for other reasons. Skilled potters can support learners economically when economic returns from making their pots may be insufficient. Learning the craft as a child is also efficient because making pottery does not compete with activities for subsistence as it does when adults learn the craft. On the other hand, having children learn to make pottery creates risks of damaged and poorly-made vessels, but children reside in a household for reasons other than economic ones, and damaged pottery can be tolerated because the long-term goal of making pots outweighs short-term losses (Arnold 2008, 40-65).[5]

## Customary muscular patterns

Besides being socially-embedded and acquired through learning, technology also consists of skills that are embodied as customary muscular patterns that come from repeated working positions (Arnold 1985, 147-150; 2008, 236-237, 240-242, 244-245). These patterns are culturally-determined and not universal. They are social in that they are learned from others, are reinforced by furniture and the lack thereof, and are consistent across different activities in a culture (Spier 1967; Arnold 1985, 147-151).

Customary muscular patterns consist of at least two different types: postural patterns and the syntax of muscular patterns (called motor habits) that are principally involved with forming a vessel. In Ticul, postural patterns consist of the muscle patterns associated with sitting on a low stool, on the floor and or squatting to mix the paste and form the pottery. These positions are consistent with postural patterns used in other activities in Ticul (Arnold 2018, 123-126, 128, 130-137). Because the hearth is on the ground, cooking and tending the fire are done in a squatting position. Further, relaxing, cutting pond fronds or other activities are all accomplished by using the same squatting position or by sitting on a low stool (see Arnold 2018, 136-137). This position is also used for making pottery (Figs. 1-3, 5, 6, and 7). Indeed, this working position has persisted from 1951 (the date of Raymond Thompson's (1958) observations) to 2008 even with massive social and technological change. It is probably the most conservative aspect of pottery production. Second, sequences of muscle use have created a habitual syntax of behaviours that are largely unconscious. These sequences (part of the chaîne opératoire) consist of behavioural strategies for preparing raw materials, mixing them to make the paste, using the paste to construct a vessel, and firing it to forever fix its shape (Arnold 2018, 79-197).

Sometimes these positional and motor patterns are referred to as 'muscle memory', but, muscles don't remember. Rather habitually patterned positions and motor habits are the results of the syntax of synapses firing in the brain.[6] This motor learning involves the increased production of myelin, a substance that surrounds and insulates axions in the central and peripheral nervous system. The increased production of myelin increases the speed of electrical communication among neurons in

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5 This summary is a very superficial treatment of the social context and composition of the population of potters in Ticul and much more detail of the population of potters, their households, the organization of production, and its changes through time are described elsewhere (Arnold 2008, 31-91; 2015, 57-241).

6 Lindholm *et al.* (2016) also cast doubt on the notion of muscle memory as a result of muscle training experiments: "We found no coherent evidence of a skeletal muscle transcriptome memory, even though there were some data indicating a training-induced memory mechanism" (Lindholm *et al.* 2016, 40).

the brain, and hence its computational power (Long and Corfas 2014; McKenzie *et al.* 2014). One view of why motor learning is habitual is that newly generated myelin is laid down preferentially in circuits that are engaged during motor learning (Long and Corfas 2014; McKenzie *et al.* 2014). This increased myelin thus alters the internal neural structure of the brain, and results in habitual behaviours (Arnold 2018, 18).

How do muscular patterns relate to innovations and their adoption? Observation of the community of potters in Ticul over a period of 43 years has revealed that the repetition of working positions and muscle syntax are so well established during the process of learning to make pottery that both the ease of adoption, and the lack of adoption of an innovation, depends on the congruency of the muscular patterns required to use an innovation and those already present in the culture. There are, of course, many other factors that affect the adoption and rejection of innovation in Ticul, and these are detailed elsewhere (Arnold 1999; 2008; Arnold *et al.* 2008), but my research in Ticul also shows that an innovation that is congruent with existing working positions and patterns of muscle syntax will be more easily adopted than an innovation that requires new and different patterns.

Since learning a craft occurs in a social context, substantial social contact must occur between learners and skilled potters to learn how to use an innovation. If that contact is not present, then the innovation may not be adopted. Consequently, innovations that require learning new muscular patterns for forming pottery are likely accompanied by movements of a population of potters into a new area such as the movement of farmers into southern Europe (Gomart *et al.* 2017), and the movement of potters that introduced the potter's wheel into Ayia Irina, Kea, Greece (Gorogianni *et al.* 2016).

## Feedback

Making an object is not just unidirectional from the human mind to the object. Potters engage their craft not just with a mental template and muscular patterns, but also by using recursive information flow (feedback) that comes from the materials, the production process (the chaîne opératoire), the environment, and the social context to the maker. This information is tactile, visual, and aural, and flows from the potter's senses into his brain and influences his/her choices. Feedback, however, is not determinative, but rather, potters monitor and evaluate this information to ensure their success in making a pot (Arnold 2000; 2018, 18-23) and make decisions about their interaction with the raw materials, the paste, and the emerging vessel. Feedback simply recognizes that the relationship between materials and humans is not unidirectional. Another way of saying this is that pottery is also the product of material agency as well as the human agency (Malafouris 2013).[7]

This point was also made by Ingold (2013) and was one of my main points in a paper in *Current Anthropology* (Arnold 1975) and in a final comment responding to criticism of that paper that led to the writing of *Ceramic Theory and Cultural Process* (Arnold 1985). The materials, the production process (the universal chaîne opératoire), and the environment exert some agency in artefact production in a way that affects choices (Arnold 2000; 2015, 24-26; 2018). As I pointed out many

7 Feedback is also important in creating chipped stone tools. The knapper does not just proceed with a set of culturally-determined patterns of choices with any stone. First, the initial choice of the appropriate stone is critical because not all stone is useful for making such tools, and the knapper must engage the stone visually and behaviourally with appropriate feedback from its physical properties. Second, if experimental flint knapping is any guide, the knapper receives visual feedback from the chipping process, choosing where to strike the next blow based upon the consequences of the previous blow.

years ago, this agency comes in the form of feedback that influences choices, but does not determine[8] them (Arnold 1975, 201; 1985, 18).

So, to successfully engage the process of making a vessel, the potter must know how to deal with the sensory feedback that comes from the raw materials and the chaîne opératoire of making a vessel (Arnold 2018). This feedback is critical for the potters' engagement in the process and consists of knowing how to choose a usable clay by engaging its physical characteristics. All clays are not alike, and contrary to what some believe, they have different properties and performance characteristics (see Shepard 1965, 374-377; Rice 1987, 5-24, 43-50). The clays around Ticul, for example, have different properties (Arnold 2018, 79-88), and forming a vessel must take these properties into account if the potter wants to make, dry, and fire a vessel successfully. The potter learns these characteristics experientially by engaging the raw material properties while preparing the paste and forming and firing a vessel. In Ticul, for example, the potter receives visual and tactile feedback from thinning the vessel wall, and from knowing how long to dry a portion of a vessel before a new stage is added so that the next stage will stick to the section below it will not collapse under its weight, and the junction between the stages will not separate during drying and firing.

How does feedback relate to the adoption of an innovation? If using a new forming technique, for example, requires the use of infrequently used muscles, potters may not adopt it at all. If they do, they will get tired more easily, and may reject the innovation. Similarly, if potters move to a new area, or for some reason, their local raw material sources become exhausted, the feedback from the physical characteristics from the new clay may require changes in paste recipes with the addition of more or less temper, and/or changes in vessel shapes that can be accommodated by the potters' extant forming technology. In Ticul, at least, any forming technology cannot be used to make any vessel (see Arnold 2008, 276-277). Feedback from the consumers also affects the production of shapes and styles. For an innovative object to be accepted by a population, the producer must have feedback from that population in the form of demand for that object (see Arnold 2008).

## Technological choice

That humans make choices is obvious and is a fundamental characteristic of human ontology in Western thought, particularly in moral and religious philosophy. Choices are also multi-dimensional and multi-layered with multiple components; no choice is made for a single reason alone, and sometimes sub-optimal choices may be made in the context of competing choices because of economic necessity (such as firing in inclement weather to provide returns for their families; Arnold 2015, 243-276; 2018, 18-26).

Adherents of the technological choice approach to pottery want to separate those non-functional choices (based upon stylistic criteria) from those that are not functional but those not based upon the physical constraints of the materials and/or the forming technology (Lemonnier 1993; Loney 2000; van der Leeuw 1993). Although the notion of technological choice being non-functional fits the old distinction of "style" vs "function" in archaeology, there is an epistemological problem in knowing whether an ancient choice is non-functional without knowing what the functional choices were.

8 In my 1985 book, acknowledging that potters (and indeed all humans) make choices was so obvious to me that I thought that it scarcely needed to be mentioned. In retrospect, however, describing feedback loops as mutually causal mechanisms (which they are) in that work may seem to diminish human agency to some, although it was not intended to do so. It is also true, however, that the book was meant to counter the overemphasis on human agency in the production of pottery that characterizes much of the archaeological interpretation of ceramics.

Speaking as an ethnographer, I misled myself by thinking that some potters' choices are non-functional only to learn later that their choices had many components including a functional component. Choices of clay in Ticul, for example, seemed to have been based on tradition, but that tradition was rooted in a choice made 1000 years ago when the potters realized that the best quality of clay to make pottery came from Hacienda Yo' K'at (Arnold 2018, 79-88, 104-106). Similarly, choices of designs and design structure on water carrying vessels in Quinua, Peru may seem to be stylistic, but the design structure and symmetry patterns were based upon deep mental structures that reflected community organization rooted in the cognitive perceptions of the ecological zonation of the community, and the organization of its irrigation system conditioned by the hydrography of the water flow (Arnold 1983; Mitchell 1976). The organization of the community and its political sub-sections were defined by the structure of the irrigation system and were reified in the structure of the design.

Choices thus may have both functional and non-functional components and distinguishing between them may not be productive. The choices used in forming a pot, for example, are not totally based upon non-technical (social) criteria, nor are they totally technically-based. Potters' knowledge of choices of forming techniques and choices of vessel shapes are acquired socially and provide the general categories for behaviour, but they are shaped by the limitation of the physical properties of clays (such as working range and plastic limits) based upon their mineralogy and the forming technology used (Rice 1987, 61; see Arnold 2018, 80-85). Further, potters learn about raw materials and their constraints socially, but their choices are reinforced by the feedback of visual and tactile experience with those raw materials that might require experimentation and modification (Arnold 1993, 80; 2018, 79-107).

Consequently, social choices (and culture) are not simply imprinted on the raw clay, but are rather the product of the potters' bodily engagement with the clay based upon feedback that involves the interaction of the potter, his/her training and tradition, the characteristics of the raw material, the forming technology, the environment, and the emerging pottery product.[9] The mineralogy of the clays used, the forming technique, and the vessel shape produced are all interdependent, and the potter's choices in making vessels are not totally free, nor are they predetermined. Rather, they are influenced by tradition, by the performance characteristics of the clay and other raw materials (Arnold 1971; 2008, 153-182, 204-214; 2018, 79-197), by the feedback resulting from the interaction of these factors during forming, and from the anticipated demand for a vessel.

## The traditional forming technique

Forming technology in Ticul has undergone great changes between 1965 and 1997. One technique is more traditional while the remainder consist of four innovations that have been introduced since the late 1930s (Arnold 1999; 2008, 229-279). Of all of these innovations, Ticul potters have adopted only two of them.

The baseline of comparison for these innovations is the traditional technique of using modified coiling on a turntable (Fig. 1; see also Arnold 2008, 234; 2018, 139, 141; Thompson 1958, 76-81). The turntable consists of a removable platform that rotates around a nail embedded in a thick piece of hard wood. To facilitate movement, a circular metal disk is placed on top of the wood base, and the potter oils the disk to reduce friction. When a vessel (or a portion of it) needs to dry, the potter simply removes the platform with the vessel on it and replaces it with

9 This approach and perspective are extensively developed in *Maya Potters'' Indigenous Knowledge: Cognition, Engagement, and Practice* (Arnold 2018).

another platform thus not risking damage to the vessel (or a portion of it) by lifting or cutting it from the turntable before it is sufficiently dry.

As with other forming techniques, modified coiling on the turntable requires a set of specific motor habit patterns. Learning these patterns involves strengthening the appropriate muscles that are used repeatedly. The potter begins by making a pancake of clay and placing it on the turntable. Then, he takes one handful of paste, rolls it between his hands to form a sausage shape (approximately 5 cm X 25 cm) and then flattens it with the hands. The flattened coil is pushed onto the pancake against the palm of one hand placed inside of what will become the vessel wall. Often this motion moves the turntable, but potters may also move it with their toe or foot to free both hands to form the vessel (Fig. 1). The newly attached coil is then drawn up and thinned with a gourd scraper using the palm of one hand inside the vessel to support the vessel wall (Thompson 1958, 75, 81-82). Additional coils are prepared, attached, and drawn up in a similar way. When the vessel is complete, the potter forms the rim and smooths the vessel with a piece of leather (Thompson 1958, 86) using the foot, or the other hand, to move the turntable.

The technique of drawing up and thinning a slab coil is made possible by a random mixed-layered clay of kaolinite and the highly plastic clay mineral montmorillonite (smectite) (Arnold 2018, 80-88). This clay is less plastic than the more common clay in the community that contains no other clay mineral besides smectite. This more common clay is inadequate to form any vessel without sagging, cracking, or breaking during drying and firing. Even the plasticity of the mixed layered clay, however, places constraints on the shape and size of a vessel because only the smallest vessels can be made in one continuous sequence without the vessel sagging and collapsing. Consequently, potters fabricate large vessels in more than one stage; each stage must dry sufficiently to support the weight of the next stage (Arnold 2008, 236; 2018, 136). Usually not more than one or two thick coils are used for each stage because of the plasticity of the clay. When the thinned coil reaches the appropriate height, the potter allows it to dry partially before adding the next coil.

The potter's choices of the stages and their size may seem to be culturally determined, but, in reality, the height of each stage (usually about 15-20 cm) is the greatest height that the potter can form at one time without it sagging because of the plasticity of the clay. Using modified (slab) coiling and building vessels in stages is thus potters' adjustment to both the benefits and the constraints of a highly plastic paste, and the modified coiling technique (Arnold 2018, 132-133).

## Innovative forming techniques

Two innovations, the potters' wheel and vertical-half moulding were introduced in the 1930s and 1940s by a government-sponsored program to help potters improve their craft. A third innovation was a modification of the traditional turntable and was introduced by the potters themselves in the late 1970s. Finally, a fourth innovation, slip casting, was used in a local ceramics factory, and was adopted by a potter who formerly worked there.

## The potters' wheel

The wheel uses rotational kinetic energy of a rotating platform propelled by a flywheel below it. The motion of the flywheel is transferred by a shaft to a platform above it upon which potter's hands shape the mass of rapidly rotating clay (Fig. 2; Rice 1987, 134).

In the late 1930s, the government wanted to refine (*purificar*) Ticul pottery in order to improve the quality and efficiency of production (Rendón 1947). So, it established a workshop near the municipal market, hired a potter from Oaxaca, and installed

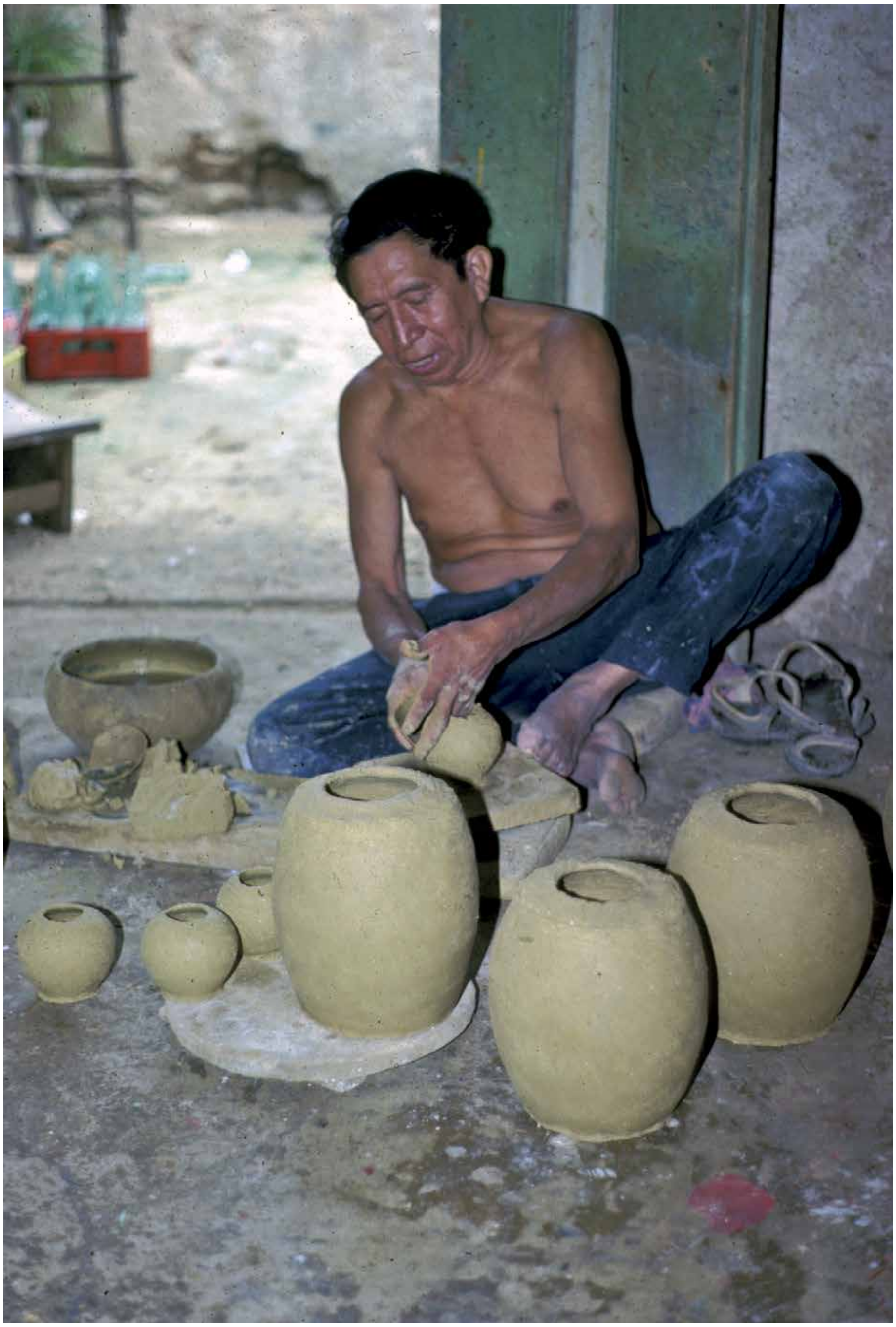

*Figure 1. A potter in Ticul, Yucatán, Mexico using the traditional turntable to form a pot in 1984. When the potter sits on the floor, he can use his foot and toes to move the turntable to free his hands to form the vessel.*

five wheels with the intent of introducing them into the community. Although the workshop existed for more than ten years, the Oaxaca potter only stayed about four to five years. Several local individuals worked with him, but only one purchased a wheel and used it to make pottery. It is unlikely, however, that he used rotational kinetic energy of the wheel to shape a lump of clay because in 1965, he was using the wheel simply as a platform upon which to make moulded vessels (Arnold *et al.* 2007).

One of the reasons that Ticul potters did not adopt the wheel was its cost. The wheel, they said, was too expensive (500 pesos) and they did not have the money to buy it. In the 1940s, potters reportedly earned only seventy-five centavos a day and only rarely did their daily income increase to one peso. Assuming a six-day work week and time off for religious holidays, the cost of a wheel required 160 percent of a potter's yearly income (300 days X 0.75 peso/day). Because potters required money for food and other necessities, they would find it difficult, if not impossible to accumulate enough cash to purchase a wheel.

The excessive cost of the wheel relative to wages at the time was corroborated by a conversation with a former president of the *Municipio* of Ticul in 1988. Potters, he said, did not want to participate in the workshop because they wanted to be paid every day. Given informant accounts that pottery making was a precarious way to make a living at that time, and that potters were retreating from the craft into swidden agriculture and wage labour, it is understandable why they wanted to be paid for their participation; learning a new forming technique without wages to support their families during the transition to making wheel-made pots was economically risky, if not disastrous. Potters thus did not have the time nor the capital to jeopardize their own livelihood by adopting an innovation without regular compensation in the interim (Arnold *et al.* 2007).

A second reason why Ticul potters did not adopt the wheel involved feedback from their engagement with it. Those that tried the wheel said that the Ticul paste was too thick, too coarse, and abraded the potters' hands because of the wheel's speed – a problem that was also noted in Temascalcingo in central Mexico (Papousek 1974, 1024). Consequently, the Oaxaca potter used ground rocks for temper. The machine used for crushing the rocks, however, came from Oaxaca and the Ticul potters could not understand why they should use such a machine to produce temper when they had their own crushed temper, and required no capital to produce it (Arnold 2008, 239; Arnold *et al.* 2007).

A third reason for the rejection of the wheel also involved feedback from the potters' engagement propelling it. Potters wear sandals and often make pottery in their bare feet so that they can move the turntable with their toes. Using their bare feet to propel the wheel, however, abraded and injured the feet. Using shoes or sandals to propel it, however, either limited their control or the leg and foot movement loosened their footwear and it flew off in the process.

A final reason for rejecting the wheel involved the feedback they experienced because of the incompatibility of the muscles used, the muscle syntax (motor habits), and the associated muscle strength required by the wheel compared to the traditional turntable (Tab. 1). The wheel required a totally different set of motor habits than the traditional technique of modified coiling. With the traditional technique, the potter sat on the floor or on a low stool with one or both legs drawn up toward the body, or with one or both legs outstretched (Fig. 1). The forming was done on a turntable with a mean height of 9.7 cm (N = 19) from the floor. The muscles utilized in this position are the hamstrings. Most of the muscle strength and coordination required to make a pot, however, involves the arms and hands, and the feet are used only occasionally for rotating the turntable. Using the wheel, on the other hand, required sitting on a bench next to the revolving platform that was eighty-seven centimetres above the floor. This position is crucial for the operation of the wheel because it leaves the legs extended with enough free space for a range of motion to propel the flywheel using the foot and the upper and lower leg. This pattern requires more strength and range of motion at the knee joint than modified coiling, and consistent use of the quadriceps muscles in the legs (Arnold *et al.*2007).

These muscular patterns were too different from those used for the traditional turntable for potters to learn without a lengthy apprenticeship. Even if someone did learn the new motor habits, the muscles required needed to be strengthened sufficiently to be able to use the wheel intensively. In order to use the wheel more than occasionally, it required concentrated effort, and persistent use.

*Figure 2. One of the wheels that the Mexican government tried to introduce to the potters of Ticul in the 1930s and 1940s. It was given to this potter in the 1980s, but he did not use rotational kinetic energy of the wheel to shape the pottery, but rather, as shown here, he used it as a turntable upon which to form his pots with the traditional method of modified coiling. Even using the wheel in this way was unsuccessful because he and his family tired more easily because the working position and motor habits required by this device that were different from those using the traditional turntable (see Table 1; compare Fig. 2 with Figs. 1 and 5). By the early 1990s, this potter had abandoned using this wheel and returned to the ball-bearing turntable that was introduced in the late 1970s.*

| | Traditional Turntable | Wheel |
|---|---|---|
| Muscle groups required | *Quadriceps* | Hamstrings |
| Individual muscles in group required | *Rectus femoris*<br>*Vastus medialis*<br>*Vastus intermedius*<br>*Vastus lateralis* | *Biceps femoris*<br>*Semimembranosus*<br>*Semitendinosus* |
| Other muscles probably required | Ankle plantar flexion, using the *gastrocnemius* and the *soleus* muscles | |

*Table 1. Muscle groups required for using the traditional turntable and the wheel (adapted from Arnold, et al. 2007, 70. Used with permission).*

## Vertical-half moulding

With this technique, a clay pancake is forced into each portion of a mould (Fig. 3). After a brief drying period, the moulds are joined, allowed to dry for a few minutes, and then, the completed vessel is removed (Brainerd 1958, 68; Foster 1948, 357; 1955, 6; 1967, 115).

This technique seems simple, but it actually consists of a total of fifteen distinct sequential behavioural steps because the potter must repeatedly pick up a mould, perform an activity, and then set it down (Tab. 2). By way of contrast, if a vessel is small and does not require multiple stages of fabrication, it can be formed and finished in one step using the turntable. With vertical-half moulding, production time does not just reflect the time of actually forming the vessel, but also includes the length of the combined segments of preparation, partial drying, and finishing (Arnold 1999; 2008, 248-251).

Step 1: Dust the first half of the mould with temper to keep the clay from sticking to the mould. (The clay minerals in the temper absorb water from the clay so that the vessel can be removed easily.)
Step 2: Remove a piece of clay from a large lump, roll it into a sausage shape, and flatten it into a pancake with a thickness of one-half centimetre in either of two ways:
(i) Place it on a piece of cloth on the floor, flatten it with the palm, and then peel the clay pancake from the cloth (large moulds)
(ii) Flatten it between the hands (small moulds)
Step 3: Press the flattened clay in the first half of the mould taking care that the clay is forced into all of the portions of the mould and has a consistent thickness. More clay may be added or subtracted, if necessary, where the moulds are joined.
Step 4: Set the mould and its contents aside to dry
Steps 5-8: Repeat steps 1 – 4 with the other portion of the mould.
Step 9: Combine the parts of the mould.
Step 10: Set aside the completed object in the mould to dry
Step 11: Remove the object from the mould
Step 12: Set the object aside to dry
Step 13: Place the mould in the sun to dry
Step 14: Obliterate the mould marks using a knife or gourd scraper
Step 15: Smooth the remaining portion of the mould marks with a hand dipped in water. (On circular vessels, the mould-marks may be smoothed and finished on the turntable.)

*Table 2. Principal steps in the behavioural chain (chaîne opératoire) for making mould-made vessels. Steps 1 and 2 and 5 and 6 may occur in reverse order, but except for this variation, the steps represent a fixed sequence or 'chain' of behaviours (adapted from Tab. 5.1 in Arnold, 1999, 62).*

This technique was also introduced in the 1940s by the government-sponsored workshop. Six men were involved in the new workshop, but only three spent enough time there to learn the technique and how to paint objects using oil-based paint. None of these men came from pottery making families, and none were potters. One had married into a family of potters and another had learned how to make figurines (such as birds) from a member of another extended family of potters, but he did not make traditional pottery (Arnold 2008, 245-248).

During the years between the 1940s and the late 1960s, two of these men were the principal agents for introducing the moulding and painting technologies to the community. By 1966, forty-three percent (12/28) of the production units had adopted the moulding technique. By 1997 and beyond, production using moulds had expanded greatly to encompass many more production units (Arnold 2008, 246).

The engagement of potters with a moulding technology also resulted in unanticipated feedback that limited its use. With a moulding technique, the clay must be plastic enough to be flattened, stretched, and forced into the mould without cracking, but not so plastic that the clay body will sag after removal from the mould (Louana Lackey, personal communication).

Even though the Ticul clay was plastic enough to be forced into a mould, potters cannot use moulds to make every vessel size and shape because shape and size are constrained by the highly plastic character of the Ticul clay. This limitation is a consequence of the presence of the highly plastic clay mineral montmorillonite

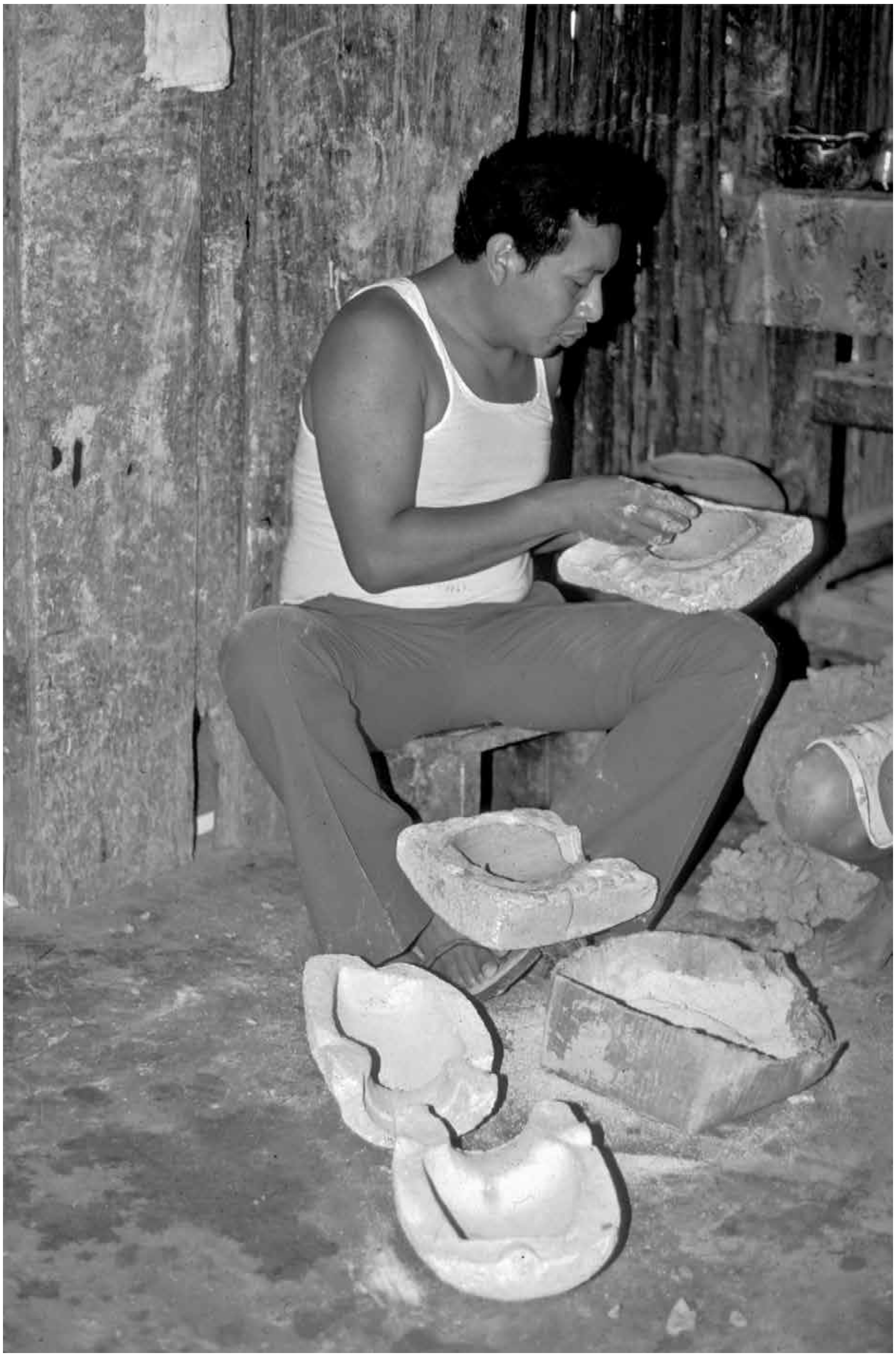

*Figure 3. A man forming a vessel using vertical half moulding that was introduced into Ticul in the 1940s. This man, however, was not a potter, but a university student home on vacation and was helping his uncle make pots. As a forming technique that requires a very low degree of skill, moulding can be used to draw unskilled family members into the craft to increase production (after Arnold 2008, 249, used with permission).*

(smectite) in the clay. Making large vessels exacerbated this problem because vessels more than 20 cm high and those with carinated, or sharp concave profiles usually sagged and collapsed after being combined with the other half of the mould. The only exceptions to this constraint are large coin banks that are totally enclosed because, like the strength of a sphere or an egg, the walls mutually support themselves in a way that is impossible with an open vessel. Consequently, except for enclosed coin banks, vessels with a height over 20 cm cannot be made using vertical-half moulding without sagging (Arnold 1999; 2008, 254-256).

## Why was the moulding technique adopted?

Ticul potters adopted vertical-half moulding for several reasons. First, they used it to make objects that could not be fabricated in any other way. Most of the mould-made objects produced between 1965 and 1970, for example, were figurines used as coin banks. Before moulding was adopted, these shapes could not be formed using modified coiling on the turntable and could only be made by the time-consuming technique of hand modelling (Arnold 2008, 247).

A second reason that moulding was adopted is that it required very little skill, many fewer muscular patterns, and much less muscular strength than the traditional technique of modified coiling. Further, moulding does not require long periods of learning. It is easy to learn, and almost anyone can produce a moulded object with little practice; it is so easy to learn that it is the first forming technique learned by children and by those who learn the craft as adults. Anyone who learns this technique can be economically productive in a relatively brief period of time (see Arnold 1999; 1985, 203-208).

Because so little skill is required for making mould-made vessels, unskilled individuals can be drawn into production quickly without going through the lengthier process of learning slab coiling on the turntable. Moulding thus was an ideal technique to increase economic returns for a household by involving unskilled relatives (such as children) in production (see Fig. 3), and it can easily supplement a potter's production during peak demand, temporarily increasing the amount of pottery produced (Arnold 1999).

The lack of elaborate motor habits required for moulding means that this technique requires no particular working position and can be easily integrated into existing work postures. Using a moulding technique, potters can sit, stand, or work in any number of positions, and it is compatible with the traditional working posture of sitting on a low stool, or on the floor. This flexibility of working position accounts, in part, for its adoption by Ticul potters and its popularity between 1965 and 1997 (Arnold 1999), and beyond to 2008.

A third reason for adopting the moulding technology is that the moulds for new, innovative shapes can be fabricated with minimum skill. Creating moulds requires more skill than making objects from them, but still requires fewer motor skills than modified coiling. To create a template for the mould, potters may model an object, or may purchase an object to use as a template. To create the mould, potters smear a paste over the template and then place plaster of Paris over each half of it taking care that the mould is thick enough (1.25-1.5 cm) so that it will not break easily. When the plaster is partially dry, one half is removed and laid out in the sun to dry. Then the template is removed so that the other half can dry (Arnold 1999).

If potters do not know how to make moulds or do not want to do so, they can often obtain them from others. In 1966, one of the men who was one of the first to learn the moulding technology, sold moulds to potters so that those who did not know how to make them could still use them to make pottery. Moulds also may be given away, borrowed from close relatives, and on one occasion, were copied surreptitiously by an employee in a large workshop, angering the owner. So, besides the low skill needed to produce mould made vessels, the ease at which potters can acquire moulds also explains the rapid adoption and dissemination of this technology (Arnold 1999).

A fourth reason that moulding was adopted is that it creates a uniform product. This uniformity is inherent in the technology, and given the low level of skill required, it is a superior technique for producing homogeneous (standardized) vessels than other techniques because uniformity comes from the use of the mould, not from the skill of the potter. Identical vessels can be made with the turntable, but doing so requires practice, skill, and a measuring device (Arnold 1999).

Homogeneity is particularly critical in figurine production because moulding can maintain the integrity of the image during repeated fabrication events. This 'iconographic integrity' may be the single characteristic that the potters desire most because modeling may produce too much variability and consumers may not recognize the image and will not want it (Arnold 1999).

Even though moulding has been used in Ticul since the 1940s, potters did not deliberately or consciously desire to make vessels uniform until after the development of the tourist market in the late 1970s. This technology thus pre-adapted potters for a changing market during the 1980s and beyond when they sold their unfinished pots to painting workshops. Vessels with elaborately painted designs on one or more fields required careful layout of the structure of the design. As a consequence, purchasers of unpainted vessels wanted standardized vessels to minimize the amount of time required to lay out the fields of design to paint multiple vessels (Arnold 1999).

Another consequence of adopting a moulding technique consists of the amount of space required to store the moulds. A different mould must be made for each size and shape produced. If shapes and sizes change (as demand dictates), then the number of moulds will increase; more moulds require more storage space. This change increases the footprint of production and exerts pressure on the available space. Consequently, the more variability and innovation that occur with shapes made with moulds, the greater the number of moulds required and the greater the need for more space for storing them (Arnold 1999; 2008, 253).

## The ball-bearing turntable

During the late 1970s, owners of larger production units adopted a new kind of turntable that mechanics had welded together from metal parts. The new device operated in the same way as the traditional turntable, but it turned with ball-bearings located either on top of, around, or below a stationary metal post upon which a movable platform of metal was attached. The metal post, however, was anchored in different ways: in cement placed in a gallon can (Fig. 4), on a large wooden block, or welded to a large piece of metal such as a sprocket gear or pulley (Ralph and Arnold 1988; Arnold 2008, 256).

This new device appeared to be an innovation from within Ticul, but its ultimate origin is unknown. In the late 1970s or early 1980s, one potter saw the new turntable in larger production units. He asked an automobile mechanic to make the device and then sold it to the potters in his extended family. By 1984, it had largely replaced the traditional turntable in fifty-four percent of the production units visited, and by 1997 (Arnold 2008, 256; Ralph and Arnold 1988), it had totally replaced the traditional turntable.

## Why was the ball-bearing turntable adopted?

Both its ball-bearing operation and its height above the floor provided significant sensory feedback for the adoption of this technique. First, this new turntable uses the same motor habits as the traditional turntable but is easier to use because it requires less muscle strength. Each time the potter used the traditional turntable, he oils the nail to make the turntable rotate more easily. By way of contrast, the ball-bearing turntable can be moved quickly and easily with the force of the hand and oil is needed only rarely. Unlike the traditional turntable, the foot is not required to turn the new device even when both hands are used to form the pot. The ball-bearing turntable thus speeds production by ease of use, and less use of oil (Arnold 2008, 256-260).

As a consequence, potters did not get as tired using the ball-bearing turntable as they did with the traditional turntable. One potter said that the new device

*Figure 4. Detail view of the ball bearing turntable created and welded together by a mechanic.*

speeds his work because it required less strength and is easier to use; others said that its operation is smoother, and allows more precision in forming, slipping and finishing (Arnold 2008, 256; Ralph and Arnold 1988).

The greater ease of using the ball-bearing turntable is verified by its long-term effect on the potter's muscles. Potters say that once they use the new device consistently, they cannot return to making pottery with the traditional turntable. This tactile feedback suggests that using the new turntable is easier because the muscles required for the traditional turntable are not being strengthened and tend to atrophy. As a result, the households that adopted the new ball-bearing device have abandoned the traditional turntable.

Second, the height of the working surface on the new turntable provides more flexibility of the working position and makes fabricating pottery easier. Because the new device is heavily anchored, the height of the working surface can be manipulated by placing blocks of cement or wood underneath it and can raise it as much as thirty-eight centimetres above the floor. The potter can thus minimize the amount of bending from the waist than was necessary for the traditional turntable with less stress on the spine and muscles in the back (Ralph and Arnold 2008, 261; compare Figs. 1 and 5, and Figs. 5 and 6).

## Slip casting

Between 1970 and 1984, a local businessman established a ceramics factory in Ticul. Unrelated to the traditional craft of pottery making in the community, the factory utilized an industrial-level technology.

I visited the factory in 1997 and discovered that production there involved a slip casting section for making white glazed porcelain and a mechanical extruder to produce earthenware tiles. The slip casting operation consisted of filling plaster moulds with liquified clay. The clay was pumped directly from the mixer through flexible tubes to fill moulds that were open at one end and held together with large elastic bands. Because the mould absorbs some of the water from the clay, the clay next to the mould hardens. Then, the moulds are up-turned and the remaining liquid is poured out and used again. Eventually, the mould is opened, and the object is removed. The mould marks are obliterated, and the vessel is smoothed, placed on a drying rack, and then dried, fired, glazed and fired again (Arnold 2008, 262-265).

The slip casting technique has all of the strengths and weaknesses of the moulding technique. Slip casting, however, reduces the time spent placing the clay in the moulds required by vertical half moulding used by household potters. But, just as drying time consumes much of the fabrication time with moulding, drying time is also the critical time-consuming factor with slip casting, and the factory has the same problem as household potters that use moulds. With both techniques, plaster moulds are necessary because the mould adsorbs water from the clay so that the vessel keeps its shape when it is removed from the mould. Drying empty moulds is thus critical for speeding the moulding process. Although the amount of handling required for moulding is reduced with slip casting, the major variable affecting production speed is the amount of time that the clay sits in the mould (Arnold 2008, 262-265).

Storing moulds for slip casting creates great pressure on production space just as it does in the smaller production units. In addition to storing some moulds on the factory floor, the owner built a large storeroom (approximately 50 m X 10 m) that contained hundreds, if not thousands, of moulds stacked two meters high (Arnold 2008, 262-265).

Making the moulds is probably the most skilled task in the factory, and skilled workers create moulds and then key them to fit together precisely. Some moulds have three or more parts and the skill of making them consists of knowing how many parts are necessary. Mould makers may use modelling clay to make a template, but they may also use plaster to make a template and then shape the template on a lathe to give it the proper shape. The finished template is then enclosed by a wooden box with two sides missing and the remainder of the box is built around the template. The void is then filled with plaster and after the plaster has hardened, the template is removed, and the mould is trimmed (Arnold 2008, 262-265).

A few Ticul potters have worked in the factory, but the factory has not significantly influenced local pottery production. One potter, however, used his experience there to develop a slip-casting technique in his own household (Fig. 7). He came from a family of potters, received a formal education, and then worked in the factory for eight years. Beginning in 1996, he quit his factory job, and used his newly acquired knowledge for making slip-cast vessels in his home (Fig. 7; Arnold 2008, 262-265). He believed that slip casting could produce vessels faster than regular moulding. With slip casting, he said, he could make thirty vessels every half hour with a sufficient

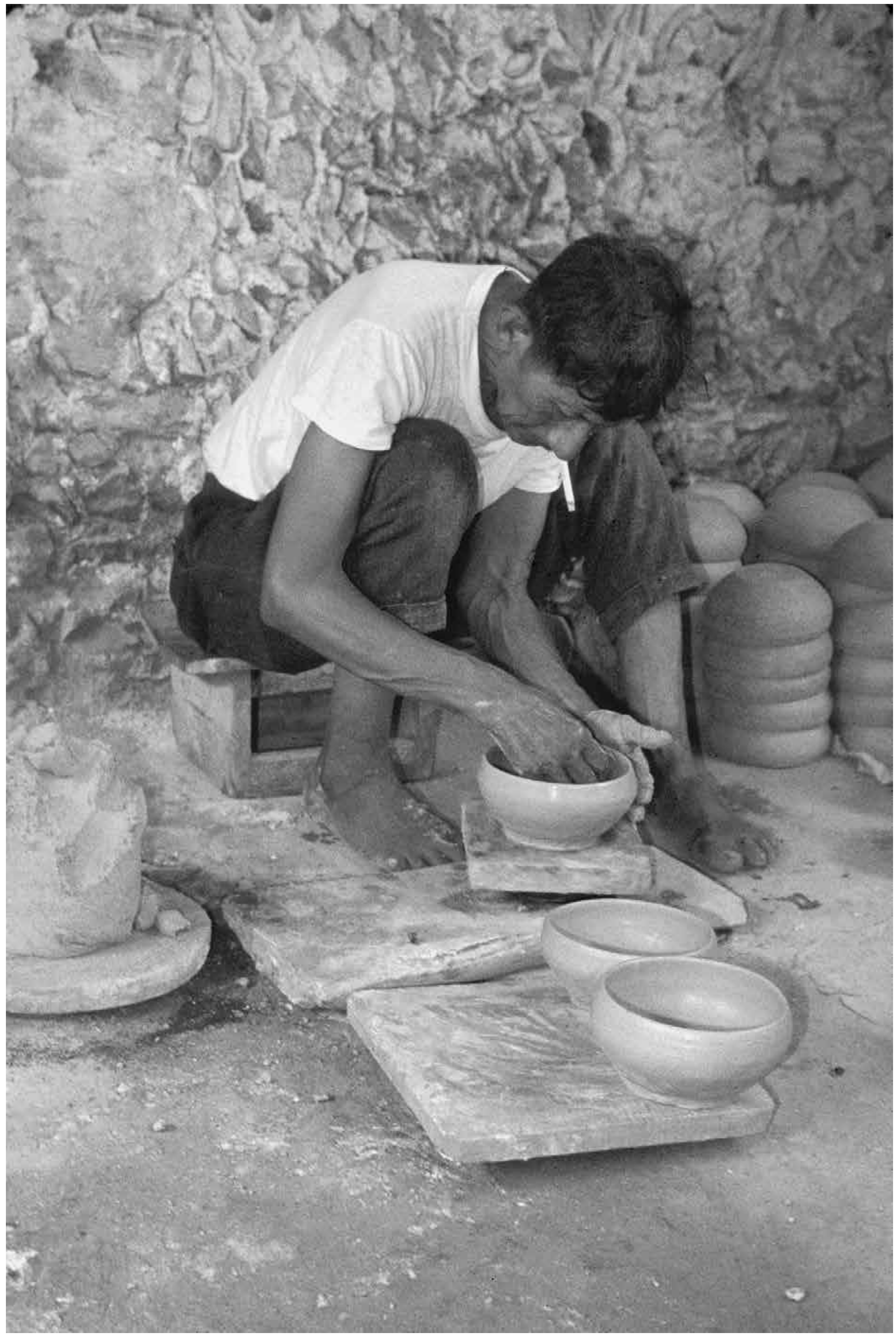

*Figure 5. Using the traditional turntable to make a small food bowl. Using the position of sitting on a stool (one of the traditional positions), the potter must bend deeply at the waist to make the vessel (after Arnold 2008, 233, used with permission).*

number of moulds whereas using regular moulding, he could only make fifteen in one and a half days. With fifty moulds for slip casting, he said, he could keep the fabrication process going without any interruption in production. Consequently, the critical factor for increased production with slip casting is the number of moulds available. Since the potter must buy plaster to make the moulds, the main obstacles to increasing his production and its efficiency are the lack of capital to buy the plaster Paris and the amount of space to store them (Arnold 2008, 262-265).

Another critical factor inhibiting the adoption of slip casting was developing a recipe for fine-grained liquid clay that would have the same properties as the commercial clay used at the factory. The potter that adopted this technology struggled with finding the proper combination of local materials to create a

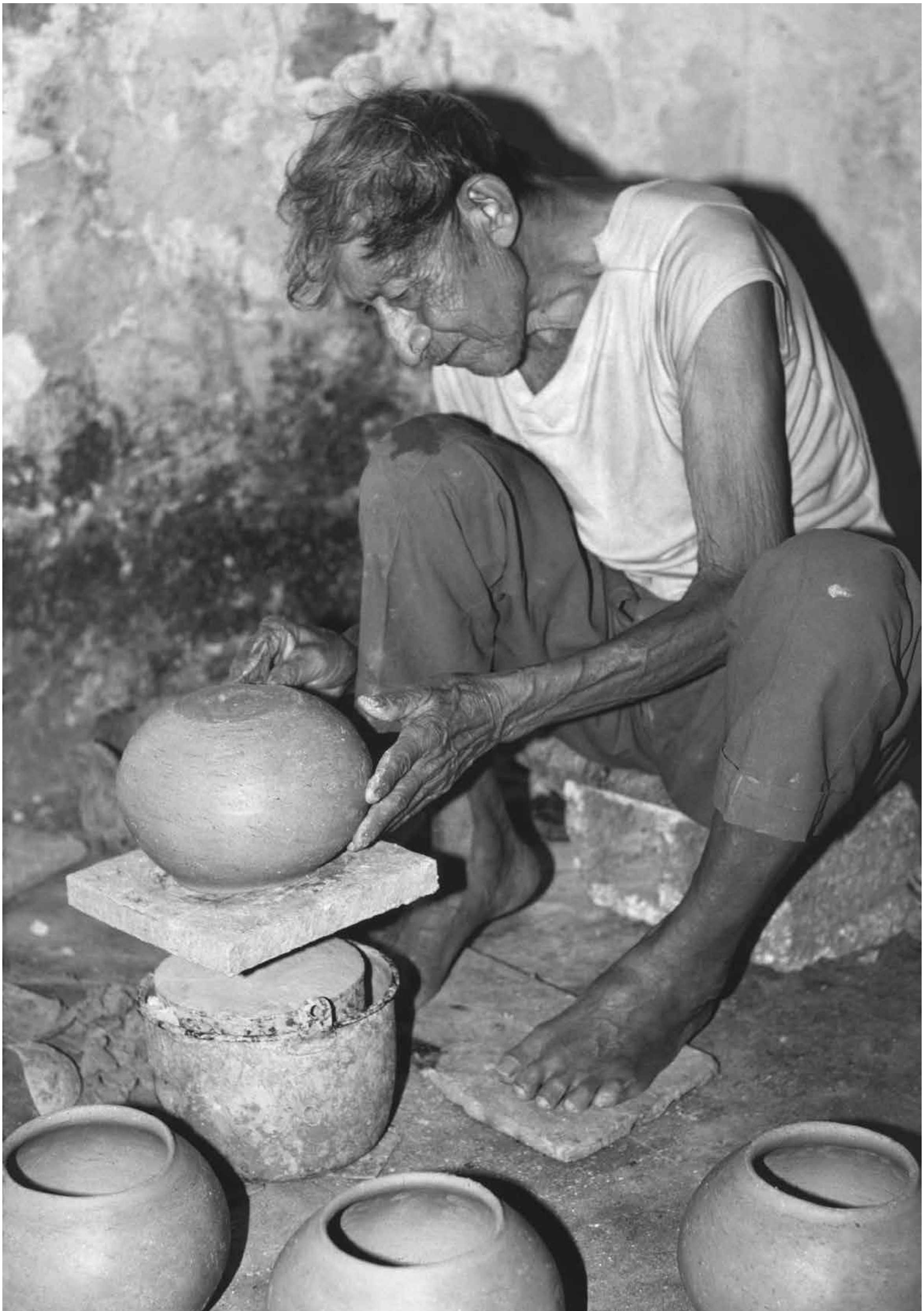

*Figure 6. The same potter in Figure 5 making a vessel using the same working position but using a ball-bearing turntable.*

liquid paste, and after much experimentation eventually succeeded in discovering a useful recipe. Other potters, however, did not adopt the practice, and during my 2008 visit, it appeared that his adoption was not very successful, unlike his brother who used vertical half moulding and the ball bearing turntable to establish a successful pottery making business.

## Conclusion

An examination of all of these innovative forming techniques reveals that they are not equal in utility and are adopted (or not adopted) for various reasons. Potters' acceptance of some techniques (and rejection of others) reveals complex interactions of the engagement with them and with social, economic and technological factors.

The government's attempt to introduce the potter's wheel as an improvement to pottery production in Ticul ultimately failed. The slip casting technique was borrowed from the local factory by a former employee, but it is unlikely that other potters will adopt the technique because the raw materials and the fabrication technology are so different from those that already exist in Ticul and require different knowledge and skill. Furthermore, the moulds and clay require much more capital investment than most potters possess. The enhancement of the traditional turntable with a ball-bearing device was an innovation that developed in the late 1970s or early 1980s and was adopted by all production units by 1997.

What factors then led to the adoption and rejection of innovative fabrication techniques? In general, those techniques that are most compatible with the existing motor habits, work positions, and low or limited capital were adopted. Further, adoption of these new techniques occurred via social relationships. For example, even though the ball-bearing turntable was expensive, it was adopted by some large production units and then by one extended family because one potter in this family was convinced of its efficacy and encouraged his relatives to adopt it by using the trust of his kin ties. It was eventually adopted by all the potters in Ticul.

Were the new fabrication techniques adopted because they were more efficient? It depends upon the meaning of efficient. If efficient means that vessels were fabricated in less time than they were previously, then, moulding, for example, was not more efficient because it requires more handling time that exceeds the fabrication time of making the same vessel on the traditional turntable.

The moulding technique, however, permitted potters to produce an innovative set of vessels for a different market. Moulding also provided iconographic integrity for figurines such as animals and religious images. Achieving this integrity was not possible with modelling or with any other technique. Further, the moulding technique allowed an increase in the amount of pottery that a household produced because unskilled personnel can be drawn into production to fabricate and finish vessels that was previously restricted to skilled potters. It also allows households to allocate unskilled members to fabrication tasks that were heretofore impossible without skill, and to reassign experienced potters to those tasks that require greater skill.

Even with the capital expenditure required to use a moulding technique, potters were able to produce vessels that could not be made in any other way, and this change allowed them to increase the diversity of their shape repertoire and tap into a new demand and market for their vessels.

Unlike modified coiling on the turntable, however, potters required capital to purchase the raw material (plaster of Paris) to make the moulds. As the use of moulds grew, capital was also required to create sheltered space to store the unused moulds. Further, the size of moulded vessels was limited by the constraints of the highly plastic Ticul clay.

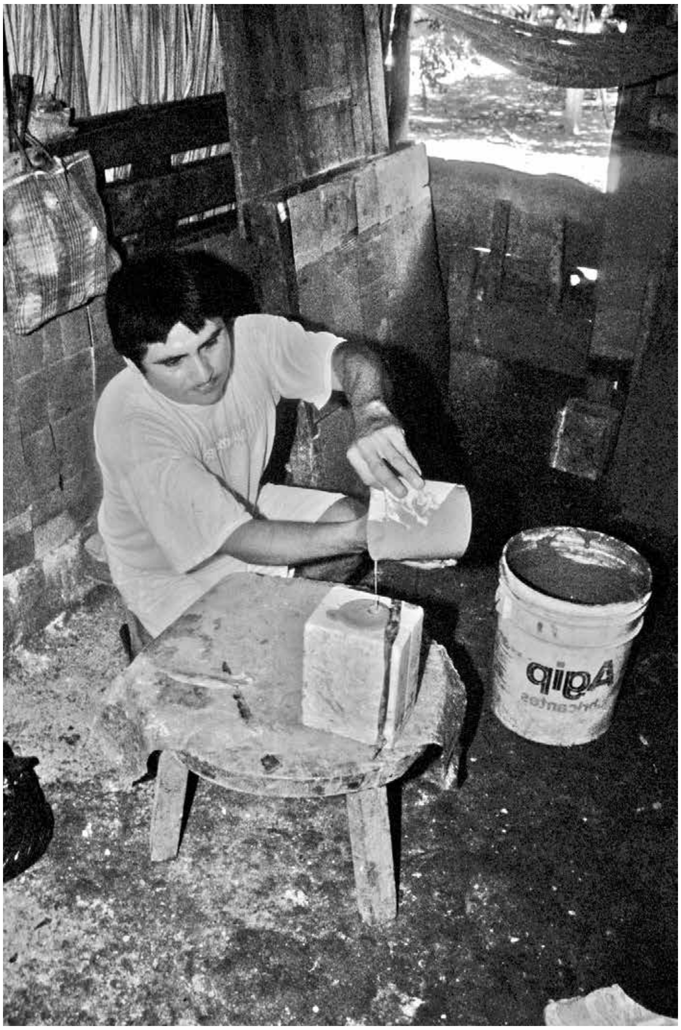

*Figure 7. A Ticul potter using the slip casting technique in 1997. The vertical half mould is held together by an elastic band, and liquid clay mixture is being poured into the mould.*

The introduction and subsequent adoption of the ball-bearing turntable resulted from a different kind of feedback. Even though it was a capital-intensive item, potters could use the same muscular patterns that they used with the traditional turntable and could do so with less muscle strength. They recognized the ease of making pottery with the new device and were less tired when using it. At least some potters believed that the device sped up production and resulted in greater productivity.

The reduced energy inputs and muscle strength from using the ball bearing turntable also provided feedback for those that were learning to make pottery for the first time. They found it easier to learn how to use the new device than the traditional turntable, and presumably could be productive in a shorter amount of time.

The existence of multiple techniques in Ticul (whether they were adopted or not) and their evolution thus suggests that a complex interdependence exists between the muscle patterns of making pottery, the constraints of the raw materials, the techniques of fabrication, and the demand of the market. Not all techniques can be used to make every shape. Rather, under certain conditions, certain techniques are better suited to producing some shapes than others. Moulds, for example, are best used to make small vessels less than twenty centimetres along their longest dimension. Moulds are also ideal for making non-circular forms such as figurines that cannot be made in any other way, but moulds cannot always be used to make uniform vessels. They can be used to make small uniform vessels but cannot be used to make large uniform vessels because the highly plastic Ticul clay causes larger vessels to sag and crack. Such vessels are best made in successive stages using modified coiling with drying periods between the stages and then measured in order to assure uniformity.

The innovation in forming technology in Ticul thus reveals the complexity of agency in the adoption and rejection of innovation. First, the same families have perpetuated the craft from the 1950s to the beginning of the 21st century, and the individuals in these families are the source of the embodiment of knowledge and skills that underlie the adoption of innovative forming techniques in Ticul. This social agency, however, is mediated through the constraints and feedback of the somatically-embodied muscular patterns. These patterns are largely unconscious, but deeply embedded cultural patterns learned by repeated muscle actions that are reinforced by furniture and working positions

Besides social agency, the fabrication techniques, skills and materials used in producing pottery also have agency because certain fabrication techniques have universal consequences that cross-cut cultural boundaries. These techniques limit choices and create new problems to which the potters must adapt. The Ticul data, for example, reveals the deeply conservative nature of work postures and motor habit patterns that constrain the adoption of new forming techniques. The devices for forming pottery may change, but the basic motor patterns and working positions involved in making pottery change very little, and then, only to make work easier (*e.g.* the ball-bearing turntable). The physical embodiment of the technology in the syntax of the muscular patterns thus also has agency.

The adoption of the vertical half moulding had long term consequences for the evolution of the craft. First introduced in Ticul in the 1940s and used primarily to make vessels that could not be made in any other way, moulding has become a preferred means to provide small uniform vessels destined for the tourist market. Painting workshops prefer uniform vessels to minimize the effort in laying out and painting the design. Equally important is the increased production intensity that potters can achieve by drawing unskilled labour into the craft. Usually, these increases are temporary and often consist of children, unskilled relatives, and other workers who may be hired temporarily to fulfil an order. The adoption of technological innovations in Ticul, as elsewhere, can have a long-term impact on social, cultural and technological evolution.

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## References

Arnold, D.E. 1971. Ethnomineralogy of Ticul, Yucatán potters: etics and emics. *American Antiquity* 36, 20-40.

Arnold, D.E. 1975. Ceramic ecology in the Ayacucho Basin, Peru: implications for prehistory. *Current Anthropology* 16 (2), 185-203.

Arnold, D.E. 1983. Design structure and community organization in Quinua, Peru, in: Washburn, D. (ed.). *Structure and cognition in art*. Cambridge: Cambridge University Press, 56-73.

Arnold, D.E. 1985. *Ceramic theory and cultural process*. Cambridge: Cambridge University Press.

Arnold, D.E. 1993. *Ecology of ceramic production in an Andean community*. Cambridge: Cambridge University Press.

Arnold, D.E. 1999. Advantages and disadvantages of vertical-half molding technology: Implications for production organization, in: Skibo, J.M., Feinman, G.M. (eds.). *Pottery and people: a dynamic interaction*. Salt Lake City: University of Utah Press, 50-80.

Arnold, D.E. 2000. Does the standardization of ceramic pastes really mean specialization? *Journal of Archaeological Method and Theory* 7 (4), 333-375.

Arnold, D.E. 2008. *Social change and the evolution of ceramic production and distribution in a Maya community*. Boulder: University Press of Colorado.

Arnold, D.E. 2012. The social evolution of potters' households in Ticul, Yucatán, Mexico, 1965 B 1997, in: Douglass, J.G., Gonlin, N. (eds.). *Ancient households of the Americas: conceptualizing what households do*. Boulder: University Press of Colorado, 163-187.

Arnold, D.E. 2015. *The Evolution of ceramic production organization in a Maya community*. Boulder: University Press of Colorado.

Arnold, D.E. 2018. *Maya potters' indigenous knowledge: cognition, engagement and practice*. Boulder: University Press of Colorado.

Arnold, D.E. Wilson, J.H., Nieves, A.L. 2007. Why was the potter's wheel rejected? Social choice and technological change in Ticul, Yucatán, Mexico, in: Pool, C.A., Bey, III, G.J. (eds.). *Pottery economics in Mesoamerica*. Tucson: University of Arizona Press, 59-87.

Brainerd, G.W. 1958. *The archaeological ceramics of Yucatán*, Anthropological Records 19. Berkeley and Los Angeles: University of California.

Foster, G.M. 1948. Some implications of modern Mexican moldmade pottery. *Southwestern Journal of Anthropology* 4 (4), 356-70.

Foster, G.M. 1955. *Contemporary pottery techniques in southern and central Mexico*, Middle American Research Institute Publication 2. New Orleans: Tulane University.

Foster, G.M. 1967. *Tzintzuntzan: Mexican peasants in a changing world*. Boston: Little Brown.

Gorogianni, E., N. Abel, Hilditch, J. 2016. Reconsidering technological transmission: The introduction of the potter's wheel at Ayia Irina, Kea, Greece. *American Journal of Archaeology* 120 (2), 195-220.

Gomart, L., Weiner, A., Gabriele, M., Durrenmath, G., Sorin, S., Angeli, L., Colombo, M., Fabbri, C., Maggi, R., Panelli, C., Pisani, D.F., Radi, G., Tozzi, C., Binder, D. 2017. Spiralled patch work in pottery manufacture and the introduction of farming to southern Europe. *Antiquity* 91 (360), 1501-1514.

Hayden, B., Cannon A. 1982. The corporate group as an archaeological unit. *Journal of Anthropological Archaeology* 1 (2), 132-58.

Ingold, T. 2013. *Making: anthropology, archaeology, art and architecture*. London: Routledge, Taylor and Francis Group

Lemonnier, P. 1993. *Technological choices: transformation in material cultures since the Neolithic.* New York: Routledge.

Lindholm, M.E., Giacomello, S., Solnestam, B.W., Fischer, H., Huss, M., Kjellqvist, S., Sundberg, C.J. 2016. The impact of endurance training on human skeletal muscle memory, global isoform expression and novel transcripts. *PLOS Genetics* 12 (9): e1006294. DOI: https://doi.org/10.1371/journal.pgen.1006294

Loney, H.L. 2000. Society and technological control: a critical review of models of technological change in ceramic studies. *American Antiquity* 65, 646-668.

Long, P., Corfas, G. 2014. To learn is to myelinate. *Science* 346, 298-299.

Malafouris, L. 2004. The cognitive basis of material engagement: Where brain, body and culture conflate, in: DeMarrais, E. Gosden, C., Renfrew, C. (eds.). *Rethinking Materiality: The engagement of mind with the material world,* McDonald Institute Monographs. Cambridge: McDonald Institute for Archaeological, University of Cambridge, 53-62.

Malafouris, L. 2013. *How things shape the mind: a theory of material engagement.* Cambridge: The MIT Press.

McKenzie, I.A., Ohayon, D., Li, H., Paes de Faria, J., Emery, B., Tohyama, K., Richardson, W.D. 2014. Motor skill learning requires active central myelination. *Science* 346, 318-322

Mitchell, W.P. 1976. Irrigation and community in the central Peruvian highlands. *American Anthropologist* 78, 25-44.

Papousek, D.A. 1974. Manufactura de alfarería: en Temascalcingo, México, 1967. *América Indígena* 34 (4), 1009-46.

Ralph, D., Arnold, D.E. 1988. Socioeconomic status, kinship, and innovation: the adoption of the *tornete* in Ticul, Yucatán, in: Kolb, C.C. (ed.), *Ceramic ecology revisited, 1987: the technology and socio-economics of pottery*, BAR International Series S436. Oxford: BAR Publishing, 145-164.

Rendón, S. 1947. Notas sobre la alfarería indígena de la Peninsula de Yucatán. *Revista Mexicana de Estudios Antropológicos* 9, 106-123.

Renfrew, C. 2004. Towards a theory of material engagement, in: DeMarrais, E. (ed.). *Rethinking materiality: the engagement of mind with the material world*, McDonald Institute Monographs. Cambridge: McDonald Institute for Archaeological Research, University of Cambridge, 23-31.

Rice, P.M. 1987. *Pottery Analysis: A Sourcebook*. Chicago: University of Chicago Press.

Shepard, A.O. 1965. *Ceramics for the Archaeologist,* Carnegie Institution of Washington Publication 609. Washington, D.C.: Carnegie Institution of Washington.

Spier, R.F.G. 1967. Work habits, postures and fixtures, in: Riley, C.L., Taylor, W.W. (eds.). *American Historical Anthropology: Essays in Honor of Leslie Spier*. Carbondale: Southern Illinois University Press, 197-220.

Thompson, R.H. 1958. *Modern Yucatec Maya pottery making*, Memoirs of the Society for American Archaeology 15. Salt Lake City: The Society for American Archaeology.

van der Leeuw, S. 1993. Giving the potter a choice: conceptual aspects of pottery techniques, in: Lemonnier, P. (ed). *Technological choices: transformation in material cultures since the Neolithic*. London: Routledge, 238-288.

## Notes on contributor

Dean E. Arnold has done field work in Peru, Mexico, Bolivia, Guatemala, and the Southwest, and published five books, two co-edited books, and more than 60 articles about potters, pottery production, and related subjects. Among them is *Ceramic Theory and Cultural Process* (1985), and two books about long-term stability and change in pottery technology and its organization in Ticul, Yucatán, Mexico, based upon field work carried out there over more than four decades. His new book *Maya Potters' Indigenous Knowledge: Cognition, Engagement, and Practice* challenges the notion that potters simply use a mental template to make their pottery. Dr. Arnold was a Fulbright Scholar in Mexico (1984) and Peru (1972-1973), and a Visiting Fellow at Clare Hall, University of Cambridge in 1985 and a Visiting Scholar at the Department of Archeology there in 1985, 1992, and 2000. He has received grants from the National Endowment for the Humanities, the Wenner-Gren Foundation for Anthropological Research, and the National Geographic Society. He received the Society for American Archaeology's Award for Excellence in Ceramic Studies in 1996. He currently Adjunct Curator of Latin American Anthropology at the Field Museum in Chicago, and is Professor of Anthropology, *Emeritus*, at Wheaton College (Illinois).

# Innovation or inheritance? Assessing the social mechanisms underlying ceramic technological change in early Neolithic pottery assemblages in Central Europe

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## Abstract

In early Neolithic Europe, where mobility is a structural component of farming communities, interpreting ceramic technological change detected in the archaeological record can be particularly challenging. Change in technical practices can correspond to local innovation or to arrivals of individuals implementing their own inherited technical traditions. To bring new lines of thoughts on this issue, we discuss here, from the perspective of ceramic forming processes, a period of major cultural change in the European Neolithic: the transition in the Carpathian Basin from the Balkan early Neolithic (Starčevo and Körös) to the Linear Pottery. The analysis of four ceramic assemblages from settlements located in this culturally contrasted area suggests that this zone of cultural mutation constitutes an area of interaction between different communities of practice, whose technical traditions can be traced over the long term. In this context, the changes perceived in ceramic forming processes do not appear to result from innovation processes. Rather, they seem associated with complex social dynamics, implying populations moving over the long term and long distances with their own inherited technical traditions. Our study serves as an example of the power of ceramic technology to act as a high spatial and temporal resolution proxy for human dynamics and trajectories, enabling to address complex social mechanisms.

*Keywords: Neolithic, Europe, Neolithisation, Starčevo, Körös, Linear Pottery, ceramic, technology, forming, communities of practice, interactions*

## Introduction

Cultural studies and bio-archaeological analyses support the idea of an introduction of farming to Europe mainly through a broad colonisation process originating from the Near East, and entering Europe through two main paths, the Mediterranean path and the Central-European path (*e.g.* Lichardus-Itten 1986; Haak *et al.* 2010; Hofmanová *et al.* 2016). The same analyses show that early Neolithic human mobility also took place at the scale of settlements areas, with possible population influx between contemporaneous settlements (*e.g.* Price *et al.* 2001; 2006; Bentley *et al.* 2002; 2003; 2008). On top of these observations, the role of hunter-gatherer communities in the Neolithisation process is still the subject of an important debate (*e.g.* Gronenborn 1999; Gronenborn 2007; Constantin *et al.* 2010; Gomart and Burnez-Lanotte 2012; Budja 2013; Lipson *et al.* 2017). In this framework, pottery, a fundamental element of the early European famers' economy, was widely studied from a stylistic point of view in order to build relative chronological sequences. This collective effort, associated with the establishment of precise absolute chronological frameworks (*e.g.* Oross and Siklósi 2012; Isern *et al.* 2017; Binder *et al.* 2017; Perrin *et al.* in press; Jakucs *et al.* 2016), led to an increasing knowledge of the rhythms of the European Neolithisation. Besides these chronological sequences, a growing number of researchers also investigate European early Neolithic pottery from a technical point of view, focusing on raw materials and paste recipes, forming processes, surface treatments, decoration techniques, and/or firing processes, thus assessing continuity and ruptures in pottery production (*e.g.* Spataro 2006; 2011; 2017; Marton 2004; 2008; 2013; Szakmány *et al.* 2005; Capelli *et al.* 2006; 2017; Szakmány and Starnini 2007; Biró *et al.* 2007; Binder *et al.* 2010; Manen and Convertini 2012; Gabriele and Boschian 2013; Kreiter 2010; Kreiter and Szakmány 2011; Kreiter *et al.* 2013; 2017; Angeli *et al.* 2015; Van Dooselaere *et al.* 2016; Angeli and Fabbri 2017; Kvetina *et al.* 2017; Neumannová *et al.* 2017). However, in the European early Neolithic contexts, where mobility is a structural component of farming communities, the interpretation of ceramic technical change perceived in the archaeological record can be challenging. Two main scenarios can be considered: first, technical change can be the result of an innovation process, which can be defined as the broad adoption by a community of an invention (an invention being defined as the conception by an individual of a new idea, a new behaviour or a new object: Roux 2009). Second, technical change can be the result of the arrival of a new population (of farmers or hunter-gatherers), whose origin and social structure has to be understood (Roux 2011).

To address the issue of technical change interpretation in early farming contexts, central Europe acts as a unique study area, as it constitutes at the same time an area where different cultural groups coexisted side by side and a space of cultural mutation. In Hungary particularly, the middle of the sixth millennium cal BCE represents a period of major cultural change: the passage of the Balkan early Neolithic to the Central European Linear Pottery (or *Linearbandkeramik,* abbreviated LBK). The emergence of this culture, which defines the first Neolithic of temperate Europe and which spreads in less than five centuries towards the Paris Basin, is accompanied by profound changes in lifestyles of farming communities originating from the Balkan, regarding their agricultural economy and their habitat structures (Raczky *et al.* 2010). At that time, the agro-pastoral communities begin to exploit new lands and build longhouses on wooden posts grouped in villages (Raczky and Anders 2009; Bánffy and Oross 2010).

This transition period is characterized by a double dynamic. On the one hand, an east-west dichotomy can be noticed. The latest manifestations of the Balkan early Neolithic are indeed characterized by the presence in Hungary of two entities, the Starčevo to the west in Transdanubia, and the Körös to the east in the Tisza region, which are notably differentiated by their ceramic styles and their settlement systems (Raczky *et al.* 2010; Bánffy 2013). Subsistence strategies of the communities belonging to these two entities are still little known on a large scale and there are considerable differences in the state of data processing concerning excavated assemblages (Anders and Siklósi 2012; Kalicz 2011). Whether these entities form a single archaeological culture including two cultural groups or should be individualized into two distinct cultural entities is an important question moving forward. The answer will presumably have an altering impact when further targeted research result in more flexible and fluid models. In addition, the origin of these two local variants of the Balkan early Neolithic remains difficult to assess: is their emergence related to specific environmental conditions or to differences that existed earlier and further south in the Balkans? (Bánffy 2013, 41).

On the other hand, a north-south dichotomy can be observed. Towards the middle of the sixth millennium BCE, a process of transition is observed in Hungary. At that time, the last Balkan early Neolithic sites are found alongside the first Linear Pottery sites. On the shores of Lake Balaton, to the west, the most recent Starčevo sites are located alongside the first LBK sites. In the Tisza region, to the east, the latest Körös sites are found alongside the first eastern Linear Pottery sites (Alföld Linear Pottery). This transition process seems to be related to the existence in this area of an agro-ecological barrier, which would require an adaptation of the agro-pastoral communities to a new environment and to new climatic, soil and geological conditions (*e.g.* Kertész and Sümegi 2001; Kertész and Sümegi 2001; Bánffy and Sümegi 2012). Regarding the eastern part of Hungary, scholars propose the concept of a "mental marginal zone": the necessary readjustments encountered by the farming communities at the agro-ecological frontier would have led to cognitive changes, resulting in the emergence of a new material culture, namely the Alföld Linear Pottery (*e.g.* Raczky *et al.* 2010; Kozłowski and Raczky 2010). In the western part of Hungary, the emergence of the LBK would be related to the integration of indigenous Mesolithic populations among the agro-pastoral communities from the Balkans (*e.g.* Bánffy *et al.* 2007; Bánffy and Oross 2010). Notably, this hypothesis is proposed on the basis of Mesolithic influences in the Transdanubian LBK flint industries and because of environmental data attesting a pre-Neolithic anthropogenic activity in Transdanubia (*e.g.* Bánffy *et al.* 2007; Bánffy and Oross 2010). Recent DNA evidence reveals, however, that this model requires further refinement (Szécsényi-Nagy *et al.* 2015; Lipson *et al.* 2017).

We carried out an "anthropological approach" (Roux 2011) to ceramic assemblages discovered in this contrasting area to address these questions. This approach, which aims at reconstructing the sequences of technical gestures implemented by the producers during the manufacture of their pottery, provides evidence for "ways of doing" transmitted over the long term within communities of practice (Roux 2016). As emphasised by several anthropological and behavioural studies rooted in the "French School of Anthropology of Techniques" (Mauss 1947; Leroi-Gourhan 1964; Latour and Lemonnier 1994), the sequence of production (chaîne opératoire) of any artefact, including pottery, is a strong marker of the social identity of its producer. Cognitive and behavioural studies show that in the course of learning, producers assimilate motor habits that they will not easily question nor transform after learning was completed (Bril 2002). This mechanism, that systematically involves a tutor and a learner who are related socially, results in the transmission of technical gestures sequences over generations within a given learning network, whose geographic extension defines the perimeter of a community of practice (Gosselain 2000; Roux 2016). A community of practice thus corresponds to a social group, whose sociological nature depends on the structure of apprenticeship. The transmission process can occur, for instance, within a clan, a lineage, an ethnic group or an ethno-linguistic group (Dietler and Herbich 1994; Gosselain 2000; Livingstone-Smith 2001; Gelbert 2003; Roux 2011; 2016). Therefore, while imitation or reinterpretation of a specific vessel shape and decorative architecture can occur without close contact between producers, the implementation of a given manufacturing sequence requires transmission of gesture sequences, and thus direct interaction between individuals.

This methodological framework, providing access to individuals *via* their motor habits and enabling therefore to differentiate groups of producers, enabled us to raise several questions about the dynamics involved in the transition from the Balkan early Neolithic to the Linear Pottery. From a synchronic point of view, two main issues arose: first, can we observe a relation between the Starčevo and the Körös ceramic forming processes, which would suggest that these two entities belonging to the Balkan stream correspond to the same community of practice? Then, can we relate these ways of doing to the technical traditions identified earlier and further south, in the Balkan early Neolithic? From a diachronic perspective, the following issues arose: can we observe technical continuity between the two Balkan early Neolithic entities (Starčevo and Körös) and the two Linear Pottery groups (LBK in western Hungary and Alföld Linear Pottery), which would indicate that these successive archaeological cultures correspond to the same social groups and thus to the same wave(s) of Neolithisation? Or, on the contrary, can we detect significant technical breaks suggesting (i) innovation processes implemented during this cultural mutation or (ii) contributions of populations, indigenous or exogenous, among agro-pastoral communities originating from the Balkans?

## Material and methods

To address these issues, ceramic assemblages from four settlements attributed to the different identified cultural entities were examined (Gomart 2016). Two of the studied sites are located in Transdanubia. The first one, Vörs-Máriaasszony-sziget (Aradi 1992; Kalicz *et al.* 1998; 2002; Virág and Kalicz 2001; Biró *et al.* 2007), yielded habitat structures attributable to the Starčevo culture. One non-modelled conventional radiocarbon result (Deb-8167; 6510±60 BP) dates the occupation to the 56th-54th centuries cal BCE (Kalicz *et al.* 2002, 26, Fig. 6). Within the Vörs-Máriaasszony-sziget ceramic assemblage, 178 vessels showed diagnostic macrotraces of forming operations. Among them, 90 vessels have been attributed to a forming method. The second site, Balatonszárszó-Kis-erdei-dűlő (Oross 2010; 2004; 2013; Marton 2004; 2008; 2013; Marton and Oross 2009; Kreiter *et al.* 2017) provided the plans of at least 62 houses alongside several thousand settlement features (mostly pits) over a surface of *ca* 10 hectares. It is characterized by a long occupation sequence, typo-chronologically characterised by the early to the young phases of the LBK (*c.* 5300-4900 cal BCE). For this settlement, an integrated approach to ceramic manufacture, combining raw materials, forming and decorative techniques was recently carried out at the household and the site levels (Kreiter *et al.* 2017; in press). As part of this integrated approach, we focused on eight houses which yielded ceramic assemblages attributed to the main style groups recognised at the site. Among the 9161 sherds associated with these eight houses, 109 vessels could be associated with a forming method.

The other two sites are located in the upper Tisza Valley (eastern Hungary). The first, Nagykörű-Tsz. Gyümölcsös (Raczky *et al.* 2010; Raczky 2012), is attributable to the Körös culture. It is characterized by the presence of a refuse pit containing a rich archaeological assemblage, as well as a grave with a northeast-southwest orientation. A series of non-modelled conventional radiocarbon results provided the following interval: 5880-5650 cal BCE (Raczky *et al.* 2010, 159). A model was then proposed by Oross and Siklósi (2012), proposing a start boundary for the Nagykörű early Neolithic occupation at 6010-5900 cal. BCE and an end boundary at 5710-5550 cal BCE. After examination of the whole assemblage, 233 vessels showing diagnostic macrotraces were recorded. Among them, 60 vessels could be related to a forming method. The second site, Polgár-Ferenci-hát (Raczky 2004; Raczky and Anders 2009; Whittle *et al.* 2013) provided, among a tremendous amount of archaeological features, several housing structures assignable to the Alföld Linear Pottery. Non-modelled conventional radiocarbon results provided intervals of 5467-5344 cal BCE for the lower layer of the site, and of 5285-5056 cal BCE for the upper layer, dating the occupation between the 53rd and the 51st centuries cal BCE (Raczky and Anders 2009, 43-45). After the examination of the assemblage, 201 diagnostic vessels and sherds were recorded. Among them, 73 could be associated with a forming method.

Overall, a total of 721 ceramic vessels (including sometimes only several pottery fragments) were examined. The characterisation of ceramic forming processes relies on the examination of a set of diagnostic features (*macro- and microtraces*), *i.e.* surface topography, as well as the spatial organisation in sections (radial and tangential plans) of discontinuities, pores and inclusions. The relation between these features and specific technical gestures was established thanks to a number of studies in physical and archaeological sciences which could show that the orientation of pores and inclusions, and the associated surface topography, depend on the physical constraint applied on the clay material during forming (*e.g.* Courty and Roux 1995; Pierret *et al.* 1996; Thér 2016; Thér and Toms 2016). The identified *macro-* and *microtraces* are interpreted in terms of technical gestures in the light of experimental and/or ethno-historical reference works (Shepard 1956; Rye 1981; Livingstone-Smith 2001; Gosselain 2002; Gelbert 2003).

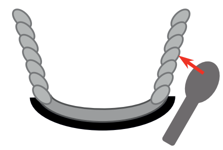
# Results

## Diversity in ceramic forming processes in the Carpathian basin

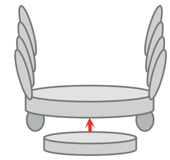
Among the four studied assemblages, we identified five distinct ways of doing regarding ceramic forming processes (Figs. 1 and 2). These ways of doing correspond to different forming methods, but all belong to a unique operational scheme (in French *schéma opératoires, i.e.* conceptual schemes underlying the chaîne opératoire): in every identified forming method, the base is built using one or several slabs formed from a coil folded in a spiral, then the body is constructed using superimposed elements (thin coils, elongated coils or slabs). Shaping is then implemented using either discontinuous finger pressure or the beating technique.

The first forming method (Fig. 1) comprises vessels characterized by a base formed with thin coils superimposed in a spiral, as shown by the presence of a sub-circular configuration in section (Fig. 1 no 3). Longitudinal depressions on the inner surface of the base (Fig. 1 no 4) suggest a shaping by compression against a support as observed in the first fashioning method. The body and the rim present, in radial cross-section, sub-oval sections of coils associated with a foliated internal structure. On the outer surface of the body and the rim, overlapping sub-circular flat areas are observed (Fig. 1 no 1 and 2). The combination of these macrotraces indicates that the belly and the rim were formed by superposition of thin coils, and then shaped using the beating technique. The regular taps of the paddle on outer surfaces cause a change in the internal structure of the clay, resulting in a foliated texture.

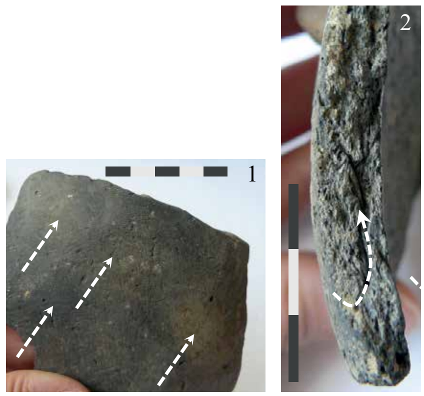
The second forming method (Fig. 2) includes vessels whose base shows, in cross-section, sub-circular sections of coils, suggesting initial forming of the base using a slab formed folding a thin coil in spiral. Some of the vessels' base is formed with two overlaid spiralled slabs, the plan of junction between these slabs being often visible in the radial plan (Fig. 2 no 2). Longitudinal depressions occurring on the base inner surface evoke the application of hand pressure during shaping (Fig. 2 no 3). This observation suggests that the vessel's base was shaped by compres-



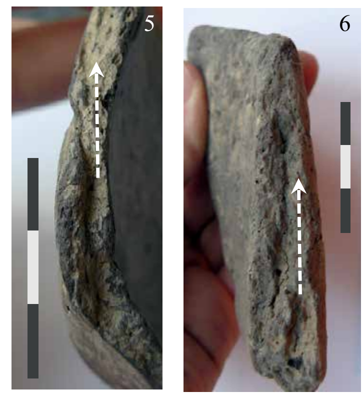
*Method 1*



*Method 3*

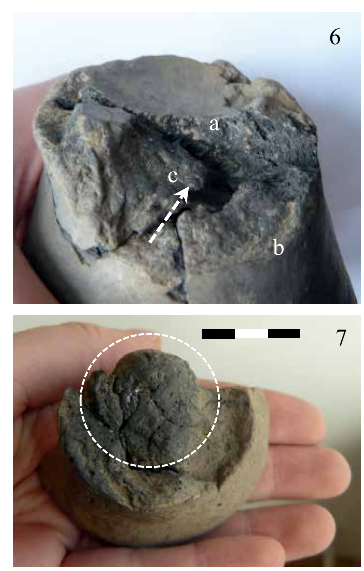



Macrotraces observed on the body and the rim of the vessels associated with Method 1. (1): Overlapping sub-circular flat areas on the outer surface suggesting shaping using the beating technique; (2): Elongated coils visible in cross-section, showing a foliated structure (sub-circular to oblique orientation of the porosity)




Macrotraces observed on the body and the rim of the vessels associated with Method 3. (5) and (6): Slabs or very elongated coils visible in cross-section (vertical orientation of the porosity)


Macrotraces observed on the base of the vessels associated with Method 1. (3): Thin coil visible in cross-section; (4): Digital pressures (along with the use of a smoother?) on the inner surface suggesting shaping by pressure against a concave support




Macrotraces observed on the base of the vessels associated with Method 3. (6a): first, a slab is formed by folding a coil in spiral, (6b): then a coil is applied at the junction between the base and the body to start the foot, (6c): ultimately, a second slab is applied at the centre of the foot; (7): a slab is visible at the centre of the base and fills the previously formed foot:

*Figure 1. Macrotraces observed on the ceramic vessels associated with Forming Methods 1 and 3 identified, in early farming contexts in the Carpathian basin (modified from Kreiter et al. 2017).*

sion against a support. The body and the rim of the vessel also show, edges of vertical fractures, sub-circular sections of coils (Fig. 2 no 1), indicating forming by superimposition of thin coils, which were deformed slightly or not during their placement.

In the third forming method (Fig. 1), the vessel bases show a wide range of technical macrotraces, which suggests fashioning in three phases (Fig. 1 no 6 and 7). First, a slab is formed by folding a coil in spiral, as shown by the sub-circular pattern visible in cross section. Secondly a coil, often visible in cross-section, is applied on the junction between the base and the body, to form an annular foot. Third, a second slab is applied at the centre of the base, in order to fill the previously formed annular foot. In the radial plan, the body and the rim of these vessels show vertical orientation of the porosity (Fig. 1 no 5 and 6). The pots associated in this way present many oblique fractures and several sherds are vertically broken. These observations suggest initial forming by juxtaposition of very elongated coils or slabs, followed by thinning operations using discontinuous finger pressure.

The vessels shaped with the fourth forming method (Fig. 2) are built “upside down”, the producer starts to form the rim of the vessel, building the body by superimposing thin non deformed coils (Fig. 2 no 4); the producer then ends the fashioning by forming the base of the vessel. This forming method can be notably identified by the presence of a sub-circular ball of clay applied in the centre of the vessels base, in order to ensure its occlusion at the end of the forming sequence (Fig. 2 no 5 and 6).

The fifth forming method (Fig. 2) includes vessels whose base and body are characterized by identical macrotraces: in cross-section, the orientation of the porosity is vertical and very high oblique vertical voids are observed (Fig. 2 no 7). On the outer surface of the shoulder, a horizontal depression is observed (Fig. 2 no 9). The rim shows in cross-section a sub-circular configuration of pores (Fig. 2 no 8). The association of these observations suggests a roughing of the base and of the belly in one piece, with thick coils. Secondly, these two parts are shaped on a concave support by moulding, with an intense stretching of the walls causing their refinement and a very important elongation of the coils. While the base and the body are still in the mould, the rim is then formed by superimposing two to four thin coils.

## Different cultural groups, different communities of practices?

Within the two study areas, namely Transdanubia and the upper Tisza valley, the spatial distribution of the five identified forming methods reveals significant differences between the studied sites (Tab. 1 and Fig. 3).

We first observed that the ceramic assemblages from the Körös site of Nagykörű-Tsz. Gyümölcsös on the one side and the Starčevo site of Vörs-Máriaasszony-sziget on the other side reflect distinct technical practices regarding ceramic forming processes. While at Vörs-Máriaasszony-sziget, all the examined ceramics show a body built using elongated coils or slabs, in most cases followed by shaping using the beating technique (Methods 1 and 3), the vessels examined at Nagykörű-Tsz. Gyümölcsös were constructed using only thin superimposed coils (Methods 2 and 4). The occurrence of distinct ways of doing regarding ceramic forming processes at these two sites suggests that the Körös potters from Nagykörű-Tsz. Gyümölcsös and the Starčevo potters from Vörs-Máriaasszony-sziget belonged to two distinct communities of practice.

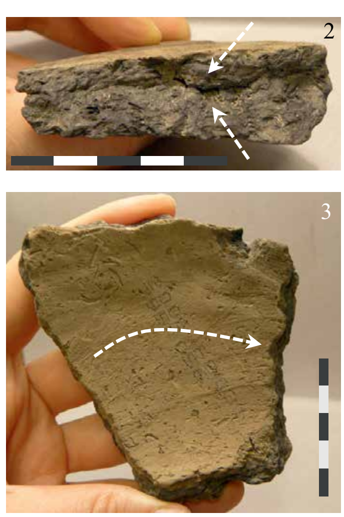
We also noted an east-west dichotomy on the two examined Linear Pottery sites. The two forming methods identified on the Starčevo site of Vörs-Máriaasszony-sziget

*Figure 2 (overleaf). Macrotraces observed on the ceramic vessels associated with Forming Methods 3, 4 and 5, identified in early farming contexts in the Carpathian basin.*

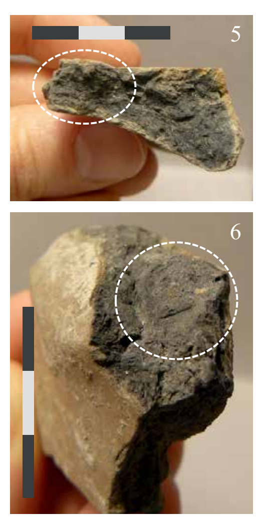

Macrotraces observed on the body and the rim of the vessels associated with Method 2. (1): Non deformed thin coils visible in cross-section (sub-circular orientation of the porosity)


Macrotraces observed on the body and the rim of the vessels associated with Method 4. (4): Non deformed thin coils visible in cross-section (sub-circular orientation of the porosity)

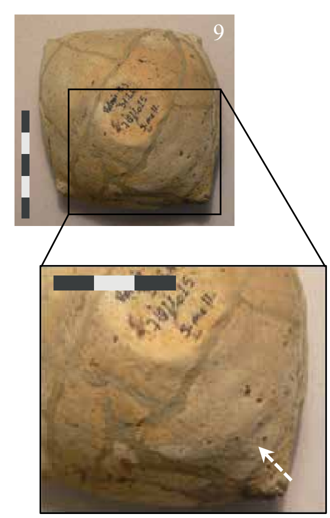

Macrotraces observed on the body and the rim of the vessels associated with Method 6. (7): Vertical orientation of the porosity, suggesting moulding against a concave support; (8): 3 or 4 thin coils visible in cross-section (sub-circular orientation of the porosity) are superimposed to form the rim




Macrotraces observed on the base of the vessels associated with Method 2. (2): overlapping of two spiralled slabs visible in cross-section; (3): Digital pressures on the inner surface suggesting a shaping by pressure against a concave support




Macrotraces observed on the base of the vessels associated with Method 4. Ball of clay used for the occlusion of the vessel's base, visible (5) in cross-section or (6) in the tangential plan.




Macrotraces observed on the base of the vessels associated with Method 6. (9): an horizontal depression is visible on the outer surface of the vessels at the level of the shoulder, suggesting the use of a concave support to shape the base and the body of the vessels

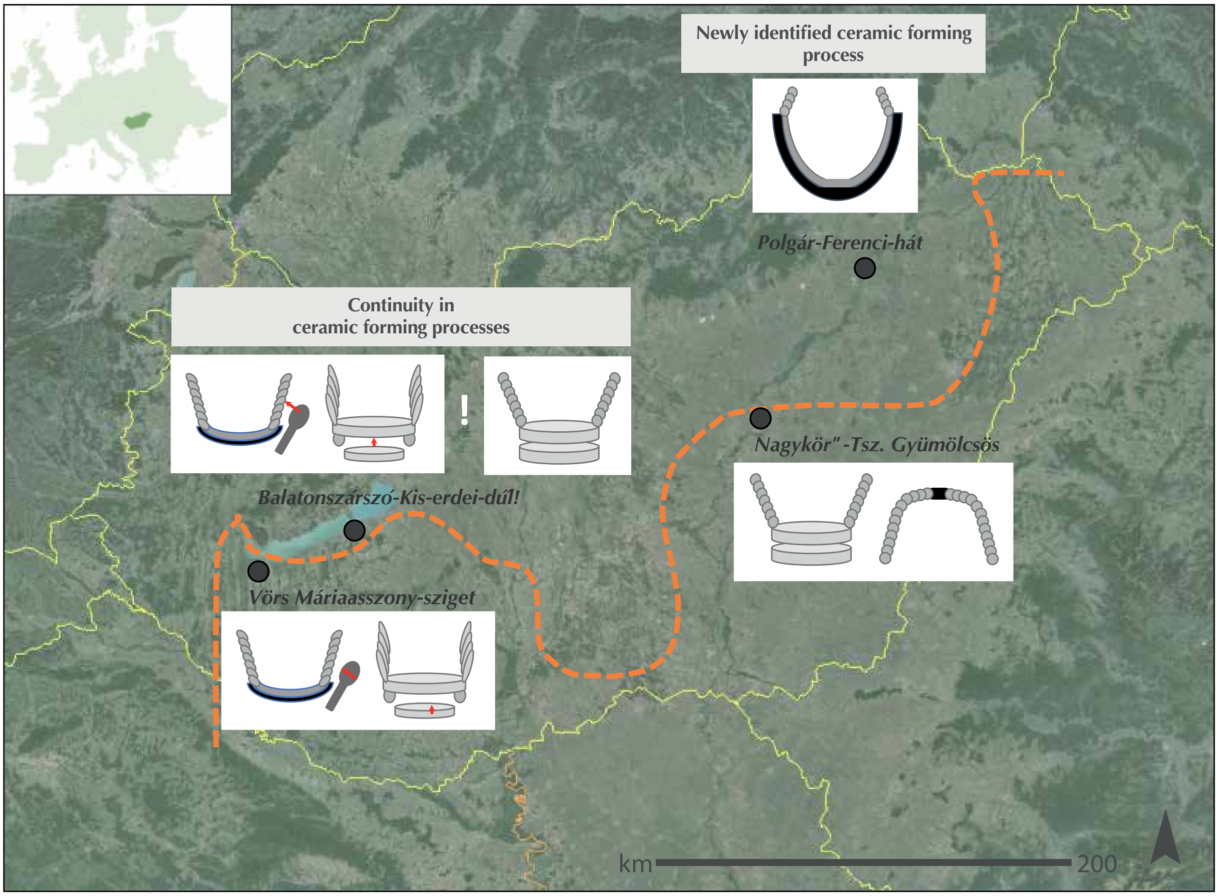



*Figure 3. Spatial distribution of the five ceramic forming methods identified at the four selected sites located in the Carpathian basin (orange dotted line: position of the northern manifestations of the Balkan early Neolithic in Hungary, after Bánffy 2013 and Raczky in press).*

| | Vörs-Máriaasszo-ny-sziget | | Nagykörű-Tsz. Gyümölcsös | | Balatonszárszó Kis-erdei-dűlő | | Polgár-Ferenci-hát | |
|---|---|---|---|---|---|---|---|---|
| | N | % | N | % | N | % | N | % |
| Method 1 | 87 | 97% | - | | 70 | 64% | - | - |
| Method 2 | - | - | 49 | 82% | 7 | 6% | - | - |
| Method 3 | 3 | 3% | - | - | 32 | 29% | - | - |
| Method 4 | - | - | 11 | 18% | - | - | - | - |
| Method 5 | - | - | - | - | - | - | 73 | 100% |
| **Total** | **90** | **100%** | **60** | **100%** | **109** | **100%** | **73** | **100%** |

*Table 1. Quantitative distribution of the five ceramic forming methods identified at the four selected sites in the Carpathian basin (modified from Gomart 2016).*

(Methods 1 and 3) and one[1] of the forming methods observed on the Körös site of Nagykörű-Tsz. Gyümölcsös (Methods 2) were also observed on the LBK site of Balatonszárszó-Kis-erdei-dűlő from the beginning of the occupation, on vessels made out of local pastes (Kreiter *et al.* 2017). The Alföld Linear Pottery structures of Polgár-Ferenci-hát yielded a single forming method (Method 5), which was not observed on

1 During the general examination of the Balatonszárszó Kis-erdei-dűlő ceramic assemblage, one single ceramic vessel built using Method 3 was observed. It was however not part of the ceramic assemblage associated with the eight houses studied in Kreiter *et al.* 2017.

other sites in the study areas. In Balatonszárszó Kis-erdei-dűlő, potters belonging to the communities of practice respectively identified earlier at Vörs-Máriaasszony-sziget and at Nagykörű-Tsz. Gyümölcsös might have therefore coexisted from the beginning of the settlement occupation (Kreiter *et al.* 2017). In contrast, we could not link the ceramic forming process found at Polgár-Ferenci-hát with a community of practice previously identified in another study area.

# Discussion

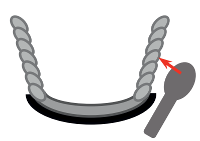
## "Everything old is new again": innovation in ceramic forming processes among early farmers in Hungary?

The results we obtained on the four selected sites suggest that the early farming communities in Hungary belong to different communities of practice regarding ceramic forming processes. But what is the origin of their ways of doing? In this contrasting cultural landscape, is technical change linked with technical innovation or does it mirror population movements and interactions?

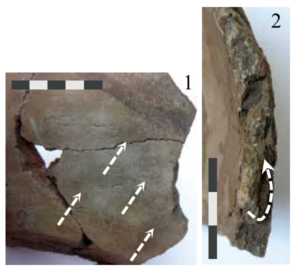
To address these questions, we needed to broaden our scale of analysis to earlier settlements on the Central European migration path. To do this, we compared the results obtained as part of the present study with available data further south, *i.e.* in Bulgaria, in the earlier phases of the Balkan early Neolithic. As shown in Figure 4, this comparison revealed that four of the five forming methods identified in Hungary (Methods 1 to 4) correspond in all respects to those observed in the early Neolithic of the Struma Valley in Bulgaria, between *c.* 6100 and 5800 cal BCE (Salanova 2014; Salanova *et al.* in press; Gomart in press 2013). Only the fifth forming method, identified in the Alföld Linear Pottery structures of Polgár-Ferenci-hát, had never been identified among the ceramic assemblages analysed in Bulgaria. Both methods observed at the Starčevo site of Vörs-Máriaasszony-sziget (Methods 1 and 3) relate in all respects to the forming methods used by the producers from the north of the Struma Valley throughout the early Neolithic of Bulgaria (Galabnik and Kraïnici sites: Salanova 2014; Salanova *et al.* in press; Gomart in press 2013). Conversely, the two forming methods identified on the Körös site of Nagykörű-Tsz. Gyümölcsös (Methods 2 and 4) relate in all respects to the ways of doing implemented throughout the Bulgarian early Neolithic in the south of the Struma valley (Kovačevo, Ilindenci and Drenkovo sites: Salanova 2014; Salanova *et al.* 2010; in press; Vieugué *et al.* 2010; Gomart in press 2013). The assemblages from the Körös site of Nagykörű-Tsz. Gyümölcsös and the Starčevo site of Vörs-Máriaasszony-sziget thus seem to mirror two distinct communities of practice, which can be related to those that previously settled respectively in the north and in the south of the Struma Valley throughout the Bulgarian early Neolithic (Salanova 2014; Salanova *et al.* in press; Gomart in press 2013).

The variability observed in ceramic forming processes in the typo-chronologically earlier structures of the LBK site of Balatonszárszó-Kis-erdei-dűlő, already described in Kreiter *et al.* (2017), enables us to make several observations: first, the co-occurrence of technical practices identified at the Starčevo site of Vörs-Máriaasszony-sziget and at the Körös site of Nagykörű-Tsz. Gyümölcsös suggests the coexistence in the settlement of producers belonging to distinct communities of practice. This result also implies strong continuity in technical practices between the Starčevo producers and some LBK producers. This observation is consistent with the hypothesis that Starčevo groups had a profound role during the formative phase of the LBK (*e.g.* Bánffy *et al.* 2007). Ceramic petrographic analysis from one of the earliest LBK sites, Szentgyörvölgy-Pityerdomb, underlines the relationship between the Starčevo and the LBK in terms of choices in raw materials and paste compositions

*Figure 4 (right). Macrotraces observed on vessels from early farming contexts in the Southern Balkans (modified from Salanova et al. 2010; Vieugué et al. 2010; Gomart in press 2013).*

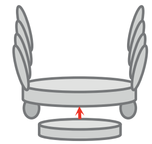


*Method 1*



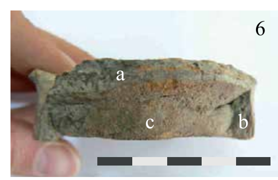

Macrotraces observed on the body and the rim of the vessels associated with Method 1. (1): Overlapping sub-circular flat areas on the outer surface suggesting shaping using the beating technique; (2): Elongated coils visible in cross-section, showing a foliated structure (sub-circular to oblique orientation of the porosity)


Macrotraces observed on the base of the vessels associated with Method 1. (3): Coil visible in cross-section; (4): Digital pressures on the inner surface suggesting a shaping by pressure against a concave support

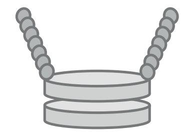


*Method 4*


Macrotraces observed on the body and the rim of the vessels associated with Method 4. (5): Slabs or very elongated coils visible in cross-section (vertical orientation of the porosity)

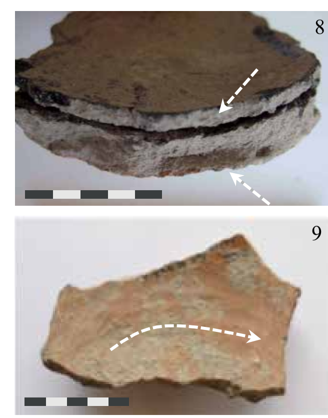



Macrotraces observed on the base of the vessels associated with Method 4. (6a): first, a slab is formed by folding a coil in spiral; (6b): then a coil is applied at the junction between the base and the body to start the foot; (6c): ultimately, a second slab is applied at the centre of the foot

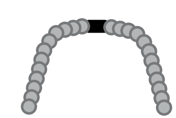


*Method 2*


Macrotraces observed on the body and the rim of the vessels associated with Method 2. (7): Non deformed thin coils visible in cross-section (sub-circular orientation of the porosity)

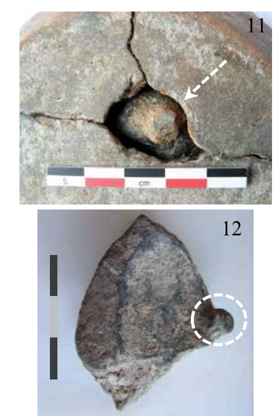



Macrotraces observed on the base of the vessels associated with Method 2. (8): overlapping of two spiralled slabs visible in cross-section; (9): Digital pressures on the inner surface suggesting a shaping by pressure against a concave support



*Method 3*


Macrotraces observed on the body and the rim of the vessels associated with Method 3. (10): Non deformed thin coils visible in cross-section (sub-circular orientation of the porosity)




Macrotraces observed on the base of the vessels associated with Method 3. (11) and (12): Ball of clay used for the occlusion of the vessel's base, visible on the base's outer surface

(Kreiter *et al.* 2013). Nevertheless, it will be essential to analyse ceramic forming practices on the sites attributed to the earliest phase of the LBK, as this phase does not occur at Balatonszárszó-Kis-erdei-dűlő. Moreover, the use in Balatonszárszó Kis-erdei-dűlő of one forming method that is typical of the Körös site of Nagykörű-Tsz. Gyümölcsös (and of sites located in the south of the Struma Valley) could indicate interactions and/or arrivals of communities at the site. Such coexistence of distinct communities of practice at a single settlement in a context of cultural transformation is not unique for the European Neolithic, and was for instance observed at the site of Pavlovac-Čukar in Serbia (Vuković 2017). The study of a larger corpus of sites is required before commenting on the exact nature of these influences. Lastly, one has to note that the question of the integration of hunter-gatherers at the settlement remains difficult to address using the sole ceramic forming data, as over the long term, specific technical gestures can be transmitted to individuals after their integration to a given social group (*e.g.* Gelbert 2003).

The use of Method 5 throughout the Alföld Linear Pottery occupation of Polgár-Ferenci-hát, which had not been identified on another early or middle Neolithic assemblage, represents a rupture in regards to the technical practices observed on the Körös site of Nagykörű-Tsz. Gyümölcsös (Methods 2 and 4). This preliminary result encourages us to pursue technological studies in the Tisza region to look for possible connections with other sites. It will be, for instance, necessary to verify whether this forming method characterizes other Alföld Linear Pottery ceramic assemblages, as well as earlier Balkan early Neolithic assemblages. A rupture between the Körös and the Alföld Linear Pottery was also observed by Szakmány and Starnini (2007) regarding ceramic raw material preparation and temper. The results on ceramic forming thus reinforce the hypothesis of an implementation of new ceramic technical practices along with the emergence of the Alföld Linear Pottery, indicating either the arrival of a new communities of practice in the Tisza Valley or local innovations in ceramic practices occurring along with cultural mutation.

## The central European Neolithisation path: continuity or breaks in ceramic forming processes?

The research presented in this article enabled us to connect the early Neolithic contexts of the southern Balkans (Salanova 2014; Salanova *et al.* 2010; in press; Vieugué *et al.* 2010; Gomart in press 2013) and those of the Linear Pottery in Central Europe through pottery technical practices. It appeared that the early European farmers built their ceramics according to a common operational scheme, but they implemented different forming methods according to their region of origin.

Throughout the whole early Neolithic sequence in Bulgaria, four forming methods could be identified, two of them being used in the north of the Struma Valley (Methods 1 and 3), the other ones being used in the south of the Struma valley (Methods 2 and 4), this technical dichotomy being observed along with differences in pottery shapes and decorations (Salanova 2014; Salanova *et al.* 2010; in press; Vieugué *et al.* 2010; Gomart in press 2013). We could then show that the exact same ceramic forming methods could be traced centuries later and 800 kilometres north, within the first Neolithic of Hungary alongside the east-west Körös-Starčevo dichotomy, despite significant changes in ceramic shapes and decorations.

The two communities of practice that coexisted in the Struma valley throughout the early Neolithic might have thus disseminated further north, maintaining the initial technological boundary regarding their ceramic forming processes. It is important to note that the technological boundaries identified in the Struma valley and then in Hungary regarding ceramic forming processes do not mean that these two groups were altogether disconnected. On the contrary, ethnographical studies examining the conditions for persistence of technological boundaries show that non-diffusion of techniques tends to occur when distinct communities of practice living closely together interact (Cauliez *et al.* 2017; Roux *et al.* 2017). Thus, the fact that the two identified communities of practice implemented all over the Balkans a unique operational scheme, and used a common paste recipe (Spataro 2006; 2011; 2017; Szakmány and Starnini 2007; Kreiter 2010; Kreiter and Szakmány 2011; Kreiter *et al.* 2013; 2017) points towards their strong relatedness.

Strikingly, when looking even further, in the first Neolithic of north-eastern France and Belgium (*c.* 5100-4950 cal BCE), characterized by the Western Linear Pottery Culture, the forming methods used in the Balkans and Central Europe are still observed, despite again significant shifts in ceramic shapes and decoration. While the superimposition of slabs to form the base is not employed anymore, the coiling and the slab techniques are still implemented to rough-out the vessels. Moreover, the beating technique is still frequently used as a shaping technique (Gomart 2014). The identified forming methods are now often associated within the same settlements and we note an important increase in idiosyncrasies, regarding for instance procedures of coil adjunction, which tend to vary between the contemporary houses of a same village or within a micro-region (Gomart *et al.* 2015; 2017a; Gomart and Ilett 2017). As the data on forming processes between the area of emergence of the LBK culture and its final expansion area is still sparse, it remains difficult to understand the exact causes for this increase in idiosyncrasies. One has to note, however, that variety in procedures of coil adjunction was also observed on the LBK site of Bylany, in Bohemia (Neumannová *et al.* 2017).

Ultimately, this view of very distant regions along the Central European path of Neolithisation shows a general continuity in cognitive schemes from the southern Balkans to west-central Europe, over one thousand years and substantial population movements. This conservatism in ceramic forming processes is even more noticeable when focusing on the Mediterranean path of Neolithisation, where a strong technical rupture in operational schemes could be observed between the first *Impressa* settlements in south-eastern Italy (*c.* 5900-5600 cal BCE: Binder *et al.* 2017) and those located in the Ligurian-provencal arc (*c.* 5800-5600 cal BCE: Binder *et al.* 2017). While the farmers of south-eastern Italy build their pottery using the slab and the coiling techniques recognized in the Southern Balkans, the farmers settled in the Ligurian-Provencal Arc implement a radically different operational scheme, building their pottery by juxtaposition of "spiralled patches" (Gomart *et al.* 2017b). In the current state of data, this technical rupture is not interpreted as an innovation process, but as the presence of two distinct groups of farmers in the northern Mediterranean: one group, socially related to the farmers of the southern Balkans area, reaching the south-eastern Italian coasts; and another group of unknown origin, reaching the Ligurian-Provencal Arc (Gomart *et al.* 2017b).

## Conclusion

Analysing the sequences of technical gestures implemented for the manufacture of the first ceramic productions of Hungary provided new lines of thought on a period of major cultural transformation. We propose that the Starčevo and the Körös populations belonged to two distinct communities of practice, both of which had already been identified centuries earlier and 800 km further south in the early Neolithic of Bulgaria. If these results are confirmed on a larger number of Körös and Starčevo ceramic assemblages, we could then consider that the emergence of these two local variants of the Balkan early Neolithic in Hungary are related to differences existing previously within the first farming communities of the southern Balkans.

The transition between these two cultural entities of Balkan tradition and Linear Pottery might have happened according to substantially different mechanisms between the east and the west of Hungary. To the west, in Transdanubia, while continuity in ceramic forming processes was observed between the Starčevo site of Vörs-Máriaasszony-sziget and the LBK site of Balatonszárszó-Kis-erdei-dűlő, the identification of forming methods characteristic of the Körös enabled us to assume strong interactions, whose nature still needs to be determined. To the east, in the Tisza valley, a break between ways of doing implemented on the Körös site of Nagykörű-Tsz. Gyümölcsös and in the Alföld Linear Pottery structures of Polgár-Ferenci-hát was observed. This rupture and its causes (arrival of a new community of practice or local innovation) remain to be further understood through the study of a larger number of assemblages. The occurrence of a different technical tradition in the Carpathian basin shows that future research may lead to the identification of more communities of practice implied in the diffusion of Neolithic ways of life over continental Europe.

On a larger scale, we observed a transmission of the same forming methods from Bulgaria at the beginning of the sixth millennium cal BCE, to Hungary in the middle of the sixth millennium cal BCE. Furthermore, the technical practices initially observed in the Balkans and in Hungary are recognised, as being almost unchanged, among the early farmers of the Paris basin at the end of the sixth millennium cal BCE. In the considered early Neolithic contexts, it is thus difficult to interpret the perceived ceramic changes as the result of innovation processes. Rather, the technical ruptures identified in the early Neolithic ceramic assemblages seem associated with specific social dynamics, mostly implying population influx moving with their own inherited technical traditions. In the current state of data, the question of local innovation in ceramic practices remains however open for the Alföld Linear Pottery structures of Polgár-Ferenci-hát.

These observations leave open questions regarding the sociological nature of the identified communities of practice: how can we interpret the persistence of the identified technical borders along the Central European path of Neolithisation? One hypothesis to explore is the occurrence of different Neolithisation pathways from the beginning of the Balkan early Neolithic, as proposed by Salanova (2014) for Bulgaria. Data on other technological proxies should be taken into account, such as flint and bone industries: among central European farming pioneer populations, can we distinguish distinct communities of practice? Do these correlate with those observed in the ceramic technical sub-system? Does conservatism define all technical sub-systems along the European path of Neolithisation? Regarding pottery, further research on a larger corpus of sites along the central European path, focusing on the whole ceramic chaîne opératoire and including raw material data (Kreiter 2010; Kreiter *et al.* 2013; 2017) and decorative data (Marton 2004; 2008; 2013) will be needed to trace the paths of diffusion of the identified technical traditions, as well as their exact origin back to the stages of invention and broad adoption.

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## References

Anders, A., Siklósi, Z., (eds.). 2012. *The first Neolithic sites in Central/South-East European transect ; Volume III. The Körös culture in Eastern Hungary*, BAR International Series S2334. Oxford: Archaeopress.

Angeli, L., Fabbri, C., Parisi, M., Bertini, A. 2015. Pottery smoothers from Colle Santo Stefano (Ortucchio, L'Aquila). *The Old Potter's Almanack* 20, 2-16.

Angeli, L., Fabbri, C. 2017. Matières premières et technologie: l'exemple de la Céramique Imprimée à Colle Santo Stefano (Italie), in: Burnez-Lanotte, L. (ed.). *Workshop "Matières à Penser": Raw Materials Acquisition and Processing in Early Neolithic Pottery Productions*, Proceedings of the Workshop of Namur (Belgium), 29-30 May 2015 University of Namur, Séances de la Société Préhistorique Française 11. Paris: Société préhistorique française, 93-108.

Aradi, C. 1992. Vörs, Máriaasszony-sziget. *Régészeti Füzetek* 44, 26-27.

Bánffy, E. 2013. *The early Neolithic in the Danube-Tisza interfluve*, BAR International Series S2584. Oxford: Archaeopress.

Bánffy, E., Eichmann, W. J., Marton, T. 2007. Mesolithic foragers and the spread of agriculture in Western Hungary, in: Kozłowski, J.K., Nowak, M. (eds.). *Mesolithic/Neolithic Interactions in the Balkans and in the Middle Danube Basin*, Proceedings of the XVth World Congress, 04 – 09 September 2006 Lisbon, BAR International Series S1726. Oxford: Archeopress, 53-62.

Bánffy, E., Oross, K., 2010. The earliest and earlier phase of the LBK in Transdanubia, in: Gronenborn, D., Petrasch, J. (eds.). *The spread of the Neolithic to Central Europe*, International Symposium, 24 June – 26 June 2005 Mainz. Frankfurt am Main: Römisch-Germanisches Zentralmuseum, Forschungsinstitut für Vor- und Frühgeschichte, 255-273.

Bánffy, E., Sümegi, P., 2012. The early Neolithic agro-ecological barrier in the Carpathian Basin: a zone for interaction, in: Anreiter, P., Bánffy, E., Bartosiewicz, L., Meid, W., Metzner-Nebelsick, C. (eds.). *Archaeological, cultural and linguistic heritage: Festschrift for Erzsébet Jerem in Honour of Her 70th Birthday.* Budapest: Archaeolingua, 57-69.

Bentley, R., Price, T., Luning, J., Gronenborn, D., Wahl, J., Fullagar, P. 2002. Prehistoric migration in Europe: Strontium isotope analysis of early Neolithic skeletons. *Current Anthropology* 43 (5), 799-804.

Bentley, R., Krause, R., Price, T., Kaufmann, B. 2003. Human mobility at the Early Neolithic settlement of Vaihingen, Germany: evidence from strontium isotope analysis. *Archaeometry* 45, 471-486.

Bentley R., Price T., Wahl J., Atkinson T. 2008. Isotopic signatures and hereditary traits: snapshot of a Neolithic community in Germany. *Antiquity* 82, 290-304.

Binder, D., Clop Garcia, X., Convertini, F., Manen, C., Sénépart, I. 2010. Les productions céramiques du Néolithique ancien entre Provence et Catalogne, in: Manen, C., Sénépart, I., Convertini, F., Binder, D. (eds.). *Premières sociétés paysannes de Méditerranée occidentale Structures des productions céramiques*, Séance de la Société Préhistorique Française, 11 – 12 Mai 2007 Toulouse, Mémoires de la Société Préhistorique Française 51. Paris: Société préhistorique française, 115-129.

Binder, D., Lanos, P., Angeli, L., Gomart, L., Guilaine, J., Manen, C., Maggi, R., Muntoni, I., Panelli, C., Radi, G., Tozzi, C., Arobba, D., Battentier, J., Brandaglia, M., Briois, F., Carré, A., Delhon, C., Gourichon, L., Marinval, P., Nisbet, R., Rossi, S., Rowley-Conwy, P., Thiébault, S. 2017. Modelling the earliest north-western dispersal of Mediterranean Impressed Wares: new dates and Bayesian chronological model. *Documenta Praehistorica* 44, 54-77.

Biró, K.T., Gherdán, K., Szakmány, G. 2007. Ceramic sequence of 7000 years: archaeometrical study of pottery finds from Vörs, Máriaasszonysziget (SW Hungary), in: Waksman, Y. (ed.). *Archaeometric and Archaeological Approaches to Ceramics, EMAC '05 Lyon, 8th European Meeting on Ancient Ceramics*, BAR International Series S1691. Oxford: Archeopress, 25-31.

Bril, B. 2002. L'apprentissage de gestes techniques : ordre de contraintes et variations culturelles, in: Bril, B., Roux, V. (eds.). *Le Geste technique. Réflexions méthodologiques et anthropologiques.* Ramonville Saint-Agne: Editions Erès – Revue d'Anthropologie des connaissances, Technologies/Idéologies/Pratiques, 113-150.

Budja, M. 2013. Neolithic pots and potters in Europe: the end of 'demic diffusion' migratory model. *Documenta Praehistorica* 40, 38-56.

Capelli, C., Starnini, E., Cabella, R., Piazza, M. 2006. Archaeometric research on the Early Neolithic pottery production in Liguria (Northern Italy): preliminary data from San Sebastiano di Perti (Savona). *ArcheoSciences* 30, 89-94.

Capelli, C., Starnini, E., Cabella, R., Piazza, M. 2017. The circulation of Early Neolithic pottery in the Mediterranean: A synthesis of new archaeometric data from the Impressed Ware culture of Liguria (north-west Italy). *Journal of Archaeological Sciences: Reports* 16, 532-541.

Cauliez, J., Manen, C., Ard, V., Caro, J., Bruxelles, L., Convertini, F., Ben Amara, A., Bocquet-Liénard, A., Cantin, N., Savary, X., Borgen, V. 2017. Technical traditions and potter craftsmanship among the Woloyta and Oromo groups in Ethiopia. Ethnographic field for refining prehistoric ceramic analytical protocols, in: Burnez-Lanotte, L. (ed.). *Workshop "Matières à Penser": Raw Materials Acquisition and Processing in Early Neolithic Pottery Productions*, Proceedings of the Workshop of Namur (Belgium), 29-30 May 2015 University of Namur, Séances de la Société Préhistorique Française 11. Paris: Société préhistorique française, 29-58.

Commenge, C. 2009. Techniques séquentielles appliquées aux argiles: résonances orientales dans le Néolithique de Macédoine, in: Collective (ed.). *De Méditerranée et d'ailleurs…:* Mélanges offerts à Jean Guilaine. Toulouse: Archives d'Écologie Préhistorique, 205-220.

Constantin, C., Ilett, M., Burnez-Lanotte, L. 2010. La Hoguette, Limburg and the Mesolithic : some questions, in: Vanmontfort, B., Kooijmans, L., Amkreutz, L., Verhart, L. (eds.). *Pots, Farmers and Foragers : Pottery traditions and social interactions in the earliest Neolithic of the Lower Rhine area*, Archaeological Studies Leiden University 20. Leiden: Leiden University Press, 41-48.

Courty, M.A., Roux, V. 1995. Identification of wheel throwing on the basis of ceramic surface features and microfabrics. *Journal of Archaeological Sciences* 22 (1), 17-50.

Dietler, M., Herbich, I. 1994. Ceramics and ethnic identity: ethnoarchaeological observations on the distribution of pottery styles and the relationship between the social contexts of production and consumption, in: Binder, D., Audouze, F. (eds.). *Terre Cuite et Société: La Céramique, Document Technique, Économique, Culturel,* XIVe Rencontre Internationale d'Archéologie et d'Histoire d'Antibes Juan-les-Pins: Éditions APDCA, 459-472.

Gabriele, M., Boschian, G. 2013. Neolithic pottery from Pianosa Island (Tyrrhenian Sea): preliminary provenance data. *The Old Potter's Almanack* 14, 8-14.

Gelbert, A. 2003. *Ceramic traditions and technical borrowings in the Senegal Valley*. Paris: Éditions de la Maison des Sciences de l'Homme – Éditions Epistèmes.

Gomart, L. 2014. *Traditions Techniques et Production Céramique au Néolithique Ancien. Étude de Huit Sites Rubanés du Nord-Est de la France et de Belgique*. Leiden: Sidestone Press.

Gomart, L. 2016. What factors of emergence of the first Neolithic in temperate Europe? Contribution of the anthropological approach of ceramic assemblages from the early and middle Neolithic in Hungary. *Annales de la Fondation Fyssen* 29, 143-160.

Gomart, L. (in press 2013). Diversity of pottery fashioning methods during the early Neolithic in the Struma Valley (Bulgaria), in: Grebska-Kulova, M., Salanova, L. (eds.). *The Neolithization process of the Struma Strymon Valley and adjacent regions*, Proceedings of the workshop held in Blagoevgrad, *8th-10th June 2011* Blagoevgrad.

Gomart, L., Burnez-Lanotte, L. 2012. Techniques de façonnage, production céramique et identité de potiers : une approche technologique de la céramique de style non Rubané du site du Staberg à Rosmeer (Limbourg, Belgique). *Bulletin de la Société Préhistorique Française* 109, 231-250.

Gomart, L., Hachem, L., Hamon, C., Giligny, F., Ilett, M. 2015. Household integration in Neolithic villages: A new model for the Linear Pottery Culture in west-central Europe. *Journal of Anthropological Archaeology* 40, 230-249.

Gomart, L., Constantin, C., Burnez-Lanotte, L. 2017a. Ceramic production and village communities during the Early Neolithic in France and Belgium: questions about tempers and forming processes, in: Burnez-Lanotte, L. (ed.). *Workshop "Matières à Penser": Raw Materials Acquisition and Processing in Early Neolithic Pottery Productions*, Proceedings of the Workshop of Namur (Belgium), 29-30 May 2015 University of Namur, Séances de la Société Préhistorique Française 11. Paris: Société préhistorique française, 111-132.

Gomart, L., Ilett, M., 2017. From potters' hands to settlement dynamics in the early Neolithic site of Cuiry-lès-Chaudardes (Picardy, France). *Archeologické Rozhledy* 69 (2), 209-226.

Gomart, L., Weiner, A., Gabriele, M., Durrenmath, G., Sorin, S., Angeli, L., Colombo, M., Fabbri, C., Maggi, R., Panelli, C., Pisani, D.F., Radi, G., Tozzi, C., Binder, D. 2017b. Spiralled patchwork in pottery manufacture and the introduction of farming to Southern Europe. *Antiquity* 91, 1501-1514.

Gosselain, O.P. 2000. Materializing identities: An African perspective. *Journal of Archaeological Method and Theory* 7, 187-217.

Gosselain, O.P. 2002. *Poteries du Cameroun méridional: Styles techniques et rapports à l'identité.* Paris: CNRS Éditions.

Gronenborn, D. 1999. A variation on a basic theme: The transition to farming in southern central Europe. *Journal of World Prehistory* 13, 123-210.

Gronenborn, D. 2007. Beyond the models: 'Neolithisation' in Central Europe. British Academy Scholarship, in: Whittle, A., Cummings, V. (eds.). *Going Over: The Mesolithic-Neolithic transition in north-west Europe*, Proceedings of the British Academy 144. Oxford: Oxford University Press, 73-98.

Haak W., Balanovsky O., Sanchez J.J., Koshel S., Zaporozhchenko V., Adler C., Der Sarkissian C., Brandt G., Schwarz C., Nicklisch N., Dresely V., Fritsch B., Balanovska E., Villems R., Meller H., Alt K., Cooper A. 2010. Ancient DNA from European Early Neolithic farmers reveals their near eastern affinities. *PLoS Biology* 8.

Hofmanová, Z., Kreutzer, S., Hellenthal, G., Sell, C., Diekmann, Y., Díez-Del-Molino, D., Van Dorp, L., López, S., Kousathanas, A., Link, V., Kirsanow, K., Cassidy, L.M., Martiniano, R., Strobel, M., Scheu, A., Kotsakis, K., Halstead, P., Triantaphyllou, S., Kyparissi-Apostolika, N., Urem-Kotsou, D., Ziota, C., Adaktylou, F., Gopalan, S., Bobo, D.M., Winkelbach, L., Blöcher, J., Unterländer, M., Leuenberger, C., Çilingiroğlu, Ç., Horejs, B., Gerritsen, F., Shennan, S.J., Bradley, D.G., Currat, M., Veeramah, K.R., Wegmann, D., Thomas, M.G., Papageorgopoulou C., Burger, J. 2016. Early farmers from across Europe directly descended from Neolithic Aegeans, *Proceedings of the National Academy of Sciences* 113, 6886-6891.

Isern, N., Zilhão, J., Fort, J., Ammerman, A. 2017. Modeling the role of voyaging in the coastal spread of the Early Neolithic in the West Mediterranean. *Proceedings of the National Academy of Sciences* 114, 897-902.

Jakucs, J., Bánffy, E., Oross, K., Voicsek, V., Bronk Ramsey, C., Dunbar, E., Kromer, B., Bayliss, A., Hofmann, D., Marshall, P., Whittle, A. 2016. Between the Vinča and Linearbandkeramik Worlds: The diversity of practices and identities in the 54th-53rd Centuries cal BC in southwest Hungary and beyond. *Journal of World Prehistory* 29, 267-336.

Kalicz, N. 2011. Forschung über die Starčevo-Kultur in Südtransdanubien (Ungarn), in: Botić, K., Kovačević, S., Kovačević, D. (eds.). *Panonski Prapovijesni Osviti,* Zbornik Radova Posvećenih Korneliji Minichreiter Uz 65. Obljetnicu Života. Zagreb: Institut za arheologiju, 105-129.

Kalicz, N., Virág, S., Biró, K. T. 1998. The Northern periphery of the Early Neolithic Starčevo culture in south-western Hungary: a case study of an excavation at Lake Balaton. *Documenta Praehistorica* 25, 151-187.

Kalicz, N., Biró, K. T., Virág, S. 2002. Vörs, Máriaasszony-sziget, in: Collective (eds.). *Rég*észeti Kutatások Magyarországon. Budapest: Archaeological Investigations in Hungary, 15-26.

Kertész, R. and Sümegi, P. 2001. Theories, critiques and a model: Why did expansion of the Körös-Starčevo Culture stop in the centre of the Carpathian Basin?, in: Kertész, R., Makkay, J. (eds.). *From the Mesolithic to the Neolithic*, Proceedings of the International Archaeological Conference, September 22-27, 1996 Szolnok, Damjanich Museum of Szolnok. Budapest: Archaeolingua, 225-246.

Kozłowski, J.K., Raczky, P. 2010. Concluding remarks, in: Kozłowski, J.K., Raczky, P. (eds.). *Neolithization of the Carpathian Basin: Northermost Distribution of the Starcevo/Körös Culture*. Krakow/Budapest: Polish Academy of Arts and Sciences, 349-360.

Kreiter, A. 2010. Crafting difference: early Neolithic (Körös culture) ceramic traditions in north-east Hungary, in: Kozłowski, J.K., Raczky, P. (eds.). *Neolithization of the Carpathian Basin: Northermost distribution of the Starčevo/Körös Culture*. Krakow/Budapest: Polish Academy of Arts and Sciences, 266-282.

Kreiter, A., Szakmány, G. 2011. Petrographic analysis of Körös ceramics from Méhtelek-Nádas, in: Kalicz, N. (ed.). *Méhtelek. The first excavated site of the Méhtelek group of the Early Neolithic* Körös Culture in the Carpathian Basin, BAR International Series S2321, Central European Series 6. Budapest: Archaeolingua, 113-130.

Kreiter, A., Pető, Á., Pánczél, P., Bánffy, E. 2013. Materializing tradition: ceramic production in Early Neolithic Hungary, in: Bánffy, E. (ed.). *The Early Neolithic of the Danube-Tisza Interfluve*, BAR International Series S2584. Oxford: Archaeopress, 127-140.

Kreiter, A., T. Marton, L. Gomart, K. Oróss, Pánczél, P. 2017. Looking into houses: Analysis of LBK ceramic technological change on a household level, in: Burnez-Lanotte, L. (ed.). *Workshop "Matières à Penser": Raw Materials Acquisition and Processing in Early Neolithic Pottery Productions*, Proceedings of the Workshop of Namur (Belgium), 29-30 May 2015 University of Namur, Séances de la Société Préhistorique Française 11. Paris: Société préhistorique, 111-132.

Kreiter, A., Marton, T., Oross, K., Pánczél, P. in press. Looking into pots: understanding Neolithic ceramic technological variability from Western Hungary, in: Amicone, S., Radivojević, M., Quinn, P., Marić, M., Mirković, M. (eds.). *Tracing Pottery Making Recipes in the Balkans, 6th – 4th Millennium BC*. Oxford: Archaeopress.

Kvetina, P., Gomart, L., Thér, R., Neumannová, K. 2017. Beyond the technological chain: Neolithic potters in social networks, *Archeologické Rozhledy* 69, 163-171.

Latour, B., Lemonnier, P. 1994. *De la Préhistoire aux missiles balistiques. L'intelligence sociale des techniques*. Paris: Éditions La découverte.

Leroi-Gourhan, A. 1964. *Le Geste et la Parole, Tome 1 : Technique et Langage*. Paris: Albin Michel.

Lichardus-Itten, M. 1986. Premières influences méditerranéennes dans le Néolithique du Bassin parisien, in: Demoule, J.-P., Guilaine, J. (eds.). *Le Néolithique de La France. Hommage à Gérard Bailloud*. Paris: Picard, 147-159.

Lipson, M., Szécsényi-Nagy, A., Mallick, S., Pósa, A., Stégmár, B., Keerl, V., Rohland, N., Stewardson, K., Ferry, M., Michel, M., Oppenheimer, J., Broomandkhoshbacht, N., Harney, E., Nordenfelt, S., Llamas, B., Mende, B.G., Köhler, K., Oross, K., Bondár, M., Marton, T., Osztás, A., Jakucs, J., Paluch, T., Horváth, F., Csengeri, P., Koós, J., Sebők, K., Anders, A,. Raczky, P., Regenye, J., Barna, J.P., Fábián, S., Serlegi, G., Toldi, Z., Nagy, E.G., Dani, J., Molnár, E., Pálfi, G., Márk, L., Melegh, B., Bánfai, Z., Domboróczki, L., Fernández-Eraso, J., Mujika-Alustiza, J.A., Fernández, C.A., Echevarría, J.J., Bollongino, R., Orschiedt, J., Schierhold, K., Meller, H., Cooper, A., Burger, J., Bánffy, E., Alt, K.W., Lalueza-Fox, C., Haak W., Reich, D. 2017. Parallel palaeogenomic transects reveal complex genetic history of early European farmers. *Nature* 551, 368-372.

Livingstone-Smith, A. 2001. *Chaîne opératoire de la poterie : références ethnographiques, analyses et reconstitution*. Bruxelles: Thèse de Doctorat en Philosophie et Lettres de l'Université Libre de Bruxelles – Faculté de Philosophie et Lettres.

Manen, C., Convertini, F. 2012. Neolithization of the western Mediterranean: Pottery productions, circulation and recombination, in: Borrel, M., Borrel, F., Bosc, J., Clop, X., Molist, M. (eds.). *Networks in the Neolithic. Exchange of Raw Materials, Products and Ideas in the Western Mediterranean (VII-III Millenium BC)*, Actes del Congrés Internacional Xarxes al Neolític 02 – 04 Février 2011. Gavà: Museu de Gavà, 363-368.

Marton, T. 2004. Material finds from Balatonszárszó Neolithic settlement: connections within and without the TLPC territory. *Antaeus* 27, 81-86.

Marton, T. 2008. Development of pottery style on the LBK settlement of Balatonszárszó-Kis-Erdei-Dűlő in Hungary, in: Luca, S.A. (ed.). *Acta Terrae Septemcastrensis VII*, Proceedings of the International Colloquium: The Carpathian Basin and its role in the Neolithisation of the Balkan Peninsula. Sibiu: Editura ALTIP, 197-216.

Marton, T. 2013. LBK households in Transdanubia: a case study, in: Anders, A., Kulcsár, G. (eds.). *Moments in time, papers presented to Pál Raczky on his 60th birthday*, Ősrégészeti Tanulmányok, 1. Budapest: L'Harmattan, 159-172.

Marton, T., Oross, K., 2009. Reconstructing space in a familiar world: the formation of late LBK settlements in Central Transdanubia, in: Kozłowski, J.K. (ed.). *Interactions between Different Models of Neolithization North of the Central European Agro-Ecological Barrier*, Prace Komisji Prehistorii Karpat 5. Kraków: Polska Akademia Umiejętności, 51-73.

Mauss, M. 1947. *Manuel d'ethnographie*. Paris: Payot.

Neumannová, K., Petřík, J., Vostrovská, I., Dvořák, J., Zikmund, T., Kaiser, J. 2017. Variability in coiling technique in LBK pottery inferred by experiments and pore structure micro-tomography analysis. *Archeologické Rozhledy* 69, 163-171.

Oross, K. 2004. Das neolithische Dorf von Balatonszárszó. Forschungen zwischen 2000-2002. *Antaeus* 27, 61-80.

Oross, K. 2010. Architecture of the Linearbandkeramik settlement at Balatonszárszó-Kis-erdei-dűlő in Central Transdanubia, in: Gheorghiu, D. (ed.). *Neolithic and Chalcolithic archaeology in Eurasia: Building techniques and spatial organization*, Proceedings of the XVth World Congress UISPP, 04-09 September 2006, Lisbon, BAR International Series S2097. Oxford: Archaeopress, 63-80.

Oross, K. 2013. *Balatonszárszó-Kis-erdei-dűlő lelőhely középső neolit településszerkezete és Közép-európai párhuz-amai, The Middle Neolithic settlement structure of the Site at Balatonszárszó-Kis-erdei-dűlő in a Central European Context.* (Unpublished Doctoral dissertation) Budapest: Eötvös Loránd University.

Oross, K., Siklósi, Z. 2012. Relative and absolute chronology of the early Neolithic in the Great Hungarian Plain, in: Anders, A., Siklósi, Z. (eds.). *The first Neolithic sites in Central/South-East European transect, Volume III. The Körös culture in Eastern Hungary*, BAR International Series S2334. Oxford: Archeopress, 129-159.

Perrin, T., Manen, C., Valdeyron, N., Guilaine, J. 2018. Beyond the sea… The Neolithic transition in the southwest of France. *Quaternary International* 470, 318-332.

Pierret, A., Moran, C. J., Bresson, L.-M. 1996. Calibration and visualization of wall-thickness and porosity distributions of ceramics using X-radiography and image processing. *Journal of Archaeological Sciences* 23, 419-428.

Price, T.D., Bentley, R.A., Lüning, J., Groneneborn, D., Wahl, J. 2001. Prehistoric human migration in the Linearbandkeramik of Central Europe. *Antiquity* 75, 593-603.

Price, T.D., Wahl, J., Bentley, R.A. 2006. Isotopic evidence for mobility and group organization among Neolithic farmers at Talheim, Germany, 5000 BC. *European Journal of Archaeology* 9, 259-284.

Raczky, P. 2004. Polgár, Ferenci-hát, in: Collective (eds.). Régészeti Kutatások Magyarországon, Archaeological Investigations in Hungary. Budapest: Hungarian National Museum.

Raczky, P. 2012. Nagykörű-Tsz. Gyümölcsös (co-operative orchard), in: Anders, A., Siklósi, Z. (eds.). *The first Neolithic sites in central/south-east European transect. Volume III. The Körös culture in eastern Hungary*, BAR International Series S2334 Oxford: Archeopress, 97-105.

Raczky, P., Anders, A., 2009. Settlement history of the Middle Neolithic in the Polgár micro-region (The development of the Alföld Linearband Pottery in the Upper Tisza Region, Hungary), in: Kozłowski, J.K. (ed.). *Interactions between different models of Neolithisation north of the central European agro-ecological barrier*, Papers presented on the symposium organized by the EU Project FEPRE, Prace Komisji Prehistorii Karpat 5. Kraków: Polska Akademia Umiejętności, 31-50.

Raczky, P., Sümegi, P., Bartosiewicz, L.,·Gál, E., Kaczanowska, M., Kozłowski, J.K., Anders, A. 2010. Ecological barrier versus mental marginal zone? Problems of the northernmost Körös Culture settlements in the Great Hungarian Plain, in: Gronenborn, D., Petrasch, J. (eds.). *The spread of the Neolithic to central Europe*, International symposium, 24 – 26 June 2005 Mainz. Frankfurt: Römisch-Germanisches Zentralmuseum Forschungsinstitut für Vor- und Frühgeschichte, 147-172.

Roux, V. 2009. Technological Innovations and Developmental Trajectories: Social Factors as Evolutionary Forces, in: O'Brien, M.J., Shennan, S.J. (eds.). *Innovation in cultural systems: Contributions from evolutionary Anthropology*. Massachusetts/London: The MIT Press, 217-234.

Roux, V. 2011. Anthropological interpretation of ceramic assemblages : foundations and implementations of technological analysis, in: Scarcella, S. (ed.). *Archaeological ceramics: A review of current research*, BAR International Series S2193. Oxford: Archeopress, 80-88.

Roux, V. 2016. Ceramic manufacture: the chaîne opératoire approach, in: Hunt, A. (ed.). *Oxford handbook of archaeological ceramic analysis*. Oxford: Oxford University Press, 101-113.

Roux, V., Bril, B., Cauliez, J., Goujon, A.-L., Lara, C., Manen, C., de Saulieu, G., Zangato, E. 2017. Persisting technological boundaries: Social interactions, cognitive correlations and polarization. *Journal of Anthropological Archaeology* 48, 320-335.

Rye, O.S. 1981. *Pottery technology*, Manuals on archeology 4. Washington: Taraxacum.

Salanova, L. 2014. *Les premières communautés agro-pastorales de Bulgarie (6100-5600 av. J.-C.)*, Compte-rendu de l'Académie des Inscriptions et Belles-Lettres. Paris: De Boccard, 421-441.

Salanova, L., Vieugué, J., Gomart, L. 2010. Методика на изследване на големи керамични комплекси: сериация на неолитната керамика от Ковачево (България). *Arheologia (Sofia)* 34, 7-23.

Salanova, L., Gomart, L., Vieugué, J. (in press). 6000 BC in Southwest Bulgaria: diversity and discontinuities during the Neolithization process, in: Biehl, P., Rosenstock, E. (eds.). *Times of change: The turn from the 7th to the 6th millennium BC in the Near East and South-east Europe*. Cambridge: Cambridge University Press.

Shepard, A.O. 1956. *Ceramics for the archaeologist.* Washington D.C: Carnegie Institution of Washington.

Spataro, M. 2006. Typology versus technological choices: an Early Neolithic case study from Banat (Romania). *Analele Banatului* 14, 63-77.

Spataro, M. 2011. A comparison of chemical and petrographic analyses of Neolithic pottery from South-eastern Europe. *Journal of Archaeological Sciences* 38 (2), 255-269.

Spataro, M. 2017. Innovation and regionalism in the middle/late Neolithic of south and south-eastern Europe (ca. 5,500-4,500 cal. BC): a ceramic perspective, in: Burnez-Lanotte, L. (ed.). *Workshop "Matières à Penser": Raw Materials Acquisition and Processing in Early Neolithic Pottery Productions*, Proceedings of the Workshop of Namur (Belgium), 29-30 May 2015 University of Namur, Séances de la Société Préhistorique Française 11. Paris: Société préhistorique, 61-80.

Szakmány, G., Starnini, E., Raucsik, B. 2005. Preliminary archaeometric investigation of early-Neolithic pottery of the Körös culture (Hungary), Proceedings of the 33rd international symposium on archaeometry, 22-26 April 2002 Amsterdam, Geoarchaeological Bioarchaeological Studies 3. Amsterdam: Institute for Geo- and Bioarchaeology, 269-272.

Szakmány, G., Starnini, E. 2007. Archaeometric research on the first pottery production in the Carpathian Basin: manufacturing traditions of the Early Neolithic, Körös Culture ceramics. *Archeometriai Műhely* 2, 5-21.

Szécsényi-Nagy, A. Brandt, G., Haak, W., Keerl, V., Jakucs, J., Möller-Rieker, S., Köhler, K., Mende, B.G., Oross, K., Marton, T., Osztás, A., Kiss, V., Fecher, M., Pálfi, G., Molnár, E., Sebők, K., Czene, A., Paluch, T., Šlaus, M., Novak, M., Pećina-Šlaus, N., Ősz, B., Voicsek, V., Somogyi, K., Tóth, G., Kromer, B., Bánffy, E., Alt, K.W. 2015. Tracing the genetic origin of Europe's first farmers reveals insights into their social organization. *Proceedings of the Royal Society B* 282.

Thér, R. 2016. Identification of pottery-forming techniques using quantitative analysis of the orientation of inclusions and voids in thin sections. *Archaeometry* 58, 222-238.

Thér, R., Toms, P. 2016. Quantification of the orientation and alignment of aplastic components of a ceramic body as a method for distinguishing among various means of using a rotational device in pottery forming. *Journal of Archaeological Sciences: Reports* 9, 33-43.

Van Dooselaere, B., Burnez-Lanotte, L., Gomart, L., Livingstone-Smith, A. 2016. The end of diversity? Pottery technology at the LBK-Blicquy/Villeneuve-Saint-Germain transition in Hesbaye, Belgium, in: Amkreutz, L., Haack, F., Hofmann, D., van Wijk, I. (eds.). *Something out of the ordinary? Interpreting diversity in the early Neolithic Linearbandkeramik and beyond.* Newcastle upon Tyne: Cambridge Scholars Publishing, 159-189.

Vieugué, J., Gomart, L., Salanova, L. 2010. Les Estèques en céramique des potiers néolithiques de l'habitat de Kovačevo (6200-5500 av. J.-C.), *Bulletin de La Société Française* 107/4, 709-723.

Virág, Z.M., Kalicz, N. 2001. Neuere Siedlungsfunde der Frühneolithischen Starčevo-Kultur aus Südwestungarn, in: Ginter, B. (ed.). *Problems of the Stone Age in the Old World*. Kraków: Uniwersytet Jagielloński-Instytut Archeologii, 265-279.

Vuković J. 2017. Erasing boundaries or changing identities? The transition from Early/Middle to Late Neolithic, new evidence from Southern Serbia, in: Gori M., Ivanova, M. (eds.). *Balkan dialogues: Negociating Identity between Prehistory and the Present*. London: Routledge, 240-253.

Anders, A., Arbogast, R.-M., Bentley, A., Bickle, P., Blesl, C., Cramp, L., Cullen, P., Dale, C., Dočkalová, M., Domboróczki, L., Fibiger, L., Francken, M., Gerling, C., Griffiths, S., Grupe, G., Hamilton, J., Hedges, R., Hofmann, D., Kalicz, N., Kovács, Z. E., Lenneis, E., Marton, T., Mateiciucová, I., Neugebauer-Maresch, C., Nowell, G., Oross, K., Pap, I., Pavúk, J., Pechtl, J., Raczky, P., Reynard, L., Schultz, M., Stadler, P., Stephan, E., Teschler-Nicola, M., Tiefenböck, B., Wahl, J., Whittle A., Wright, C. 2013. Hungary, in: Bickle, P., Whittle, A. (eds.). *The First Farmers in Central Europe: Diversity in LBK Lifeways*. Oxford: Oxbow Books, 49-100.

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# Changes in the pottery production of the Linear Pottery Culture. Origins and directions of ideas

*Anna Rauba-Bukowska, Agnieszka Czekaj-Zastawny*

## Abstract

The recipe of clay masses used in the pottery production of the Linear Pottery Culture, or Linearbandkeramik (LBK; 5500-4900 BCE) is extremely standardised. In south-eastern Poland, significant changes in this respect appeared from the late 6th millennium, that is, since the beginning of the 3rd chronological phase of this culture's development (Želiezovce phase). This period also witnessed an intensification of contacts with the south, manifested by an increase in the number of imported artefacts (obsidian and ceramic) from the Eastern (or Alföld) Linear Pottery Culture (ALPC). During this phase, changes in ceramic recipes are noticeable. They become technologically similar to the production characteristics of the Eastern Linear Pottery Culture (the Bükk Culture is chronologically simultaneous to Želiezovce phase).

Detailed analysis of vessel fragments indicates that contacts between the LBK and the Eastern Linear Pottery Culture were not only based on the exchange of material goods, but also on the exchange of innovations (*i.e.* information on recipes for preparing ceramics). The exchange of ideas is also expressed by the presence of vessels interpreted as local imitations of Eastern Linear pottery (local clay, foreign ornamentation). However, the existence of individual manufacturers of the Bükk Culture origin within LBK settlements cannot be excluded either.

*Keywords: Early Neolithic, Linear Pottery Culture, Bükk Culture, pottery production, south-eastern Poland*

## Introduction

The LBK (belonging to the Western Linear Pottery Circle) extended to south-eastern Poland in its Pre-Music-Note phase (I) (the Bíňa and the Milanovce phases in SW Slovakia; cf. Pavúk 2004; Kulczycka-Leciejewiczowa 1983; Czekaj-Zastawny 2009, 2017). The earliest groups of the LBK migrated to SE Poland from SW Slovakia and

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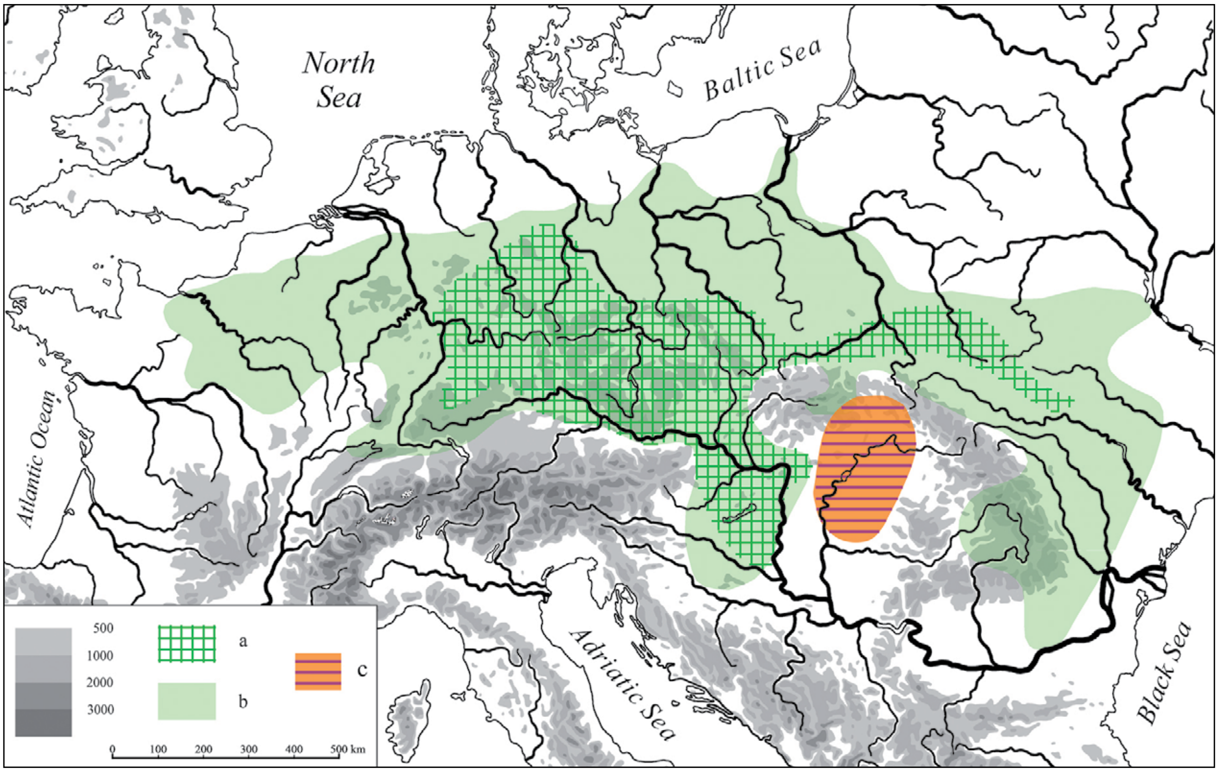


*Figure 1. Linear Pottery Circle in Europe: a – extent in the early phase of the Linear Pottery Culture development (LBK), b – maximum extent of the Linear Pottery Culture, c – maximum extent of, the Bükk Culture.*

Moravia through the Moravian Gate. There are nearly 30 sites representing the oldest LBK phase in Lesser Poland (Kozłowski *et al.* 2014). In the Music-Note phase (II), the LBK population gradually increased, reaching its peak in the Želiezovce phase (III) (Fig. 1). At the same time, in the 6th and 5th millennium BCE, the Eastern Linear Pottery Circle (ALPC) developed in the Middle and Upper Tisza River Basin and the Eastern Slovak Lowland (Kozłowski *et al.* 2014). During the second phase of the ALPC, the number of flint artefacts imported from south-eastern Poland grew within the ALPC area. Simultaneously, imports into south-eastern Poland of obsidian artefacts began, accompanied by the Eastern Linear pottery.

In total, over 50 sites in south-eastern Poland with imported artefacts were reported. It seems that in the primary stage the contacts were rather occasional given the lack of obsidian artefacts, while early ALPC pottery is only known from 19 sites (Kaczanowska and Godłowska 2009). Moreover, on the other side of the Carpathians only a few sites with Jurassic and chocolate flint can be mentioned (Kaczanowska *et al.* 2001; Mateiciucová 2002). In the course of the LBK development, a gradual flourishing of goods' exchange between both Linear Circles took place. There are many more sites known from the Music-Note and Želiezovce phases (53 for the Music-Note phase, and 51 for the Želiezovce phase; Kaczanowska and Godłowska 2009). An intensification of contacts with the south is noticeable at most of the LBK settlements in south-eastern Poland, especially from the late Music-Note phase. This can mainly be observed in an increase of the amount of obsidian artefacts imported (cf. Czekaj-Zastawny 2014, 123-125). This intensification of contact has also been proved by a rapid growth in the contribution of Jurassic flint from the Polish Jurassic Highland at sites of the Eastern Linear Pottery Circle, which could have reached up to 70% of the lithic assemblage (Kaczanowska and Godłowska 2009, 143). Those contacts suddenly ceased simultaneously with the decline of LBK and Bükk Culture. Nowadays, based on studies of pottery like vessels from the site no. 17 in Brzezie, it is possible to identify the exact regions from which these imports originated. The Šariš Valley and the Eastern Slovak Lowland should be mentioned. From these areas pottery characteristic of the Tiszadob-Kapušany group of ALPC had been imported almost since the beginning of the Music-Note phase of the LBK, and from the late Music-Note phase and during the Želiezovce phase, Bükk Culture pottery with obsidian artefacts were the main imports (Czekaj-Zastawny 2017).

## Development of pottery technology in the LBK

Technological aspects of the pottery made by the LBK communities in the south-eastern part of Poland have been studied in recent years within the scope of several scientific projects (*e.g.* Czekaj-Zastawny and Rauba-Bukowska 2013; Rauba-Bukowska 2014a; Rauba-Bukowska 2016; Moskal-del Hoyo *et al.* 2017), with a special focus on the grain-size distribution of samples, their mineralogical and petrographic composition, as well as the quantity ratios of particular inclusions (Czekaj-Zastawny and Rauba-Bukowska 2013; Czekaj-Zastawny *et al.* 2017; Moskal-del Hoyo *et al.* 2017; Rauba-Bukowska *et al.* 2007, 2014a). The technological aspects of the pottery were investigated with the use of various techniques (*e.g.* Scanning Electron Microscopy-Energy Dispersive Spectroscopy, X-ray powder diffraction, X-ray fluorescence), including thin sections observed under a polarising microscope. The grain-size distribution in samples, their mineralogical and petrographic composition, and the component quantity ratios using the point counting method (Bolewski and Żabiński 1988; Quinn 2013), were determined (Rauba-Bukowska *et al.* 2007; Rauba-Bukowska 2014a). There are three main functional kinds of LBK pottery which are characterised by different technologies (Tab. 2; Rauba-Bukowska *et al.* 2007; Rauba-Bukowska 2014a; Czekaj-Zastawny *et al.* 2017; Moskal-del Hoyo *et al.* 2017). The first kind represents "table ware" (so called thin-walled pottery or fine ware) usually made of heavy or silty clay, not containing coarser mineral components (technological type I and II; Tab. 2). This pottery is vulnerable to shrinking and cracking during drying and firing and is poorly resistant to heat. Its surfaces are well-polished and decorated with linear ornamentation. The fabric contains a small amount of organic material. The second kind of pottery (so called medium thick-walled pottery or "kitchen ware") was made of a clay fabric with a higher content of larger and well-sorted sand grains (technological type III and V; Tab. 2), which increases its resistance to thermal shock during firing, and the subsequent use of vessels for cooking. They have well-finished surfaces and were often decorated with plastic ornamentation, such as knobs and lines of finger impressions. The raw material was tempered with mineral and organic matter. The last kind includes big storage pots (so called 'thick-walled pottery' or 'coarse ware') made of clay tempered with large amounts of varying organic (plant) and inorganic materials, which increases the porosity of this ware (technological type IV, VI and VII; Tab. 2). This pottery has hygroscopic properties and is suitable for storing dried products. Its surfaces are coarse and not ornamented.

The differences in ceramic fabrics are also noticeable during all three basic chronological phases of the LBK development (phase I – Pre-Music Note; phase II – Music Note; phase III – Želiezovce). A sample consisting of 302 thin sections of LBK and 43 thin sections of the Eastern Linear Pottery Culture (Tab. 1), obtained from pottery fragments, was subjected to statistical analyses. They indicated changes in utilisation of intentional admixtures, mostly plant and grog (Czekaj-Zastawny *et al.* 2017; Moskal-del Hoyo *et al.* 2017).

Based on the microscopic point counting method, various amounts of organic temper, mainly of plant origin, were observed in the three morphological types of the LBK pottery, being the highest in the coarse ware, and the lowest within the fine ware (Fig. 2). Initially, during the early phase of LBK development, the use of organic additives was very common, as evidenced by visible plant remains and voids in all morphological types of vessels, as they were present in approximately

| Country | site | cultural affiliation | LBK phase | | | ALPC | Total number of samples tested | sources |
|---|---|---|---|---|---|---|---|---|
| | | | Pre-Music-Note | Mu-sic-Note | Želiezovce | Bükk Culture | | |
| Poland | Aleksandrowice 2 | LBK | | 8 | | | 8 | Czekaj-Zastawny and Rauba-Bukowska 2013 |
| Poland | Brzezie 17 | LBK, ALPC (Bükk Culture) | | 31 | | 6 | 37 | Rauba-Bukowska *et al.* 2007; Rauba-Bukowska 2014b; Czekaj-Zastawny, Rauba-Bukowska 2013 |
| Poland | Brzezie 40 | LBK | | | 50 | | 50 | Rauba-Bukowska 2013 |
| Poland | Gwoździec 2 | LBK | 12 | 6 | | | 18 | Czekaj-Zastawny, Rauba-Bukowska 2013 |
| Poland | Kobylany 1 (cave) | LBK | | | 1 | | 1 | Czekaj-Zastawny, Rauba-Bukowska 2013 |
| Poland | Krzesławice 42 | LBK, ALPC (Bükk Culture) | | 2 | | 3 | 5 | Kozłowski *et al.* 2014 |
| Poland | Łoniowa 18 | LBK | | | 8 | | 8 | Czekaj-Zastawny and Rauba-Bukowska 2013 |
| Poland | Modlnica 5 | LBK | 10 | 12 | | | 22 | Czekaj-Zastawny and Rauba-Bukowska 2013 |
| Poland | Modlniczka 2 | LBK | 6 | 6 | | | 12 | Czekaj-Zastawny and Rauba-Bukowska 2013 |
| Poland | Mogiła 62 | LBK, ALPC (Bükk Culture) | 26 | 13 | 8 | 4 | 51 | Czekaj-Zastawny and Rauba-Bukowska 2013; Kozłowski *et al.* 2014 |
| Poland | Ojców 3 (cave) | LBK | | 2 | 1 | | 3 | Czekaj-Zastawny and Rauba-Bukowska 2013 |
| Poland | Pleszów 17-20 | LBK, ALPC (Bükk Culture) | 4 | 2 | 9 | 2 | 17 | Czekaj-Zastawny and Rauba-Bukowska 2013; Kozłowski *et al.* 2014 |
| Poland | Samborzec 1 | LBK | 7 | 8 | 5 | | 20 | Czekaj-Zastawny and Rauba-Bukowska 2013 |
| Poland | Targowisko 16 | LBK | | | 13 | | 13 | Rauba-Bukowska 2007 |
| Poland | Targowisko11 | LBK | 19 | 7 | | | 26 | Rauba-Bukowska *et al.* 2007; Czekaj-Zastawny and Rauba-Bukowska 2013 |
| Poland | Wierzchowie 2 (cave) | LBK | | | 1 | | 1 | Czekaj-Zastawny and Rauba-Bukowska 2013 |
| Poland | Więckowice 4 | LBK | | | 1 | | 1 | Czekaj-Zastawny and Rauba-Bukowska 2013 |
| Poland | Wyciąże 5 | LBK | | 5 | 2 | | 7 | Czekaj-Zastawny and Rauba-Bukowska 2013 |
| Poland | Zagórze 2 | LBK | 15 | 1 | 1 | | 17 | Czekaj-Zastawny and Rauba-Bukowska 2013; Rauba-Bukowska 2016 |
| Slovakia | Košice-Galgovec | ALPC (Bükk Culture) | | | | 1 | 1 | Kozłowski *et al.* 2014 |
| Slovakia | Matejovce | ALPC (Bükk Culture) | | | | 1 | 1 | Kozłowski *et al.* 2014 |
| Slovakia | Prešov-Solivar | ALPC (Bükk Culture) | | | | 6 | 6 | Kozłowski *et al.* 2014 |
| Slovakia | Šarišské Michaľany | ALPC (Bükk Culture) | | | | 9 | 9 | Czekaj-Zastawny *et al.* 2018 |
| Slovakia | Stráne pod Tatrami | ALPC (Bükk Culture) | | | | 1 | 1 | Kozłowski *et al.* 2014 |
| Slovakia | Veľky Šariš | ALPC (Bükk Culture) | | | | 3 | 3 | Kozłowski *et al.* 2014 |
| Slovakia | Zemplínske Kopčany | ALPC (Bükk Culture) | | | | 7 | 7 | Czekaj-Zastawny *et al.* 2018 |
| **total** | | | **99** | **103** | **100** | **43** | **345** | |

*Table 1. List of analysed samples (N=345).*

90% of pottery fragments studied. In the middle phase, the organic material was found in 69% of the analysed vessels, while in the late phase only 51% of specimens contained organic material (Fig. 3).

The largest changes in this respect are detectable in the fired clay tempered with organic material in potsherds from thin-walled vessels. In the early phase, 87% of

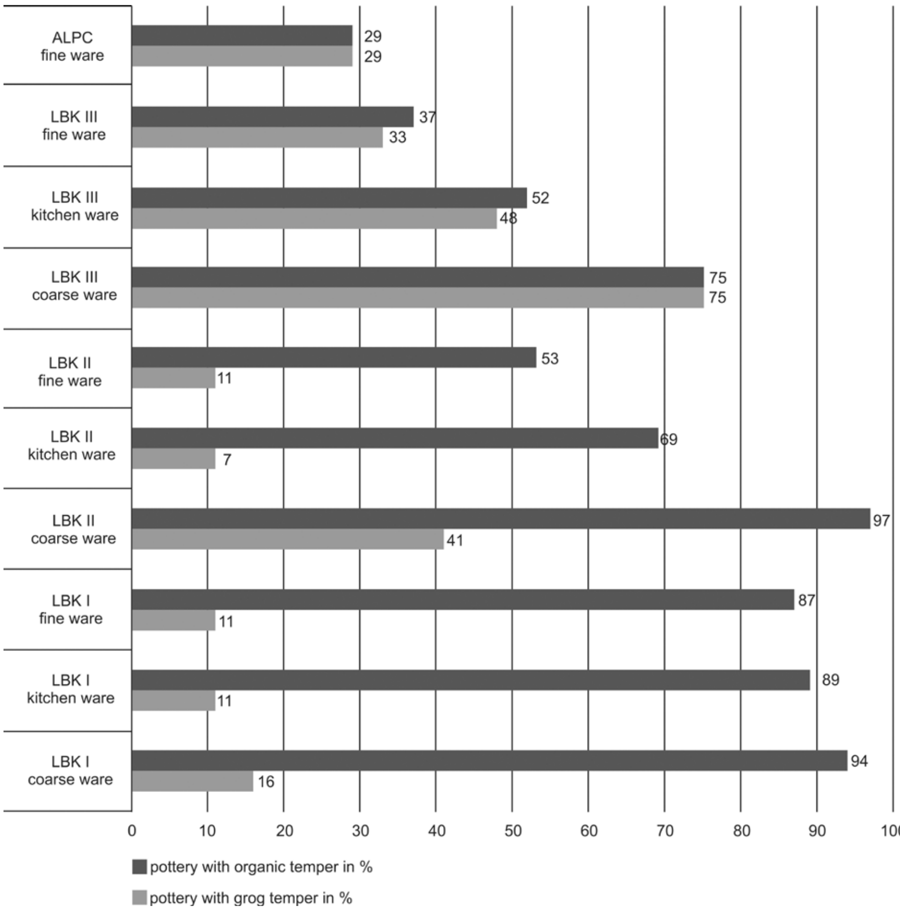


*Figure 2. Percentage of samples with grog and organic admixtures with the division into morphological types and chronological phases (total number of samples N=345).*

fine ware contained organic temper, whereas in the late phase only 37% revealed these kinds of additives (Fig. 2). A similar effect can be observed in the pottery classified as "kitchen ware" (Fig. 2). The third group of pottery (coarse ware) was less sensitive to the above-mentioned trends, yet a significant decrease in the content of organic material was observed in the youngest chronological phase (Fig. 2). Therefore, a clear and systematic trend in the process of preparing clay for potting can be noted, showing much less use of organic material as temper in the pottery from the late phase (Fig. 3). These differences can be correlated with the changes in the selection of raw materials suitable for making pottery. During the early and classical phases, mostly heavy clays, often of marine origin, were used (Czekaj-Zastawny and Rauba-Bukowska 2014a). The average amounts of clay minerals and quartz in fine vessels from the oldest phase were 64% and 22%, respectively (Fig. 4). In the following phase, the changes were almost imperceptible. Significant differences can be seen in the late phase, when the average amounts of clay minerals and quartz were 56% and 27%, respectively (Fig. 4). In the latter phase, fine pottery was frequently made of fine silty clay (Fig. 5a, c). Another feature indicating the change in pottery production technique was an increase in the amount of crushed ceramics (grog) used as tempering material in the pottery. This can be correlated with a decreasing use of organic temper, as mentioned above. This difference is well illustrated by an example of coarse ware, in which crushed ceramics totalled 16%, 41% and 75% of the analysed vessels for the early, classic and late phase, respectively (Fig. 2, 5b, d).

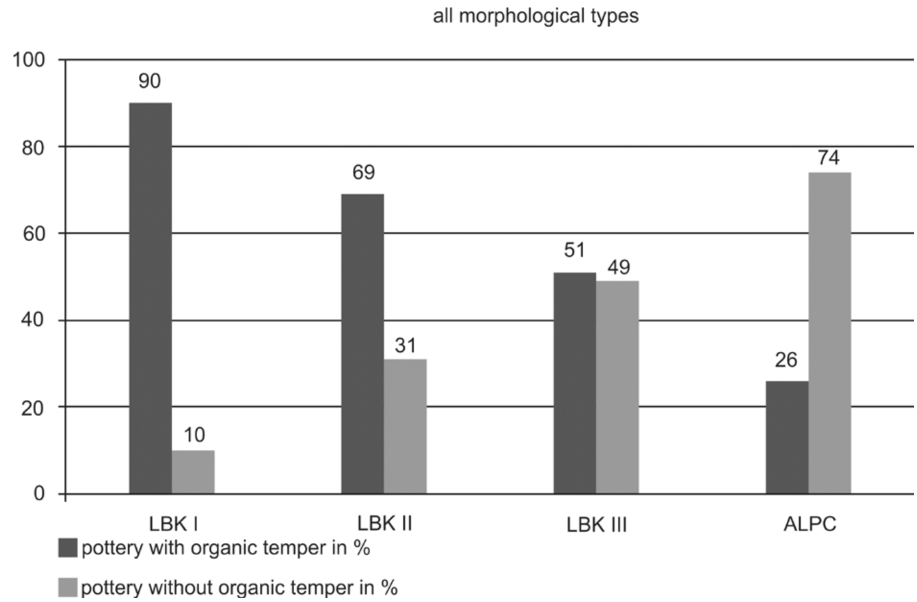


*Figure 3. Graph presenting a percentage of samples with organic admixture in the chronological phases of the LBK and the ALPC pottery (N=345).*

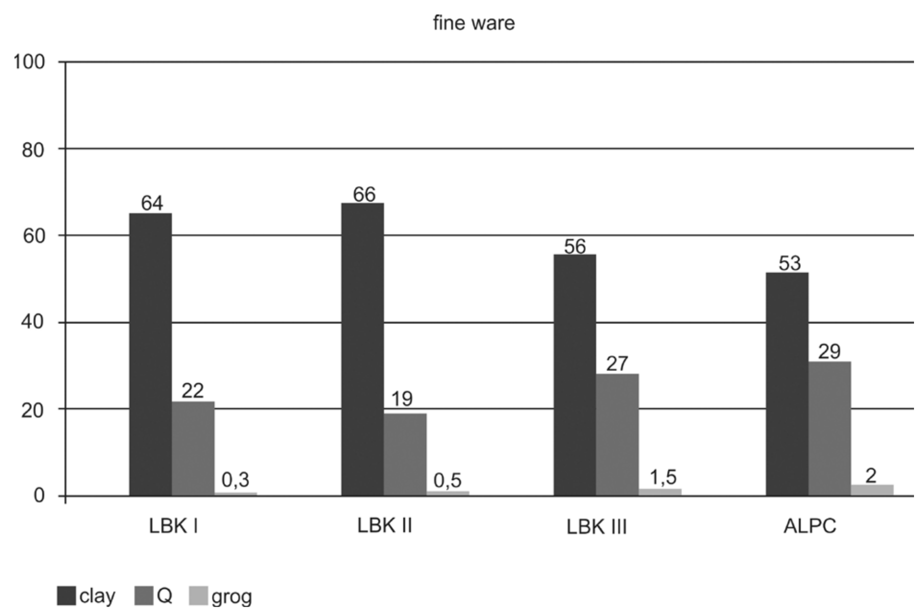


*Figure 4. Graph showing an average content of clay minerals (clay), quartz (Q) and grog in ceramics of all phases of the LBK development and in the ALPC (N=345). Value in %.*

## Pottery of the Bükk Culture

The Bükk Culture developed a very high standard of ceramic production. Generally, a limited range of pottery forms is in strong contrast with their rich and unique decoration. The most common element for Bükk thin-walled pottery is a deep semi-spherical to three-quarter-spherical decorated bowl with a wide mouth. Seven variants of this type have been recognised. Amongst other distinctive types there are bowls, pseudo-amphorae, amphorae and vases. Thick-walled pottery is represented by semi-spherical bowls, conical bowls, bottle-shaped storage vessels, pots, amphora-shaped pots, and stemmed bowls. The decoration on pottery can be divided into six groups, regarding its position on the vessel: main, complementary inter-decoration, under the rim, above the bottom, on the bottom and on the internal surface (Hreha and Šiška 2015). With regard to the ornamentation technique, it is generally divided into several groups such as: A/grooves, B/punctures, C/impressed shallow circular dimples, D/"plastic" protrusions, tapes, barbotine, E/perforation. In respect of the thin-walled pottery, thinly engraved ornamentation prevails. The thick-walled pottery is mostly decorated with "plastic" protrusions and perforations (Hreha and Šiška 2015).

The ceramic fabric used in the production of Bükk Culture pottery from eastern Slovakia is characterised by several features. Analysis of thin sections was performed on 43 fragments of the Bükk pottery (mostly thin-walled), (Tab. 1, Fig. 6). Average contents of clay minerals, quartz and grog, for thin-walled pottery were respectively: 53%, 29% and 2% (Fig. 4). Grog was present in 29% of thin-walled vessels. Organic admixture was also established in 29% of the examined pottery (Fig. 2). Certain vessels were produced using the grog technology, others by adding an organic (plant) admixture. Finally, there is in 42% of the Bükk pottery analysed a ceramic fabric without any added temper, neither organic nor grog – these fine wares show a homogenous, well made, preselected paste with subangular grains (Kozłowski *et al.* 2014; Rauba-Bukowska 2014b; Czekaj-Zastawny *et al.* 2018: Fig. 6a, c). Pottery of the Bükk Culture from the Hungary area corresponds in this respect with the pottery from eastern Slovakia. Thin-walled vessels are generally characterised by a fine-grained, compact, homogeneous fabric. The raw material is assumed to have been carefully selected and prepared; ceramic fabrics were not artificially tempered (Szilágyi *et al.* 2011; Szilágyi *et al.* 2014).

## Conclusions

The authors recorded a tendency for using raw materials containing significant amounts of silty quartz fraction in the preparation of ceramic fabrics for making pottery from the third phase of the LBK (Želiezovce phase). The second significant feature of the examined pottery from this phase is a predominance of sand and grog admixtures. As the grog admixture emerged, the amount of organic additives decreased. In general, thin-walled vessels of the Želiezovce phase were most frequently made in the II-type technology, therefore using silty, fine-grained materials, sometimes with admixtures of fine grog and organic material. Thick-walled vessels were usually made in the III-, VI- and VII-type technology, thus with admixtures of sand and grog, sometimes with plant admixture as well (Tab. 2; Rauba-Bukowska *et al.* 2007; Rauba-Bukowska 2014a; Czekaj-Zastawny 2014, 53-55, 113-116, 152-153). In contrast to the Pre-Music Note phase and Music Note phase of the LBK, there are very few examples of vessels produced in the I-type technology (fine-grained mass with very small compound of quartz, without mineral, and with little organic admixture), and IV-type technology (mass with a little amount of quartz and admixture of fragments of clay rocks).

Based on the microscopic amount of data collected, it can be stated that the pottery of the Želiezovce phase and that of the Bükk Culture reveal very similar features in terms of their ceramic fabrics. This mainly concerns thin-walled pottery, made of homogenous, fine-grained, compact pastes, mostly without admixtures (Figs. 5a, c, 6a, c). Values presented for the late phase of the LBK development in the Upper Vistula River Basin display similarities to the Bükk pottery from the present area of south-eastern Slovakia (Figs. 2, 3, 4). The ceramic masses are similar, but the ornaments are typical of each of these cultures.

Based on the gathered data it can be assumed that the development of the Želiezovce technology was influenced by contacts with the south. Manufacturers of the LBK pottery started to use ceramic fabric recipes similar to those of the ceramic fabrics of Bükk pottery. They probably thought of it as being more technologically advanced, especially since the manner of decorating vessels was not adopted at all. The more advanced technology from the Eastern Linear Pottery Culture had a stronger potential impact (no evidence supporting a distribution of the LBK technology to the south, only the export of flint artefacts). The style of ornamentation was a visible determinant of affiliation to the particular cultural unit. Whereas, the

| fabric type | LBK (Lesser Poland) | | | short description of fabric types |
|---|---|---|---|---|
| | I phase | II phase | III phase | |
| I | 22% | 28% | 13% | heavy clay, fine grained, moderately sorted, admixture of organic fragments |
| II | 28% | 19% | 35% | silty clay, fine grained, well sorted, admixture of organic fragments |
| III | 24% | 34% | 22% | heavy to silty clay, coarse grained, poorly sorted, admixture of organic fragments and sand |
| IV | 23% | 17% | 3% | heavy clay, fine grained, admixture of sedimentary rocks and organic fragments |
| V | 3% | 1% | 2% | heavy to silty clay, coarse grained, poorly sorted, admixture of sand and organic fragments |
| VI | - | 1% | 14% | heavy to silty clay, admixture of grog |
| VIII | - | - | 11% | heavy to silty clay, admixture of grog and sand |

*Table 2. Percentage number of samples assigned to each fabric type during all phases of the LBK development, sites from territory of Poland (N=302, Tab. 1).*

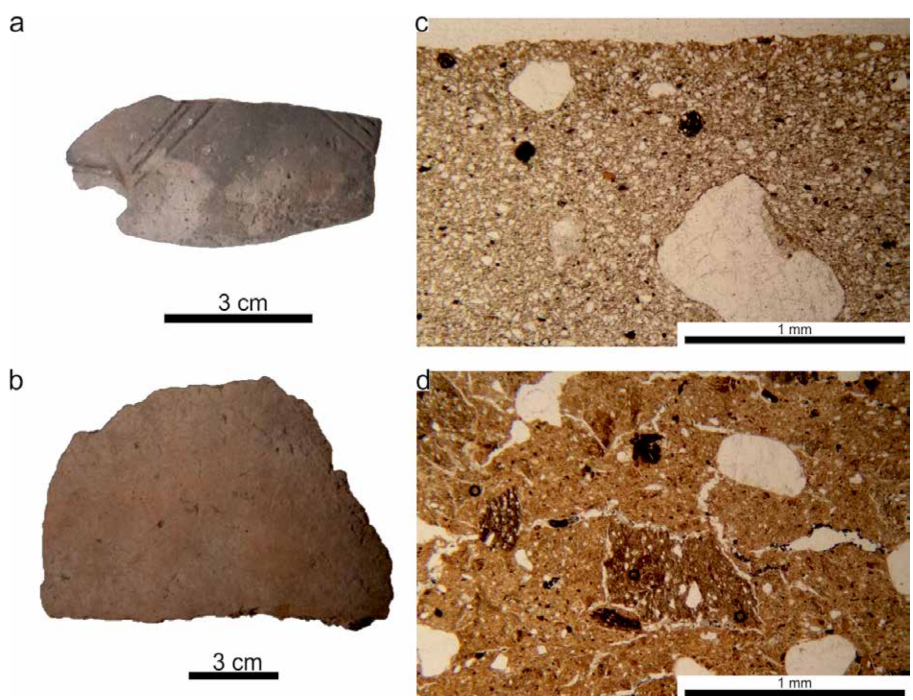


*Figure 5. LBK, Želiezovce phase, fragments of vessels (a-b) and microphotographs of ceramic masses (c-d); a – fine pottery, sample no. Ple10; b – coarse ware, sample no. Ple14; c – homogeneous, compact ceramic fabric with rare sand grains, sample no. Ple10, PPL; d – heterogeneous with grog temper ceramic fabric, sample no. Ple14, PPL.*

manners of clay preparation, determining the physical features of vessels and their durability, were clearly of utilitarian significance in pottery production. The circulation of this idea and adaptation of these types of manufacturing solutions enhanced the development of the technology itself, as well as the skills of the manufacturers.

This statement raises further questions connected with the nature of contacts between those two cultural circles (Czekaj-Zastawny 2014, 123-125). Perhaps they involved the meeting of people from two different areas, exchanging goods and ideas (according to P. Valde-Nowak 1998, which could have taken place, for example, during the summer pasturage in mountain valleys), or the migration of small groups (families?) or individuals to the Upper Vistula River Basin from the south.

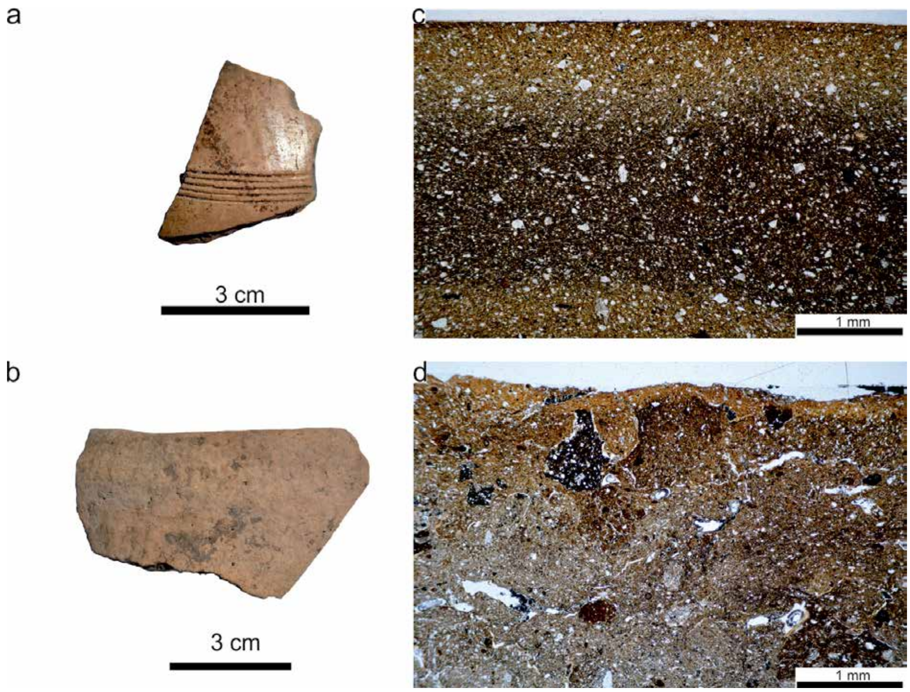


*Figure 6. Bükk Culture, fragments of vessels (a-b) and microphotographs of ceramic masses (c-d); a – fine pottery, sample no. SarMich23; b – coarse ware, sample no. ZempKop33; c – homogeneous, compact ceramic fabric, sample no. SarMich23, PPL; d – heterogeneous with grog temper ceramic fabric, sample no. ZempKop33, PPL.*

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## References

Bolewski, A., Żabiński, W. (eds.). 1988. *Metody badań minerałów i skał*. Warszawa: Wydawnictwo Geologiczne.

Czekaj-Zastawny, A. 2009. *Settlement of the Linear Pottery Culture in Southeastern Poland. The First Neolithic Sites in Central/South-East European Transect,* Volume V, BAR International Series S2049. Oxford: Archaeopress.

Czekaj-Zastawny, A. 2014. *Brzezie 17. Osada kultury ceramiki wstęgowej rytej*, Via Archaeologica, Źródła z badań wykopaliskowych na trasie autostrady A4 w Małopolsce. Kraków: Krakowski Zespół do Badań Autostrad.

Czekaj-Zastawny A. 2017. The first farmers from the South – Linear Pottery culture, in: Urbańczyk, P. (ed.). *The Past Societies. Polish Lands from the First Evidence of Human Presence to the Early Middle Ages 2 (5500 – 2000 BC)*. Warszawa: Instytut Archeologii i Etnologii PAN, 21-62.

Czekaj-Zastawny, A., Rauba-Bukowska, A. 2013. *Technologia i chronologia najstarszych naczyń glinianych w dorzeczu górnej Wisły (VI/V tys. BC).* Kraków (unpublished report for the National Centre of Science – the project no. N109 181040).

Czekaj-Zastawny, A., Rauba-Bukowska, A. 2014. Technology of the earliest vessels in the upper Vistula River basin – imports against local pottery, in: Kienlin, T.L., Valde-Nowak, P., Korczyńska, M., Cappenberg, K., Ociepka, J. (eds.). *Settlement, Communication and Exchange around the Western Carpathians*, International Workshop held at the Institute of Archaeology, 27-28 October 2012 Jagiellonian University, Kraków. Oxford: Archaeopress, 95-107.

Czekaj-Zastawny, A., Kadrow, S., Rauba-Bukowska, A. 2017. Ceramic raw material acquisition and transfer of technological ideas among the Early Neolithic communities around the Western Carpathians, in: Burnez-Lanotte, L. (ed.). *Workshop "Matières à Penser": Raw Materials Acquisition and Processing in Early Neolithic Pottery Productions*, Proceedings of the Workshop of Namur (Belgium), 29-30 May 2015 University of Namur, Séances de la Société Préhistorique Française 11. Paris: Société préhistorique, 81-91.

Czekaj-Zastawny, A., Rauba-Bukowska, A., Hreha, R. 2018. Colorants used to decorate the Bükk Culture vessels, in: Valde-Nowak, P., Sobczyk, K., Nowak, M., Źrałka, J. (eds.). *Multas per Gentes et Multa per Saecula. Amici magistro et collegae suo Ioanni Christopho Kozłowski dedicant*. Kraków: Alter, 351-359.

Hreha, R., Šiška, S. 2015. *Bukovohorská Kultúra na Slovensku vo svetle výskumov v Šarišských Michaľanoch and Zemplínskych Kopčanoch*. Nitra: VEDA, vydavateľstvo SAV, Archeologický ústav SAV.

Kaczanowska, M., Godłowska, M. 2009. Contacts between the Eastern and Western Linear Cultures in south-eastern Poland, in: Kozłowski, J. (ed.). *Interactions between different models of neolithization north and central European agro-ecological barrier*. Kraków: Polska Akademia Umiejętności, 137-149.

Kaczanowska, M., Kaminská, L., Kozłowski, J.K., Nowak, M., Vizdal, M. 2001. Slovensko-polský výskum neolitického sídliska v Moravanoch. *AVANS* 2000, 97-100.

Kozłowski, J., Kaczanowska, M., Czekaj-Zastawny, A., Rauba-Bukowska, A., Bukowski, K. 2014. Early/Middle Neolithic Western (LBK) vs Eastern (ALPC) Linear Pottery Cultures: ceramics and lithic raw materials circulation. *Acta Archaeologica Carpathica* 49, 37-76.

Kulczycka-Leciejewiczowa, A. 1983. O zofipolskim stylu ceramiki wstęgowej rytej w Polsce. *Archeologia Polski* 28, 67-97.

Mateiciucová, I. 2002. Štipaná kamenná industrie z pohřebiště v "Široké u lesa", in: Podborský, V. (ed.). *Dvě pohřebiště neolitického lidu s lineární keramikou ve Vedrovicích na Moravě*. Brno: Filozofická fakulta Masarykovy univerzity, 217-234.

Moskal-del Hoyo, M., Rauba-Bukowska, A., Lityńska-Zając, M., Mueller-Bieniek, A., Czekaj-Zastawny, A. 2017. Plant materials used as temper in the oldest Neolithic pottery from south-eastern Poland. *Vegetation History and Archaeobotany* 26 (3), 329-344.

Pavúk, J. 2004. Early Linear Pottery Culture in Slovakia and the Neolithisation of Central Europe, in: Lukes, A., Zvelebil, M. (eds.). *LBK Dialogues. Studies in the formation of the Linear Pottery Culture*, BAR International Series S1304. Oxford: Archaeopress, 71-82.

Quinn P.S. 2013. *Ceramic Petrography. The Interpretation of Archaeological Pottery and Related Artefacts in Thin Section*. Oxford: Archaeopress.

Rauba-Bukowska, A., Czekaj-Zastawny, A., Grabowska, B., Zastawny, A. 2007. Wyniki badań mineralogiczno-petrograficznych naczyń kultury ceramiki wstęgowej rytej i malickiej ze stanowisk Brzezie 17 i Targowisko 11, gm. Kłaj, woj. Małopolskie, Results of mineralogical and petrographic research on vessels of linear band pottery culture and malice culture from sites Brzezie 17 and Targowisko 11, Kłaj commune, małopolska province. *Sprawozdania Archeologiczne* 59, 63-113.

Rauba-Bukowska, A. 2007. Charakterystyka mineralogiczno-petrograficzna ceramiki z epoki wczesnego neolitu z wybranych stanowisk w okolicy Krakowa, [PhD thesis], typescript in the archives of the AGH University of Science and Technology. Kraków (unpulished).

Rauba-Bukowska, A. 2013. Analiza mineralogiczno-petrograficzna szlifów ceramiki KCWR z fazy żeliezowskiej ze stanowiska Brzezie 40, gmina Kłaj, woj. Małopolskie. Typescript in the archives of the Institute of Archaeology and Ethnology Gdańsk University (unpublished).

Rauba-Bukowska, A. 2014a. Wyniki badań mineralogiczno-petrograficznych naczyń kultury ceramiki wstęgowej rytej ze stanowiska Brzezie 17, gm. Kłaj, in: Czekaj-Zastawny, A. *Brzezie 17. Osada kultury ceramiki wstęgowej rytej*, Via Archaeologica, Źródła z badań wykopaliskowych na trasie autostrady A4 w Małopolsce. Kraków: Krakowski Zespół do Badań Autostrad, 437-458.

Rauba-Bukowska, A. 2014b. Wyniki badań mineralogiczno-petrograficznych naczyń importowanych kręgu wschodniolinearnego, odkrytych na stanowisku Brzezie 17, gm. Kłaj, in: Czekaj-Zastawny, A., *Brzezie 17. Osada kultury ceramiki wstęgowej rytej*, Via Archaeologica, Źródła z badań wykopaliskowych na trasie autostrady A4 w Małopolsce. Kraków: Krakowski Zespół do Badań Autostrad, 459-468.

Rauba-Bukowska, A. 2016. Analiza mineralogiczna i technologiczna fragmentów naczyń ceramicznych kultury ceramiki wstęgowej rytej ze stanowiska Zagórze 2, gm. Niepołomice. *Raport* 11, 7-22.

Szilágyi, V., Taubald, H., Biró, K.T., Koós, S.J., Csengeri, P., Tóth, M. and Szakmány, Gy. 2011. Preliminary archaeometric data on fine ware from the Middle Neolithic Bükk culture, in: Memmi, I. (ed). *Proceedings of the 37th International Symposium on Archaeometry, 13th-16th May 2008 Siena, Italy, Part 1*. Berlin/Heidelberg/New York: Springer, 159-167.

Szilágyi, V., Biró, K.T., Csengeri, P., Szakmány, Gy., Taubald, H., Mihály, J., Berthold, C., Koós, J.S., Zöldföldi, J. 2014. Petro-mineralogical and geochemical characterisation of Middle Neolithic Bükk Culture fine ware from Garadna, NE Hungary, in: Martinón-Torres, M. (ed.). *Craft and science: International perspectives on archaeological ceramics*. Doha: Bloomsbury Qatar Foundation. DOI: http://dx.doi.org/10.5339/uclq.2014.cas.ch20

Valde-Nowak, P. 1998. The Pastoral Neolithic of European Mid Mountains, in: Pearce, M., Tosi, M. (red.). *Papers from the EAA Thid Annual Meeting at Ravenna 1997, vol. I: Pre- and Protohistory*, BAR International Series S717. Oxford: Archaeopress, 86-91.

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# Innovations in ceramic technology in the context of culture change north of the Carpathians at the turn of the 6th and 5th millennia BCE

*Sławomir Kadrow*

## Abstract

This article explains the place, and role of innovation in selected aspects of ceramic technology in the process of the transformation of areas located north of the Carpathians in the early Neolithic. Due to the availability of rich archaeological materials and their geographical location, this goal can most easily be achieved through a multilateral analysis of the early Neolithic remains, represented mainly by Linearbandkeramik (LBK), in the Rzeszów settlement region. Among others, the trends of the variability of the technology and stylistics of ceramics, the supply of stone raw materials, and the size of settlements against the dynamics of the development of demographic processes were analysed. As the most effective method of interpretation, the theory of Pierre Bourdieu was recognized. In the transformation process of early Neolithic communities in the Rzeszów region, innovations in ceramics technology appeared to be a routinized and non-discursive element of a broad stream of social and culture changes. They are the result and mirror of these changes and, at the same time, one of their co-constitutive and co-shaping factors.

*Keywords: LBK, society, technological innovation, pottery, transformation*

## Introduction

The purpose of this article is to explain the place and role of innovation in selected aspects of ceramic technology (replacing the organic admixture in the ceramic mass by adding grog), in the process of the transformation of areas located north of the Carpathians in south-eastern Poland during the early Neolithic. The appearance, adaptation and dissemination of new techniques for preparing ceramic clays in vessels produced by the population of the *Linearbandkeramik* (LBK) are analysed. Due to

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the availability of rich archaeological materials and their geographical location, this goal can most easily be achieved through a multilateral analysis of the early Neolithic remains in the Rzeszów settlement region. It provides an insight into the processes of settlement and socio-cultural changes (see Kadrow 1990a), accompanying technological innovations in ceramics. The projection of observations made in this region on the wider background of south-eastern Poland and the northern part of the Carpathian Basin enriches and confirms the explanation of the sequence of changes and the nature of the socio-cultural transformation.

Another goal of the article is to find answers to the questions, whether innovation in ceramics technology was one or only one of many factors causing transformation in the social and cultural sphere? Or maybe the innovation in ceramics technology was only a side effect of other, more important transformation factors in the early Neolithic period in south-eastern Poland?

I intend to achieve these goals by outlining changes in ceramic technology against the background of changes in selected categories of remains (pottery, stone raw materials *etc.*) and other material remnants of the past (dwellings, settlement patterns and demography) from the early Neolithic in areas north of the Carpathians. In the outlined context of the change processes of the above-mentioned elements, the role and impact of ceramics technology innovation on cultural change will be assessed (substitution of the LBK by the Malice culture). The Pierre Bourdieu's theory of practice and the theory of cultural analysis of Robert Wuthnow help us in understanding the reconstructed transformation processes.

## The social context of technological innovations

In everyday language, innovation is any change that improves something, gives a new quality or allows you to create a new product or service. It is not important whether this change occurs quickly or slowly, whether it is of a rapid or evolutionary nature. The innovation described in this article in the preparation of the mineralogical composition of ceramic masses for the production of vessels took place in the long-term development of the LBK communities in south-eastern Poland over approximately a 500 year period (see Rauba-Bukowska 2014b; Kadrow and Rauba-Bukowska 2017a; 2017b). This innovation had the character of fluent, slow but targeted changes, imperceptible from the perspective of the transient generations of ceramic manufacturers.

This innovation fits perfectly within the system of activities and production behaviours known as habitus, which is a system of embodied dispositions, usually shared by people with a similar cultural background, that organize the ways in which individuals perceive the social world around them (Bourdieu 2008). Activities of this type are always routinized. They are therefore taken consciously but never in a discursive manner, *i.e.* known, fully aware of the technological correctness and accepted recipe. Such a character of the described changes in technological activities is perfectly confirmed by the graph of the correspondence analysis of the analysed ceramic samples from the whole LBK development period in south-eastern Poland. The clear trend of changes also consists of quite numerous cases of "inconsistent", *i.e.* not in accordance with the predicted "behaviour" of the analysed samples.

The human body is a medium through which artefacts are made and used. The human body has individuality and is socialized (Dobres 2000, 5). The properties of the body of the manufacturer / producer and the character of the habitual technological operations mean that during any production, random changes ("mutations") can inevitably appear in the current system of embodied dispositions. Will they become the beginning of rapid or evolutionary innovations in a particular technology, or will they only be unnoticed mutations without any consequences? This, however, depends not on the producer himself but primarily on the socio-political context in which he operates.

Important mainstays of culture (world views, social values) are expressed, reaffirmed, contested, and changed in the course of mundane and taken-for-granted routines of everyday artefact production and use (Dobres 2000, 5). The knowledge engendered during habitual technical practices is simultaneously personal and social. It is deeply entrenched in history and symbolic representations. Technological knowledge has both transformative and political potential and technology always has the possibility of being about relations of power (Dobres 2000, 5).

The understanding of the social and material plexus of technological activities manifesting in everyday practice is most comprehensible in light of the reflexive sociology of Pierre Bourdieu, in which he develops the concepts of field, habitus, social capital and symbolic violence (see Bourdieu and Wacquant 2001, 45-170; Bourdieu 2007, 192-226, 265-286; 2008, 72-90, 154-185). Taking into account only one of the mentioned terms and omitting the others does not allow for the proper explanation and understanding of the phenomena studied (Bourdieu and Waquant 2001, 76), including the processes of early Neolithic transformation. This is also due to the theory of practice being part of the theory of becoming a society (*e.g.* Sztompka 2007, 204-208) or structuring theory as part of a more general theory of the constitution of society (Giddens 2003, 39-75), in which the respective constituent elements of theories always work together in inseparable relationships. The fairly common acceptance of the habitus concept (*e.g.* Květina *et al.* 2017, 163), with the lack of interest in the concept of symbolic power, field, social capital *etc.* will allow an explanation of the causes and mechanisms of even long periods of stagnation, but will not allow for penetration into the generators and dynamics of real processes of social and cultural transformation.

The field is comparable to the economic, political, religious, aesthetic, or intellectual "order of life" (*Lebensordnugen*) of Max Weber. In the case described in this article, one can speak of a (sub) technological field. Fields are characterized by specific values and have their own regulating principles (Wacquant 2001, 20-22). Fields are not the result of free creativity but obey undisclosed and uncodified regularities. Operation in a given field is like a card game. Players combine participation in the game with acceptance of its rules and common beliefs (*doxa*) (see Bourdieu and Wacquant 2001, 78-79). The field theory must be accompanied by an adequate theory of *agency* and *social agents* (Wacquant 2001, 22).

Habitus is – as already mentioned – a system of permanent dispositions, functioning as structuring structures, *i.e.* as principles generating and organizing practices and ideas that can be objectively adapted to the goal, without requiring a conscious goal orientation and deliberate mastery of activities necessary to achieve this goal. The system of disposition is a past that continues in the present and seeks to survive in the future through updating in practices structured in accordance with its principles (Bourdieu 2008, 72-74). Habitus is the internationalization of external structures and generates strategies that allow a person to deal with different situations in a consistent and systematic way. Both concepts – field and habitus – are relational and can only function in a mutual relationship. Habitus leaves some space for improvisation (Wacquant 2001, 22).

The concept of social capital is also relational with the concept of field. Capital is something effective in a given field, something that is both a weapon and a stake in the game that allows its owner to exercise power and influence. In a particular research practice, determining what is a field is tantamount to determining what types of capital are important in this field (Bourdieu and Wacquant 2001, 78-80). In the case of studies on early Neolithic ceramic technology in south-eastern Poland, it seems that social capital of considerable importance is the mastering of the ceramic technology of the Bükk culture, so readily imported and imitated, which also affects ceramic production in many regions of the LBK.

Symbolic violence (power) is also a relational concept with the concept of field and social capital and a key concept for understanding and explaining socio-cultural transformation. Symbolic violence (power) results from the possibility of having and using economic and/or symbolic capital. In the case of the early Neolithic communities, this symbolic type of capital was definitely more important. There is an adequacy of cognitive and social structures in every community, with social divisions and thought patterns being structurally homologous. Symbolic systems are not just tools of cognition but also tools of domination (ideologies according to Marx). As factors of cognitive integration, they participate – thanks to their logic – in integrating society around a freely/arbitrarily imposed order (Wacquant 2001, 19). Ideologies not only legitimize the existing order but also participate – as a driving force – in the creation of new socio-cultural systems as tools that people use to defend their interests and achieve their goals (see Wuthnow 1987; Kadrow 2017, 174-176, 180 -182).

Robert Wuthnow's theory of cultural analysis is particularly helpful in the archaeological detection of periods of uncertainty characterized by the intensification of ritualistic activities. Conflicts then grew and it is easy to grasp the action of various forms of symbolic violence (ideology). As a result, there was a change or deep socio-cultural transformation (Wuthnow 1987; Kadrow 2017).

## The spatial and chronological range of the analysis

Analyses of technological innovations in ceramics in the context of socio-cultural transformation of the early Neolithic are conducted in the area of two settlement regions of south-eastern Poland, one of which is located in the vicinity of Krakow. There is a sequence of early Neolithic (LBK and Malice culture – MC) evolution documented in the archaeological sites investigated under the large, modern, wide-scale rescue excavations on the A4 motorway route (Czekaj-Zastawny and Przybyła 2012; Czekaj-Zastawny 2014; Czerniak *et al.* 2007; Czerniak 2013; Kadrow and Okoński 2008; Kadrow 2015; Zastawny 2014 *etc.*). The region is located south-east of Kraków, between the Vistula and Raba rivers (the so-called "Brzezie region" – see Czekaj-Zastawny 2008, Figs. 52, 61, or "Targowisko" region – see Czerniak 2013). It is part of the extensive settlement area of the LBK over the upper Vistula (Czekaj-Zastawny 2008, 82-115; Fig. 53). To the north of the Vistula, on the area of the region described above, there is a site 62 in Kraków Nowa Huta-Mogiła. The full LBK pottery evolution sequence discovered there, represented by numerous materials, made it possible to reconstruct the development trends of the ceramic technology of this culture, which were also confirmed in other areas occupied by this culture (Kadrow and Rauba-Bukowska 2017a, 271-276).

The second region is located in the same place as the modern city of Rzeszów in the Wisłoka river valley (Fig. 1; cf. Kadrow 1990a). Most of the materials from this area come from rescue excavations conducted in the 1950s and 1960s (Aksamit 1961; 1962; 1963; 1964; 1966; 1968; Dębowski 1968; Dzieduszycka-Machnikowa 1959). Due to the rushed nature and research methods used then, the settlement traces registered there do not meet current expectations. The system of small and narrow excavation units made it impossible, for example, to document the presence of long houses in the majority of the sites surveyed there, with the exception of site 34 in Rzeszów (Kadrow 1990b, 1990c; 1997). Fortunately, on one of the Neolithic settlements of this region, modern excavations were carried out in recent years (Zwięczyca, site 3 – cf. Dębiec 2015), thanks to which it is now easier to interpret older discoveries. This region cannot be omitted, however, due to the presence of materials from the oldest phase of the MC, found there, which

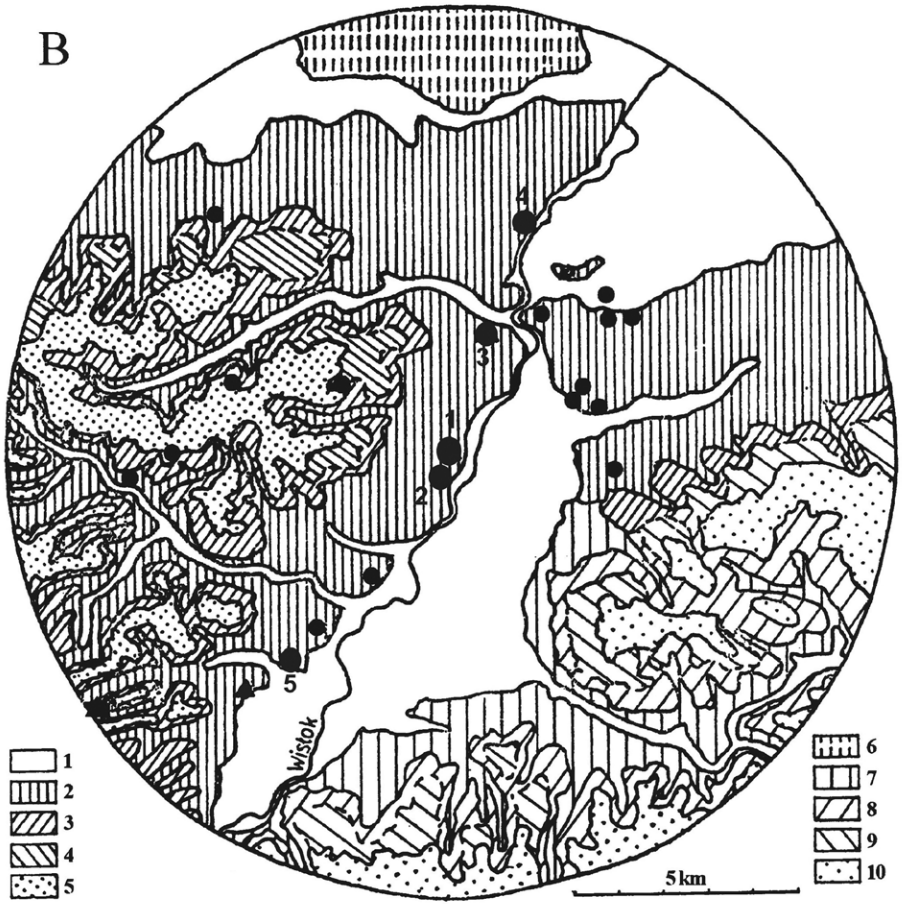


*Figure 1. Rzeszów region of early Neolithic settlement; legend: 1 – bottom of the river valley, 2 – over floodplain loess terrace; 3-5 – higher zones of landscape with loess cover; 6-10 – higher zones of landscape without loess cover; black circles – early Neolithic sites including: 1 – Rzeszów, site 16; 2 – Rzeszów, site 20; 3 – Rzeszów, site 3; 4 – Rzeszów, site 34; 5 - Zwięczyca, site 3.*

makes it possible to reconstruct the cultural transformation at the threshold of the LBK and the culture mentioned above.

Both regions are located on the northern foreland of the Carpathians. The vast majority of settlements are located in the valleys of small rivers but also in the direct hinterland of the valleys of the larger rivers: the Vistula in the Kraków and Wisłok in the Rzeszów region (Fig. 1). Loess and loess-like soils predominate there. In addition to long-term occupied settlements, where traces of long houses are discovered (*e.g.* Czekaj-Zastawny 2008, 38-55, Figs. 7-33, Czerniak 2013), there is a greater number of small traces of settlement (encampments, non-permanent settlements), located around the former (see Kadrow 1990a, Fig. 7).

The bases of LBK's relative chronology, developed some years ago by Juraj Pavúk for south-western Slovakia (1969; 1980) and Anna Kulczycka-Leciejwiczowa for south-eastern Poland (1979), also work in the Kraków and Rzeszów region in the light of new discoveries (Kadrow 1990b; Czekaj-Zastawny 2008, 116-117; Dębiec 2015). The relative chronology of MC is based on stylistic and typological arrangements of ceramics from the Rzeszów region (Kadrow 1996).

The number of 14C dates for LBK is still far from sufficient. Only three published short series of radiocarbon dates originate from south-eastern Poland: Olszanica (9 dates – see Milisauskas 1986), Brzezie 17 (16 dates – see Czekaj-Zastawny 2008, 25, Tab. 1) and Zwięczyca 3 (9 dates – see Dębiec 2014, 107-108, Tab. 13) and some single dates from other sites. It is not always in accordance with these dates that the first, oldest phase (I) of LBK should be dated to 5600-5400 BCE phase II (music-note) on 5400-5100 BCE and phase III (Želiezovce) on 5100-5000 BCE. However, it is clear that a certain number of dates from this phase even indicate the period 4700-4550 BCE (Czekaj-Zastawny 2008, 116). Two decades earlier, a slightly different time frame was proposed for the subsequent phases of the early Neolithic period in the Rzeszów region: phase I 5600-5500 BCE, phase II 5500-5050 BCE and phase III LBK 5050-4800 BCE. The beginning of MC (phase Ia.) falls on 4800-4700 BCE and the classic phase (Ib.) MC for the period 4700-4500 BCE (Kadrow 1990a, 39-41, Fig. 6).

## The cultural evolution and cultural change around the Western Carpathians in the Neolithic in light of previous research

The LBK spread to south-eastern Poland and the Western Volhynian Upland in Ukraine in its pre-music-note phase (I) (the Bíňa and the Milanovce phases in south-western Slovakia; cf. Pavúk 2004; Kulczycka-Leciejewiczowa 1983; Czekaj-Zastawny 2008, 16-18; Dębiec 2015). The earliest LBK groups migrated to south-eastern Poland from south-western Slovakia and Moravia through the Moravian Gate (Kozłowski *et al.* 2014, 39).

In the music-note phase (II), the LBK population gradually increased reaching its peak in the Želiezovce phase (III), although some researchers believe the maximum demographic development fell in phase II (Czekaj-Zastawny 2008, 116). During the LBK evolution, the inner rhythm of cultural change was the same throughout almost the whole of south-eastern Poland and in south-western Slovakia. The course of its development ran differently, however, on the borderland of Poland and the Ukraine, and more to the east and south-east, where assemblages from the music-note phase (II) have only been the LBK pottery recorded, and where no ceramic materials representing the Želiezovce phase (III) have been found to date. It is difficult to determine, therefore, whether LBK settlement lasted there solely to the end of phase II (*e.g.* Larina 1999; Larina and Dergachev 2017, 7-9) or longer, to the end of phase III, but without adapting the Želiezovce style used in the ornamentation of ceramics in south-western Slovakia. However, there are some influences from the youngest phase of LBK (*e.g.* Kozłowski 1985; Kadrow and Rauba-Bukowska 2017a, 275-276).

Some archaeologists argue that there was no cultural or settlement continuation of the LBK in the MC. They believe that contacts between south-eastern Poland and the borderland between east Slovakia and north-eastern Hungary ceased abruptly with the end of the LBK and the Bükk culture (Kozłowski *et al.* 2014, 41). Post-Linear settlers, *i.e.* MC communities, presumably came from the Carpathian Basin across the mountains (Kaczanowska 1990; Kamieńska and Kozłowski 1990; Kozłowski 2004, 11).

Other researchers question this explanation. They prefer the model of a gradual but profound process of change within the LBK community in its late phase (III) (Kulczycka-Leciejewiczowa 2004, 21). The change, they maintain, brought about the transformation of the LBK into the MC (Kadrow 2005, 26-27). Reconstruction of the trend of changes (innovations) in the technology of LBK ceramics and the discovery of their inspiration helps to understand the mechanism of this cultural transformation.

## The innovations in the LBK ceramics in south-eastern Poland

About 400 samples of ceramics and clay ascribed to the LBK from south-eastern Poland, including imports and imitations of the ALPC (Alföld Linear Pottery culture), have been collected in recent years as part of the implementation of two grant projects financed by Polish National Science Centre (NCN) grant Nos N 109 181040 and 2013/09/B/HS3/03334.

The technological analysis of these ceramics has centred on the mineralogical and petrographic composition and component quantity ratios. Subsequently, quantitative petrographic analysis (point counting; see Quinn 2013 with references within) was used to determine the percentage of individual components (cf. Rauba-Bukowska 2014b; Kadrow and Rauba-Bukowska 2017a; 2017b). Due to limited funds and lack of access to the appropriate ceramic material, chaîne opératoire analyses were abandoned.

The petrographic analysis of pottery from Site 62 in Kraków – Nowa Huta-Mogiła, which has been dated to every phase of the LBK, identified the basic trends in the evolution in clay preparation. The organic material contained in the ceramic fabric used by the LBK changed with time, and depended on the type of pottery. It has been recorded in 90 % of the analysed ceramic fragments dating from phase I in 53 % of fine pottery and 97 % of coarse pottery in the classic phase (II); in 37 % of fine pottery and 75 % of coarse pottery in the last phase (III). During this phase of the LBK, the content of silty raw material increased in comparison to phases I and II. Statistically, the ceramics from this phase became more similar to the ALPC ceramics (Fig. 2; cf. Czekaj-Zastawny *et al.* 2017). The ceramic material from other multi-stage sites in south-eastern Poland, as well as from eastern Romania and from Moldova confirms the developmental trend in the clay preparation of the LBK ceramics reconstructed in the analysis of the material from Kraków Nowa Huta-Mogiła 62 (cf. Kadrow and Rauba-Bukowska 2017a, 273-275).

## The influence of the ALPC on the evolution of the LBK pottery in south-eastern Poland

One determinant of the technological changes in the LBK ceramics in south-eastern Poland, especially in its late phase, was the adaptation of Transcarpathian influences of the ALPC in the LBK environment in south-eastern Poland (cf. Kaczanowska and Godłowska 2009; Kozłowski *et al.* 2014; Kicińska 2014; Czekaj-Zastawny *et al.* 2017).

The analysis of the ceramics from Site 17 in Brzezie helped to distinguish imported vessels from the ALPC area from vessels which were produced locally, but which imitated the southern patterns (Rauba-Bukowska 2014a; Czekaj-Zastawny and Rauba-Bukowska 2014). Those two kinds of ceramics differ primarily in the type of raw material used in their production, although both groups are made of silty clay. In the imported pottery, the average content of quartz amounts to 33 %, while the content of clay minerals is 51 %. Similarly, the pottery recovered from Brzezie 17 has the average content of quartz equaling 26 % and the average content of clay minerals of 67 %. The most striking difference, however, consists in the content of muscovite and feldspars. In the imported ceramics, the content of muscovite is 3.8 %, and that of feldspars is 4 %, while the imitations and the locally produced pottery have the contents amounting to 0.8 % and 0.4 %, respectively. The quantity of organic material in both kinds of ceramics is similarly very low. However, the locally produced pottery more often includes organic temper, destroyed to a greater or lesser extent (Czekaj-Zastawny and Rauba-Bukowska 2014; Czekaj-Zastawny *et al.* 2017).

The development of the LBK, phases I to III, was marked by the following trends:

1. The increasing use of silty clay;
2. The decreasing use of organic material as an admixture;
3. The use of grog in the mass of clay toward the end of the LBK evolution. The evolutionary changes in the LBK ceramics resulted mostly from intensifying contacts with the ALPC (Fig. 2; Kadrow and Rauba-Bukowska 2017a, 275).

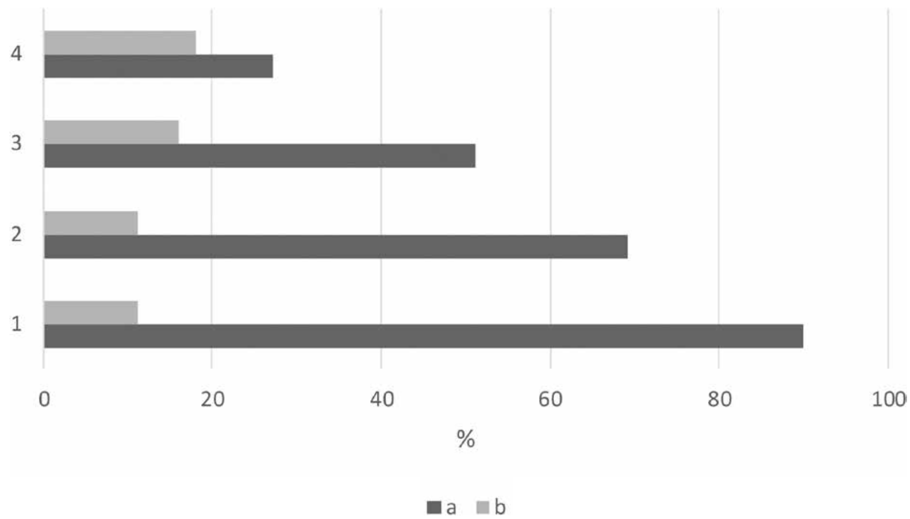


*Figure 2. Kraków Nowa Huta-Mogiła, site 62. Frequency plot of organic admixture (a) and grog (b) in LBK and ALPC pottery (1 – LBK I, 2 – LBK II, 3 – LBK III, 4 – ALPC; after Kadrow and Rauba-Bukowska 2017a).*

## Character, chronology and dynamics of pottery imports and imitations from ALPC areas

The beginning of the inflow of imported pottery of ALPC from the northern part of the Carpathian Basin falls in the middle section of the II (music-note) phase of LBK in south-eastern Poland. It was the ceramics of the Tiszadob-Kapušany group. In the final part of phase II (music-note), the first imports of the older phase of the Bükk culture also appeared. At site 17 in Brzezie (Kraków region), 89 fragments of imported ceramics were discovered (Czekaj-Zastawny 2014, 68-72, Figs. 45, 47-48). Considering that almost 40,000 fragments of LBK ceramics were discovered in this site (Czekaj-Zastawny 2014, 52), the frequency of imported ceramics is only approx. 0.2%. Imports and imitations of ceramics from behind the Carpathians are registered only in some long houses. In the middle of phase II (music-note), they only occurred in objects associated with two houses. At the end of this phase at the site 17 in Brzezie, imports and imitations of Bükk culture pottery are listed in the inventories of 4 houses. In total, 22 houses were discovered there, the vast majority of which date to the middle part of phase II (Czekaj-Zastawny 2014, Fig. 56). It seems, therefore, that ceramics from the Carpathian Basin were initially imported or imitated sporadically by residents of only some houses in the settlement. Later, at the end of phase I, residents of a larger number of houses imported larger quantities of ceramics from the south (Fig. 3).

Imported ALPC ceramics (Tiszadob-Kapušany group) were also found in LBK phase II contexts in the settlement complex in Targowisko (Kulczycka-Leciejewiczowa 1973; Kaczanowska and Godłowska 2009, Fig. 3). On the vast majority of other settlements from that time in the Kraków region, however, no imports of ceramics were registered.

The increase in the number of imports of ceramics from the Carpathian Basin occurs in the Krakow region at the turn of the LBK phases II (music-note) and III (Želiezovce) (also in the caves of the Krakow Jura; see Kaczanowska and Godłowska 2009, 144). The apogee of this phenomenon, however, is connected only with the beginning of the Želiezovce phase (III). Some relatively numerous inventories of imported ceramics have been found at several sites in Kraków Nowa Huta (Kaczanowska-Godłowska 2009, Fig.4; Sebők 2014, 85). At 65% of the analyzed LBK settlements from this period in south-eastern Poland, no imports or ceramic imitations were discovered (Kaczanowska and Godłowska 2009, 146).

In the Rzeszów region, imported ALPC ceramics in phase II were registered at site 34 in Rzeszów (Kadrow 1990a, 55-58, Fig. 14b). In the context of fewer than 60 or-

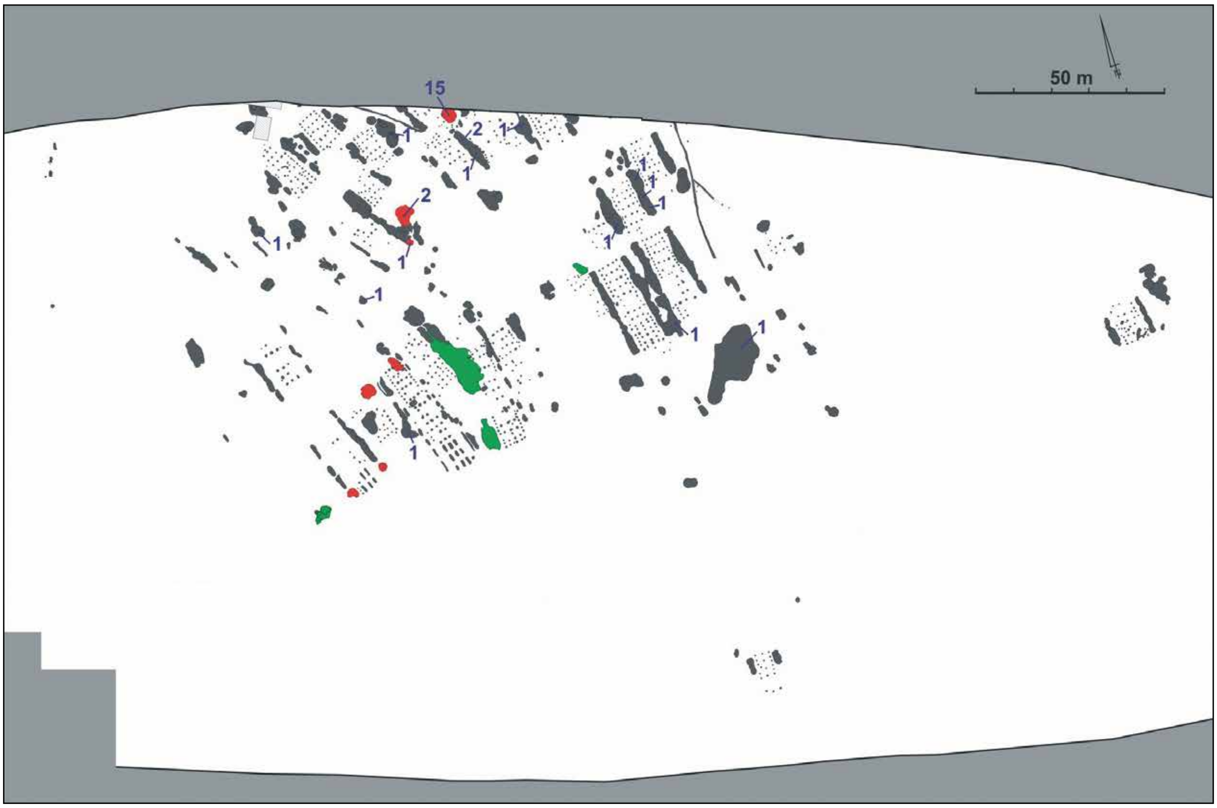


*Figure 3. Brzezie, site 17. LBK (phase II and III) settlement; green colour – pits with pottery fragments of Tiszadob-Kapušany group; red colour – pits with pottery fragments of Tiszadob-Kapušany group and Bükk culture; digits – number of obsidian artefacts discovered in some settlement pits (after Czekaj-Zastawny 2013).*

namented pieces of ceramics from this phase, 3 fragments of imported pottery from the Tiszadob-Kapušany group were found there. This is about 6% of the collection of ornamented ceramics. However, the share of imports did not exceed 1% in relation to the whole assemblage of ceramics. At site 3 in Zwięczyca, several fragments of ceramics can be linked to the final part of phase II of the LBK (cf. Dębiec 2015, 37-41, Fig. 6: 1).

The first few imports of ceramics at site 16 in Rzeszów are also related to the end of phase II (Kadrow 1990b, Fig. 7h). The intensification of the inflow of imported ceramics and the production of its local imitations gained pace only in phase III (Želiezovce) of the LBK. In several complexes of pits that are most probably connected with the accompanying houses, imports and numerous imitations of ceramics, mainly of the Bükk culture, were registered (Kadrow 1990a, Fig. 14d-j; Kadrow 1990b, Fig. 9g-i; 15c, i, l, m, 16j-p). The frequency of this type of ceramic in the facilities belonging to the alleged houses at site 16 in Rzeszów is very different. In many pit complexes, there are no ceramics of this kind at all. Its highest frequency was recorded in the no. 40 complex of pits (about 15% of ornamented ceramics). In the complexes of pits no. 38 and 96, this frequency reached 5-6% (Kadrow 1990a, Fig. 14).

At site 3 in Zwięczyca, 22 fragments of imported ceramics were discovered (Dębiec 2014, Sebők 2014, 80-83, Figs. 19-20). All of them can be included in the group of real imports, not local imitations (Sebők 2014, 84). They belong to the context of phase (III) (Želiezovce) of the discussed culture (cf. Dębiec 2015, 41, Fig. 16: 7, 8, 13, 15).

The first imports and imitations of ALPC ceramics appear north of the Carpathians already in the middle part of phase II. Over time, the number of these imports is increasing reaching the apogee at the beginning of (Želiezovce) phase III. Ceramics of this type have never been imported by the inhabitants of all settlements. In the period of the largest intensification of imports, it is registered in south-eastern Poland in less than 1/3 of all sites. In the settlements, where these ceramics were imported, it is found in the inventories of only some houses (Fig. 3). A special concentration of inflow of ALPC ceramics is observed in the Kraków and Rzeszów region (Fig. 4).

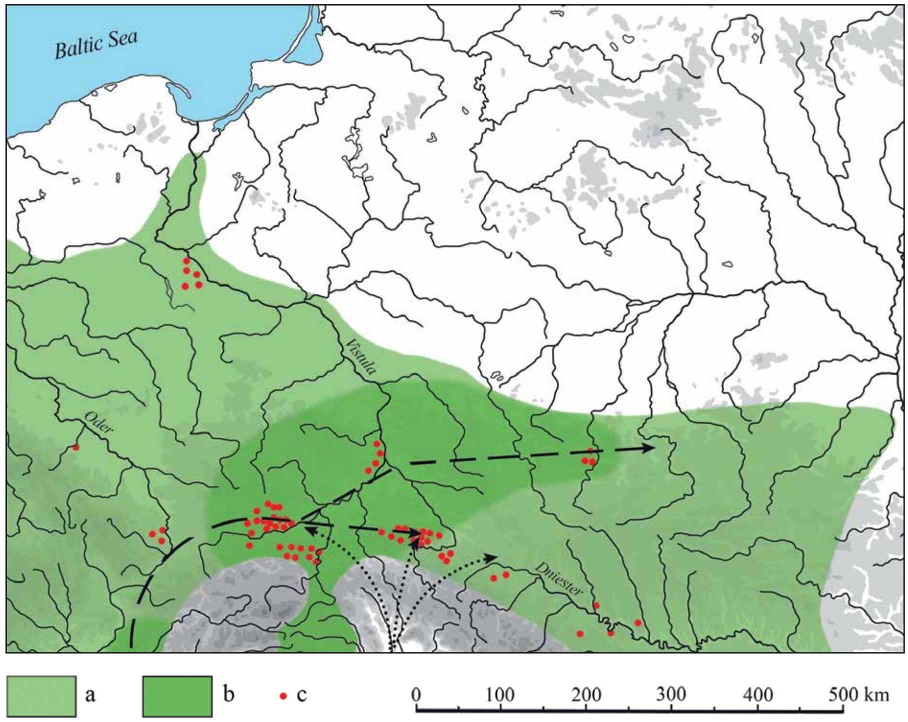


*Figure 4. ALPC pottery imitations and imports on LBK territories; a – LBK territory, b – LBK territory with pottery in Želiezovce stylistics, c – LBK sites with ALPC pottery imitations and imports (acc. to Kaczanowska and Godłowska 2008; Kicińska 2014); dashed line – directions of Želiezovce stylistics influences; dotted line – influx directions of ALPC pottery imitations and imports (after Kadrow and Rauba-Bukowska 2017b).*

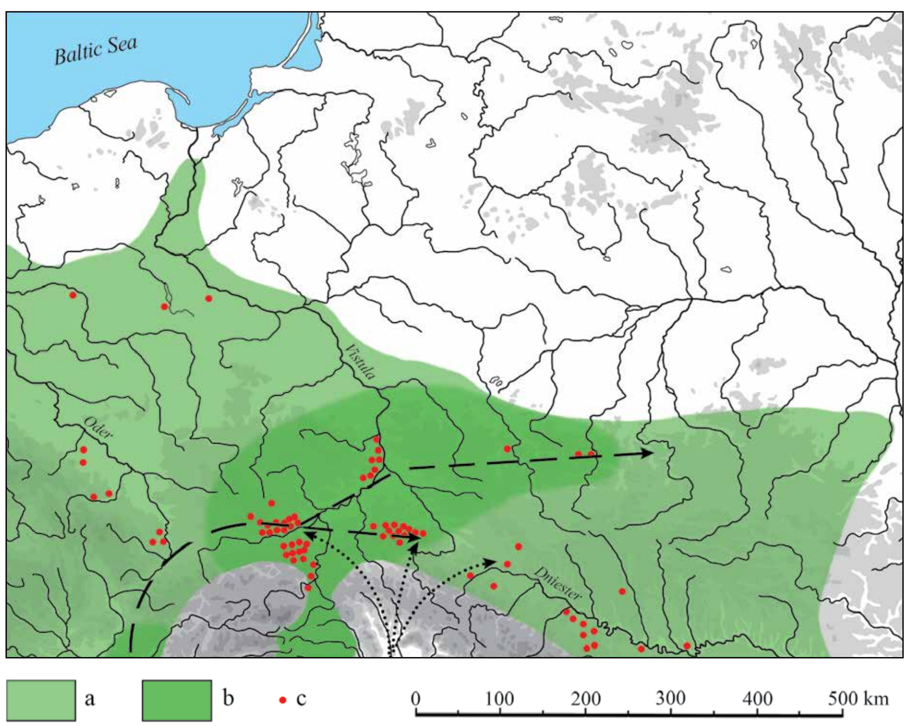


*Figure 5. Obsidian imports on LBK and MC territories; a – LBK territory, b – LBK territory with pottery in Želiezovce stylistics, c – LBK and MC sites with obsidian imports (after Raczak 2017); dashed line – directions of Želiezovce stylistics influences; dotted line – influx directions of ALPC pottery and obsidian imports.*

## The character of LBK pottery stylistic evolution in south-eastern Poland

Detailed trends of stylistic changes in LBK ceramics in south-eastern Poland were reconstructed and described until the end of the 1970s (see Kulczycka-Leciejewiczowa 1979). The rhythm of the stylistic transformations of LBK ceramics north of the Carpathians refers closely to the nature and rate of changes in south-western

Slovakia (*e.g.* Pavúk 1969; 1980; 2004). However, some peculiarities of the evolution of ceramics changes in south-eastern Poland are also evident. The most interesting is the change between the music-note phase (II) and the Želiezovce phase (III). The succession of the phases mentioned above did not consist in replacing the music-note style by Želiezovce but gradually increasing the saturation of the first one with the decorative elements and motifs of the latter one.

Music-note stylistics consisted in constructing various decorative motifs with the use of engraved lines, on which "round" shallow holes called "music-notes" were hung. In the early and advanced music-note phase (II), the decorative motifs were only constructed using this element. At the end of the music-note phase (II) there appear combined groups of shallow, round holes ("music-notes") suspended on engraved lines. At that time they formed no more than a 5% frequency of all decorative elements. At the beginning of the Želiezovce phase (III), they had achieved a 40% frequency, and then decreased to a level of approx. 3%. The presence of the decorative element in the form of the so-called "notch" determines the stylistic character of the developed Želiezovce phase. At the beginning of this phase, the frequency of notches did not exceed 20%. Later it increases to approx. 60% of all decorative motifs. However, typical "music-notes" decorative elements are still present throughout the whole Želiezovce phase. At the end of the music-note phase (II), they constituted 95%, at the beginning of the Želiezovce phase (III) approx. 40%, and in its developed stage about 30% of all decorative elements.

The stylistic change process presented above is clearly visible in the area of the Kraków and Rzeszów LBK regions (see Kadrow 1990b, 71-75, Fig. 28), *i.e.* on areas of the largest size of the LBK population and where the highest import volumes of Bükk culture ceramics and obsidian are recorded (Fig. 4). In other areas of south-eastern Poland, the presence of Želiezovce decorative elements is much more modest, for example, in the loess areas of the Sandomierz, Lublin or West-Volhynian Uplands. Approx. 25 km to the east of Rzeszów there is a total lack of ceramics in the Želiezovce style or its extremely occasional occurrence (Fig. 4).

Similarly, as in the case of imports of Bükk culture ceramics and obsidian (Fig. 5), there are sometimes quite significant differences in the intensity of decorative elements in the region of Kraków and Rzeszów and between their occurrence in pits belonging to different houses on different settlements (*e.g.* between the cluster of objects no. 80 – not enough Želiezovce elements, and cluster no. 96 – a lot of these elements, cf. Kadrow 1990b, Fig. 14, 15).

## Exchange of stone raw materials between south-eastern Poland and the Carpathian Basin

Already during the evolution of the earliest LBK phase (I), small quantities of Jurassic and chocolate flint occurs in the areas south of the Carpathians, originating from south-eastern Poland (Mateiciuciová 2008). During phase II, obsidian appears in Poland (Kadrow 1990a, Fig. 17c; Szeliga 2007, Fig. 1; Kaczanowska and Godłowska 2009, 143). Beginning with the end of phase II, the exchange of stone commodities intensifies. To the north of the Carpathians there is an increase in obsidian (Fig. 10) and to the south Jurassic and chocolate flint is still exported, as well as Świeciechów and Turonian flint (Szeliga 2014, Fig. 2, 8). After the culture change at the LBK/MC turn, obsidian is still being imported (Fig. 11; Kadrow 1990a, Fig. 17c; Szeliga 2007, 298-301).

The largest frequency of obsidian in the raw material structure of stone inventories in the early Neolithic of south-eastern Poland is observed in the no. 96 cluster of pits, dated to the beginning of the LBK Želiezovce phase (III), at site 16 in Rzeszów (Kadrow 1990a, Fig. 17c).

Like the import of ALPC ceramics, obsidian was used by residents of only some settlements and the residents of only some long houses imported it (Fig. 3). In the inventories of other contemporary settlements and houses there is no obsidian. For example, in the complex of buildings No. 111 on site 16 at Rzeszów, Volhynian flint accounts for 25% of the entire inventory of stone artefacts. At the same time, there are no imports of obsidian and ALPC ceramics at all (Kadrow 1990a, Fig. 14e). In south-eastern Poland, two concentrations of obsidian imports are observed, similarly to ALPC ceramics, *i.e.* in the Kraków and Rzeszów region (Fig. 5).

In the Rzeszów region, the inflow of obsidian begins in phase (II) (music-note) of LBK and ends at the end of the MC (Fig. 6). The culmination of its influx falls at the beginning of phase III (Želiezovce). Later, at the beginning of the MC, there is a decline in the supply of this raw material, but in the MC phase I b (classic), it does increase again (Kadrow 199a, 59-63, Fig. 17c).

## Settlement patterns and settlement evolution in Rzeszów region

LBK and MC settlements were located in the immediate surroundings of the wide, well developed floor of the great valley of the Wisłok River (Fig. 1). The greater permanently inhabited settlements occupied marginal zones of lowest parts of over flooded terraces (Kadrow 1990a, 43).

Among the 80 sites of the Danubian cultures, 13 LBK settlements and 12 MC settlements were distinguished. It is assumed that traces of Danubian settlements, with no specific cultural affiliation, were related in proportion to both cultures mentioned above. On average, one permanently inhabited LBK or MC settlement was accompanied by two settlement traces of these cultures. In reality, the number of settlement traces was distinctly greater and, in the case of LBK, could reach up to 6-8 of them (cf. Kadrow 1990a, Fig. 7). The low detectability of these kinds of sites in the Rzeszów microregion is caused by the complete modification of natural environment, mainly as a result of urbanization and industrialization (Kadrow 1990a, 45).

Studies on the dynamics of settlement processes are based on a chronological outline (Kadrow 1990a, Fig. 6), worked out on the basis of the typological and stylistic analysis of pottery assemblages from some excavated sites (sites 3, 16, 20, 23, 24 and 34 in Rzeszów, site in Zwięczyca and site 1 in Boguchwała – cf. Kadrow 1990a, 69). The results of the latest excavations at site 3 in Zwięczyca (Dębiec 2014; 2015) fully confirm this chronological scheme. In these studies, the observation was also used that settlement catchments (areas determined by the 1 km radius around them) of contemporary settlements in general had not even in part overlapped. Using such a regularity of spatial location of LBK and MC settlements, the outline of stylistic dating was supplemented with further sites: sites 4, 14 and 55 in Rzeszów and site 1 in Załęże (Kadrow 1990a, 45).

Scarce pottery fragments from phase I (pre-music-note) of LBK were recovered at a few sites (3, 16 and 34 in Rzeszów). At the beginning and in the middle part of phase II (music-note) settlements were concentrated in the northern part of the region. From the end of this phase, the centre of gravity of the LBK settlement began to shift to the south (Fig. 1). At the same time, the number of constantly inhabited settlements and the size of the whole settlement region were increasing. At site 3 in Zwięczyca, at the southern outskirts of the LBK settlement region, the youngest pottery of this culture was registered, dated to the end of the Želiezovce phase (III) (cf. Dębiec 2014, 92-93, 147).

At site 20 in Rzeszów (Kadrow 1990c), the small group of the oldest population of MC appeared in the centre of the region (phase Ia of MC), while in the southern part of the region the population of the youngest LBK still lived (at site 3 in Zwięczyca).

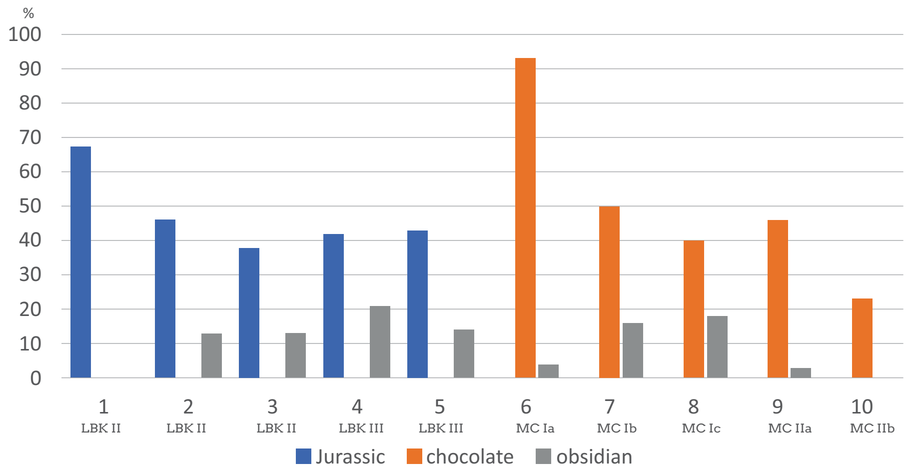


*Figure 6. Rzeszów microregion; frequency of stone raw materials during LBK and MC evolution (Jurassic and chocolate flints and obsidian; after Kadrow 1990a).*

Both sites are located only three km away (Fig. 1). In the next stage (phase Ib), the MC population replaced LBK inhabitants across the area of the whole region. The sizes of the MC settlements were much smaller than those of the LBK.

## Dynamics of the demographic processes in Rzeszów region

Attempts to estimate population size in prehistory and to study their variability over time are made using various methods. In the case of the Rzeszów region, where there are no sepulchral sources and there is usually no data on the number of houses, only one method is available, namely knowledge about the size settled on surface of settlements (*e.g.* Naroll 1962).

The size of population can be reconstructed by the multiplication of the summed surfaces of permanently inhabited settlements by the number of people which could live on the surface unit in the given period of time. It was assumed (acc. to Kruk *et al.* 1996, 36-40) that it is 24 people per one ha.

Knowing the size of the inhabited surface of sediments at various stages of LBK and MC development in the Rzeszów region (Kadrow 1990a, Tab. 6), it is possible to reconstruct the approximate number of inhabitants and its variability over time (Fig. 7). This estimation assumes that all phases of stylistic pottery evolution were equal in length of time. In order to show the dynamics of changes in population size, calculation of its size was given up in favour of percentage relations of the estimated number of inhabitants (Fig. 7).

The dynamics of population changes in various settlements was different. It is illustrated by the diagram of changes in size of occupied surfaces (which certainly implies population size) during the inhabitation of sites 3 and 16 in Rzeszów.

It is not excluded that a more correct estimation can be calculated for more or less equal time units, corresponding with a settlement phase (90-100 years), and not for pottery stylistic phases, whose duration was probably very different.

Different ways of assessing the size of the population living in the Rzeszów region in the early Neolithic period give slightly different results. However, the overall trend of change is the same (Fig. 7). The maximum size of this population was reached at the beginning of phase III (Želiezovce) of the LBK. After this time, there is a clear decline in the population.

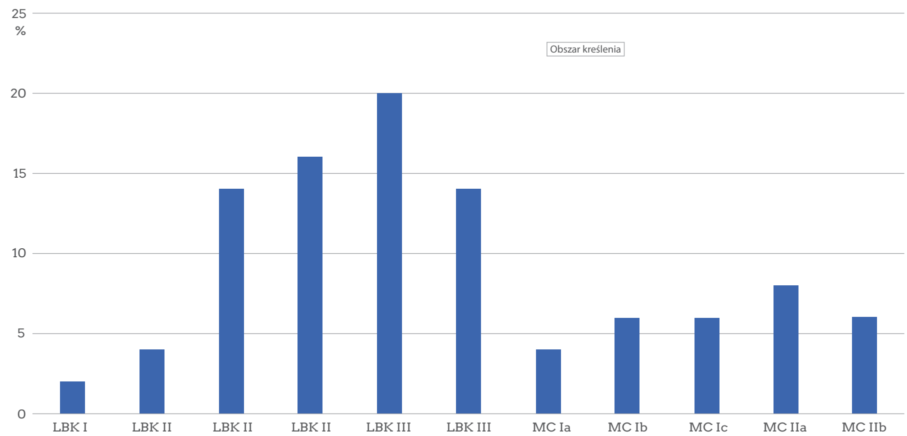


*Figure 7. Dynamics of demographic changes in Rzeszów microregion during LBK and MC evolution (after Kadrow 1990a).*

## Innovation in ceramic technology in the context of socio-cultural process

As already mentioned, thanks to the analysis of ceramics from site 62 in Kraków Nowa Huta-Mogile, slow and gradual changes of LBK vessel technology were reconstructed from the beginning to the end of its development (Fig. 8; cf. Kadrow and Rauba-Bukowska 2017a, 273-275, Fig. 4-5). The reason for these changes was the growing influence from the environment of ALPC, especially the Bükk culture (Kozłowski *et al.* 2014; Czekaj-Zastawny *et al.* 2017). The power of the influence of this pottery and the effects it caused, especially towards the end of the LBK development north of the Carpathians, permit us to regard it as a social element with a large symbolic capital.

Within the background of this technological innovation, comprehensive social and cultural changes can be observed, including changes in the construction of long houses and the internal organization of settlements and settlement regions in case of LBK (see Milisauskas 1986; 2013; Kadrow 1990a; Czekaj-Zastawny 2008; 2014; Czerniak 2013, Dębiec 2014; Zastawny and Grabowska 2014) and MC (Czerniak *et al.*, 2007; Grabowska and Zastawny 2014; Kadrow 2015).

Parallel to the technological innovations in LBK ceramics, the intensification of importing ALPC pottery and the phenomenon of local imitation of this pottery by people living in areas north of the Carpathians can be observed. Frequently, this pottery was imported at the end of the LBK development, during the reign of the Želiezovce style in ceramics. With the disappearance of the LBK, the above-mentioned import of ceramics from the Carpathian Basin also ended. In contrast to the import of ALPC ceramics, LBK's disappearance did not result in the disappearance of obsidian imports and this was continued until the end of the MCs existence.

Participation in the propagation of the Želiezovce ceramic style and the import of ALPC ceramics and obsidian was attended by populations living primarily in the Krakow and Rzeszów regions (Fig. 4, 5), and in them only residents of some settlements, and some long houses (Fig. 3).

In the Rzeszów region, a rapid demographic development of the local population was found at the end of the LBK development (Fig. 7). It is related to the period of intensification of the inflow of imports from behind the Carpathians and the heyday of the Želiezovce style in ceramics. Later, this upward demographic trend was more subdued and was accompanied by a culture change, legible in the replacement of the style of ceramics typical of late LBK by the style of MC ceramics. The sudden change in pottery style was accompanied by the disappearance of imports of ceramics from the Carpathian Basin and types of house construction also changed suddenly. The size of settlements and settlement zones decreased significantly. At the same time, however, the continuation of the trend of technological changes in ceramics produc-

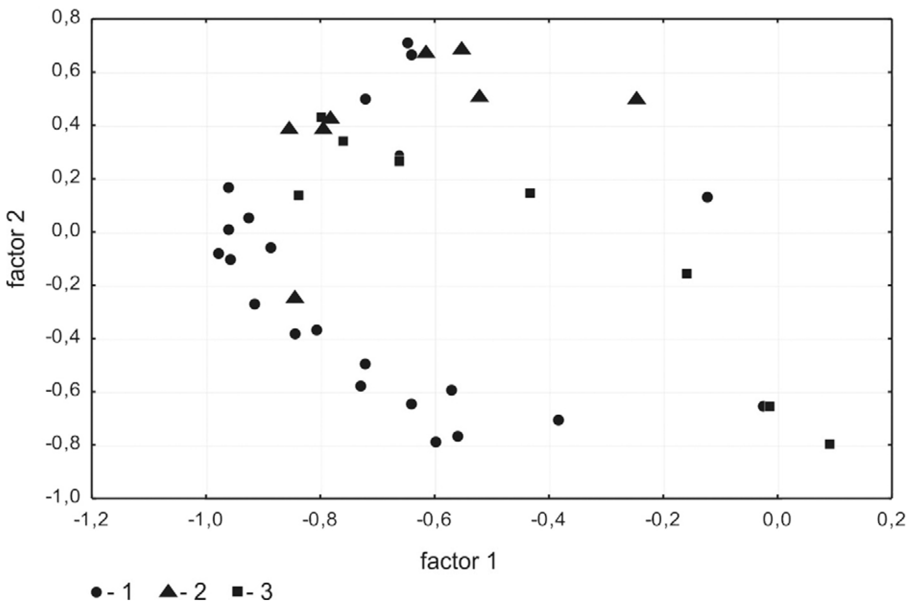


*Figure 8. Factor analysis of LBK pottery features from Kraków Nowa Huta-Mogiła, site 62; 1 – phase I (pre-music-note), 2 – phase II (music-note), 3 – phase III (Želiezovce) (after Kadrow and Rauba-Bukowska 2017a).*

tion is observed together with the continuation of obsidian inflow (Fig. 6). It seems that the basic strategies of subsistence were being continued.

The process of early Neolithic socio-cultural transformation in the Rzeszów region (Fig. 1) and the place of innovation in the ceramic technology, in conceptual terms of Pierre Bourdieu's theory of practice and the theory of cultural analysis of Robert Wuthnow, are presented in the following way.

Around the middle of the 6th millennium BCE, the region of Rzeszów was sporadically settled by small groups of the oldest farmers, representatives of LBK, who came here from the surroundings of Kraków. The result of their short stays in this area are single fragments of ceramics, characteristic of the Gniechowice and Zofipole styles from the oldest, pre-music-note phase (I) of LBK development in south-eastern Poland. To date, no traces of permanent settlement from that time have been found.

These newcomers were pioneers/scouts, with much larger groups of people coming later. Successors produced ceramics in the early music-note style (II) and built longhouses and inhabited permanent settlements. Stone tools were made of Jurassic flint (Fig. 6), imported from the Krakow area. The import of this flint is the only proof of contact with the outside world at this time. This period is characterized by the uniformity of the material culture and settlement strategies, typical for the entire eastern zone of LBK in its European range. There is no evidence of systematic contact with the local Mesolithic population or their neighbours (ALPC) from beyond the Carpathians.

The beginning of the music-note phase (II) in the Rzeszów region, according to the theory of Pierre Bourdieu (2008), can be called a period of harmonious relations of various aspects of socio-cultural life, which are called fields (*Lebensordnungen*) with their internalizations in the life of every human being involved in the habitus. In these communities, there is no indication of a serious difference of interests between individual people and various social groups (families *etc.*). Therefore, the manifestations of the activities of various ideologies competing with each other, operate on the services of various centres (institutions) with symbolic power (violence), are also not observed. There are also no material traces of the manipulation of social capital, that is, such objects that had a special, distinctive symbolic value and could be used as weapons in some form of ideological struggle. In light of Robert Wuthnow's (1987) theory of cultural analysis, this was a period of the perfect compliance of norms with practice in an integrated, closed community. "Certainty" reigned (the opposite of the key concept in this theory of “uncertainty”, characteristic of periods of conflict), typical of periods of social and culture stabilization.

In the middle stage of the music-note phase (II) of the LBK, more cases of the importation of obsidian (Fig. 5) and ALPC ceramics (Fig. 4 – Tiszadob-Kapušany group) are to be seen for the first time. Not all of the inhabitants of the Rzeszów region participated in importing foreign products, raw materials and imported artefacts have only been registered in some settlements. Only some long-houses contain such specimens in these settlements. The process of the opening up of local communities to external influences and impacts can be traced to this period. At the same time, the process of the progressive internal differentiation of the described communities can be seen. In addition to conservative groups who adhered to local traditions, there were also groups oriented towards external contact. The abovementioned phenomena are accompanied by an (initially slow) increase in the population of the Rzeszów region (Fig. 7).

These processes gained momentum over time, continuing at the end of the music-note phase (II) of the LBK. However, they were particularly intense during the Želiezovce phase (III), when in addition to the absorption of more and more elements from the Carpathian Basin (the imports of ceramics of various ALPC local groups, mainly Bükk culture and obsidian – Fig. 4, 5) in some settlements and most long-houses, the enrichment of ceramics in the music-note style with increasingly numerous elements of the Želiezovce style can be witnessed. At the same time, this was accompanied by changes in the technology of ceramic mass preparation (Fig. 2) for the production of LBK pottery, which slowly but consistently brought it closer to ALPC ceramic technology.

At this point, uniform, integrated *Lebensordnungen* (fields) began to be enriched with new norms and values that functioned in parallel with the existing rules. Individual LBK ceramic manufacturers were exposed to various degrees of impact of the technology rules, which were characteristic of ALPC. Their habitus, as the effect of the internalization of the elements of the new rules, resulted in a fluid sequence of routinized technological changes (innovations) that were equally the result of socio-cultural changes, as well as one of the co-shaping factors.

Some families (groups of people inhabiting the same house) living in some settlements, began to display their distinctiveness from others and aspired for a better social position by using symbolic violence (power), by manipulating and displaying new elements with greater social capital. This was primarily by means of ceramics imported from the ALPC. Its value as social capital is proven by its relative rarity, exoticism and high aesthetic values, as well as the fact that local imitations existed. A similar role was also played by obsidian. To a certain extent, the LBK ceramics ornamented in the Želiezovce style also had social capital.

The intensification of ritual activities – as time passed – among the LBK community in the Rzeszów region, proven inter alia by the proliferation of competing styles of ceramic ornamentation (music-note, Želiezovce and ALPC), is proof of a growing uncertainty, *i.e.* a situation of increased social conflict (Wuthnow 1987). The rivalry of some groups in the Rzeszów region is manifested by the adoption of various competing ideologies, which are mirrored in related rituals and symbols. Different groups refer to different traditions (rooted in music-note, Želiezovce and ALPC stylistics).

The inflow of new population groups (families) from the vicinity of Kraków was probably responsible for the significant increase in population size at the beginning of the Želiezovce phase (III) of the LBK in the Rzeszów region (Fig. 7), as evidenced by the strong stylistic relationships of ceramics from both regions. Multiplication of the local population at such a rapid rate in the reality of the early Neolithic was not possible (see Piasecki 1990).

The increase in the intensity of ritual activities, with the simultaneous increase in population size is a typical symptom of acute conflict within the communities living in the Rzeszów region, growing from the middle stage of the music-note phase (II) and culminating in the beginning of the Želiezovce phase (III) of the LBK. Its effect was a cultural change and the LBK gave way to the MC. It consisted of a fairly sudden change in these aspects of material culture, which had a symbolic significance for the people of that time, above all in the forms and ornamentation of ceramics, changes in the raw material of the stone industry (the replacement of Jurassic flint with chocolate flint – Fig. 6) and the constructions and sizes of houses.

Other elements typical for the LBK (obsidian import, strategies of settling the same landscape zones in the loess areas) were still continued in the new MC system. Most importantly, from the perspective of the considerations in this article, the process of changes (innovations) in ceramic technology was continued, mainly based on the elimination of organic admixture from ceramic masses and replacing it with an admixture of grog. This was a completely routinized process and did not have the characteristics of social capital. As such, it was not subject to manipulation on the part of groups of people possessing symbolic (violence) power.

In the Rzeszów region, at the turn of the LBK and MC, we can observe decisive changes in the symbolic sphere and the continuation in the sphere of other elements of material culture. Similar sequences of changes of a structural character can also be observed in other cultural contexts and areas. Intensifying the ritualization of everyday life and the accompanying increase in the size of the population is testimony to growing social conflict. It resulted in a sharp demographic crisis and changes in culture observed in *Trichterbecher* in Bronocice (Kadrow 2018, 13-16) and in the early Bronze Age in Iwanowice in south eastern Poland (see Kadrow 2017) or culture changes, as in the case of the Brześć Kujawski and Osłonki settlement complexes from the early Eneolithic period (eg. Kadrow 2016) in the Polish Lowlands. A similar course and character may also be detected in the socio-cultural process in Okolište in Bosnia (*e.g.* Arponen *et al.* 2015), carried out in the spirit of another theory from the one presented in this article.

## Conclusions

In the above-outlined transformation process of LBK in the MC in the Rzeszów region in the early Neolithic, innovations in ceramics technology is a routinized and non-discursive element of a broad stream of social and cultural changes. They are the result and mirror of these changes and, at the same time, one of their co-constitutive and co-shaping factors. Innovations in the LBK ceramics technology north of the Carpathians appeared as a side effect of the interest of the LBK community in the attractive culture of ALPC from the northern part of the Carpathian Basin. These innovations, therefore, did not initiate the abovementioned socio-cultural transformation in the early Neolithic population, inhabiting north of the Carpathians. Ceramic technology, in contrast to its forms and especially its decorations and, for example, dwellings, did not have the value of social (cultural) capital at that time and as such was not subject to conscious manipulation. Therefore, changes in ceramics technology were slow and gradual.

## References

Aksamit, T. 1961. Sprawozdanie z badań osady neolitycznej w Rzeszowie w r. 1961. *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego za rok 1961.* Rzeszów: Muzeum Okręgowe w Rzeszowie, 33-35.

Aksamit, T. 1962. Sprawozdanie z badań osady neolitycznej w Rzeszowie w r. 1962. *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego za rok.* Rzeszów: Muzeum Okręgowe w Rzeszowie, 9-11.

Aksamit, T. 1963. Badania osady neolitycznej (stanowisko nr 16) w Rzeszowie na Osiedlu Piastów. *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego za rok 1963.* Rzeszów: Muzeum Okręgowe w Rzeszowie, 12-14.

Aksamit, T. 1964. Badania archeologiczne na terenie Rzeszowa w roku 1964. *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego za rok 1964.* Rzeszów: Muzeum Okręgowe w Rzeszowie, 12-15.

Aksamit, T. 1966. Badania osad neolitycznych na terenie Rzeszowa. *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego za rok 1965.* Rzeszów: Muzeum Okręgowe w Rzeszowie, 15-23.

Aksamit, T. 1968. Wstępne wyniki badań osady kultury ceramiki wstęgowej w Rzeszowie, in: *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego za rok 1965.* Rzeszów: Muzeum Okręgowe w Rzeszowie, 110-116.

Arponen, V. P. J. Müller, J., Hofmann, R., Furholt, M., Ribeiro, A., Horn, C., Hintz, M. 2015. Using the Capability Approach to Conceptualise Inequality in Archaeology: the Case of the Late Neolithic Bosnian Site Okolište c. 5200-4600 BCE. *Journal of Archaeological Methodology and Theory* 23, 541-560. DOI: https://doi.org/10.1007/s10816-015-9252-0

Bourdieu, P. 2007. *Szkic teorii praktyki poprzedzony trzema studiami na temat etnologii Kabylów*, Biblioteka Klasyków Antropologii. Kęty: Wydawnictwo Marek Derewiecki.

Bourdieu, P. 2008. *Zmysł praktyczny*. Kraków: Wydawnictwo UJ.

Bourdieu, P., Wacquant, L. J. D. 2001. *Zaproszenie do socjologii refleksyjnej*, Terminus 21. Warszawa: Oficyna Naukowa.

Czekaj-Zastawny, A. 2008. *Osadnictwo społeczności kultury ceramiki wstęgowej rytej w dorzeczu górnej Wisły*. Kraków: Instytut Archeologii i Etnolgii PAN.

Czekaj-Zastawny, A. 2014. *Brzezie 17. Osada kultury ceramiki wstęgowej rytej*, Kraków: Krakowski Zespół do Badań Autostrad.

Czekaj-Zastawny, A., Przybyła, M.M. 2012. Modlniczka 2, powiat krakowski. Cmentarzysko kultury ceramiki wstęgowej rytej i osady neolityczne. Kraków: Krakowski Zespół do Badań Autostrad.

Czekaj-Zastawny, A., Rauba-Bukowska, A. 2014. Technology of the earliest vessels in the upper Vistula River basin – imports against local pottery, in: Kienlin, T.L., Valde-Nowak, P., Korczyńska, M., Cappenberg, K., Ociepka, J. (eds.). *Settlement, Communication and Exchange around the Western Carpathians*, International Workshop held at the Institute of Archaeology, October 27-28 October 2012 Jagiellonian University, Kraków. Oxford: Archaeopress, 95-107.

Czekaj-Zastawny, A., Kadrow, S., Rauba-Bukowska, A. 2017: Ceramic raw material acquisition and transfer of technological ideas among the Early Neolithic communities around the Western Carpathians, in: Burnez-Lanotte, L. (ed.). *Workshop "Matières à Penser": Raw Materials Acquisition and Processing in Early Neolithic Pottery Productions*, Proceedings of the Workshop of Namur (Belgium), 29-30 May 2015 University of Namur, Séances de la Société Préhistorique Française 11. Paris: Société préhistorique, 81-91.

Czerniak, L. 2013. House, household and village in the Early Neolithic of Central Europe: a case study of the LBK in Little Poland, in: Kadrow, S., Włodarczak, P. (eds.). *Environment and Subsistence – forty years after Janusz Kruk's „Settlement studies"*. Rzeszów/Bonn: Instytut Archeologii UR/Dr. Rudolf Habelt, 43-67.

Czerniak, L., Golański, A., Kadrow, S. 2007. New Facts on the Malice Culture Gained from the Rescue Excavations at the A4 Motorway Section East of Krakow, in: Kozłowski, J. K., Raczky, P. (eds.). *The Lengyel, Polgár and Related Cultures in the Middle/Late Neolithic in Central Europe*. Kraków: Polska Akademia Umiejętności, 471-486.

Dębiec, M. 2014. *Zwięczyca 3. Eine bandkeramische Siedlung am Wisłok*. Rzeszów: Oficyna Wydawnicza ZIMOWIT.

Dębiec, M. 2015. Zur relativen Chronologie der Linienbandkeramik in Südostpolen. *Sprawozdania Archeologiczne* 67, 31-56.

Dębowski, T. 1968. Badania ratownicze na osadzie neolitycznej w Zwięczycy, pow. Rzeszów. *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego za rok 1966.* Rzeszów: Muzeum Okręgowe w Rzeszowie, 107-110.

Dobres, M.-A. 2000. *Technology and Social Agency*. Oxford: Blackwell.

Dzieduszycka-Machnikowa, A. 1959. Sprawozdanie z ratowniczych prac wykopaliskowych w Boguchwale, pow. Rzeszów. *Sprawozdanie Archeologiczne* 5, 15-18.

Giddens, A. 2003. *Stanowienie społeczeństwa. Zarys teorii strukturacji.* Poznań: Zysk i S-ka.

Grabowska, B., Zastawny, A. 2014. w: Osada kultury malickiej na stan. 10, 11 w Targowisku, pow. wielicki, in: Zastawny, A. (ed.). *Targowisko stan, 10, 11. Osadnictwo z epoki kamienia*. Kraków: Krakowski Zespół do Badań Autostrad, 255-416.

Kaczanowska, M. 1990: Uwagi o wczesnej fazie kultury lendzielskiej w Małopolsce. *Acta Archaeologica Carpathica* 29, 71-97.

Kaczanowska, M., Godłowska, M. 2009. Contacts between the Eastern and Western Linear Cultures in South-Eastern Poland, in: Kozłowski, J.K. (ed.). *Interactions between Different Models of Neolithization North of the Central European Agro-Ecological Barrier*, Prace Komisji Prehistorii Karpat PAU 5. Kraków: Polska Akademia Umiejętności, 137-149.

Kadrow, S. 1990a. The Rzeszów Settlement Microregion in Neolithic. *Acta Archaeologica Carpathica* 29, 33-70.

Kadrow, S. 1990b. Osada neolityczna na stanowisku nr 16 w Rzeszowie na Osiedlu Piastów. *Sprawozdania Archeologiczne* 41, 9-76.

Kadrow, S. 1990c. Obiekt kultury malickiej na stanowisku nr 20 w Rzeszowie. *Sprawozdania Archeologiczne* 42, 95-103.

Kadrow, S. 1996. Faza rzeszowska kultury malickiej, in: Kozłowski, J.K. (ed.). *Kultura malicka. Drugi etap adaptacji naddunajskich wzorców kulturowych w neolicie północnej części środkowej Europy*. Kraków: Polska Akademia Umiejętności, 51-70.

Kadrow, S. 1997. Osada kultury ceramiki wstęgowej rytej na stanowisku 3 w Rzeszowie-Staromieściu. *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego* 18, 5-27.

Kadrow, S. 2005. The First Farmers, in: Krzyżaniak, A. (ed.). *Via Archaeologica. Rescue excavations in the Polish highways development project*. Warszawa: Ośrodek Ochrony Dziedzictwa Archeologicznego, 22-43.

Kadrow, S. 2015. Malice culture dwelling clusters in South-Eastern Poland, in: Diachenko, A. (ed.). *The Cucuteni-Trypillia Cultural Complex and its Neighbours, Essays in Memory of Volodymyr Kruts*. Lviv: Astrolabia, 299-308.

Kadrow, S. 2016. Ritual, Meaning and Moral Order. Social and Symbolic Significance of Copper Artifacts. A Case Study of an Early Eneolithic Settlement in Poland, in: Ursu, C.-E. (ed.). *Between Earth and Haeven. From Symbols to Signes, In Memory of Henrieta Todorova*, Ethnoreligion Series 2. Suceava: Editura Karl. A. Romstorfer, 107-124.

Kadrow, S. 2017. What Happened in Iwanowice at the End of the 3rd Millennium BC? Did a Rebellion Break Out?, in: Hansen, S., Müller, J. (eds.). *Rebellion and Inequality in Archaeology*, Proceedings of the Kiel Workshops "Archaeology of Rebellion" (2014) and "Social Inequality as a Topic in Archaeology" (2015) Kiel, Universitätsforschungen zur prähistorischen Archäologie 308. Bonn: Dr. Rudolf Habelt GmbH, 171-184.

Kadrow, S. 2018. Violence in Eneolithic and Early Bronze Age North of Carpathians. in: Nemeth, E. (ed.). *Violence in Prehistory and Antiquity*, Antiquitas 6. Kaiserslautern/Mehlingen: Parthenon Verlag Alexander Rubel, 9-22.

Kadrow, S., Okoński, J. 2008. Materiały stylu zofipolskiego ze stanowiska 2 w Zagórzu, gm. Niepołomice, in: Chochorowski, J. (ed.). *Młodsza epoka kamienia. Wybrane znaleziska.* Kraków: Krakowski Zespół do Badań Autostrad, 1-21

Kadrow, S., Rauba-Bukowska, A. 2017a. The selection of ceramic raw material: convenience or a technological idea? A case study of the Danubian cultures north of the Carpathians. *Archeologické rozhledy* 69, 261-280.

Kadrow, S., Rauba-Bukowska, A. 2017b. The Technology of Neolithic Pottery North and South of the Western Carpathians, in: Pereira, T. (ed.). *The Exploitation of Raw Materials in Prehistory: Sourcing, Processing and Distribution.* Cambridge: Cambridge Scholars Publishing, 414-431.

Kamieńska, J., Kozłowski, J. K. 1990: *Entwicklung und Gliederung der Lengyel- und Polgar- Kulturgruppen in Polen*, Zeszyty Naukowe Uniwersytetu Jagiellońskiego 925, Prace Archeologiczne. Kraków: Instytut Archeologii UJ.

Kicińska K. 2014. *Znaleziska obsydianów oraz ceramiki bukowogórskiej w kulturze KCWR jako wyraz transkarpackich kontaktów interkulturowych.* Rzeszów [unpublished MA thesis stored in the Archive of the Institute of Archaeology, Rzeszów University]

Kozłowski, J.K. 1985: The eastern areas of the Linear Band Pottery Culture, in: Kokowski, A. (ed.). *Mémoires Archéologiques*. Lublin: Wydawnictwo UMCS, 51-70.

Kozłowski, J.K. 2004. Problem kontynuacji rozwoju pomiędzy wczesnym a środkowym neolitem oraz genezy „cyklu lendzielsko-polgarskiego" w basenie górnej Wisły. *Materiały Archeologiczne Nowej Huty* 24, 11-18.

Kozłowski, J.K., Kaczanowska, M., Czekaj-Zastawny, A., Rauba-Bukowska, A., Bukowski, K. 2014. Early/Middle Neolithic Western (LBK) vs. Eastern (ALPC) Linear Pottery Cultures: Ceramics and Lithic Raw Materials Circulation. *Acta Archaeologica Carpathica* 49, 37-76.

Kruk, J., Milisauskas, S., Alexandrowicz, S., Śnieszko, Z. 1996. *Osadnictwo i zmiany środowiska naturalnego wyżyn lessowych. Studium archeologiczne i paleogeograficzne nad neolitem w dorzeczu Nidzicy*. Kraków: Instytut Archeologii i Etnologii PAN.

Kulczycka-Leciejewiczowa, A. 1979. Pierwsze społeczeństwa rolnicze na ziemiach polskich. Kultury kręgu naddunajskiego, in: Hensel, W., Wislański, T. (eds.). *Pahistoria ziem polskich* 2. *Neolit*. Wrocław: Ossolineum, 19-164.

Kulczycka-Leciejewiczowa, A. 1983. O zofipolskim stylu ceramiki wstęgowej rytej w Polsce. *Archeologia Polski* 28, 67-97.

Kulczycka-Leciejewiczowa, A. 2004. Kultura lendzielsko-polgarska w Polsce, jej identyfikacja i podziały taksonomiczne. *Materiały Archeologiczne Nowej Huty* 25, 19-23.

Larina, O.V. 1999. Kultura lineyno-lentochnoy keramiki Pruto-Dnestrovskogo regiona. *Stratum Plus* 1999/2, 10-140.

Larina, O.V, Dergachev, V.A. 2017. *Pamiatniki kultury lineyno-lentochnoy keramiki Respubliki Moldova (svod istochnikov)*. Kishinev: Akademia Nauk Moldovy, Instytut Kulturnogo Nasledya.

Mateiciuciová, I. 2008. *Talking Stones. The Chipped Stone Industry in Lower Austria and Moravia and the Beginnings of the Neolithic in Central Europe*. Brno: Masaryková Univerzita.

Milisauskas, S. 1986. *Early Neolithic settlement and society at Olszanica*. Ann Arbor: University of Michigan.

Milisauskas, S. 2013. Life at Olszanica, in: Kadrow, S., Włodarczak, P. (eds.). *Environment and Subsistence – forty years after Janusz Kruk's „Settlement studies"*. Rzeszów/Bonn: Instytut Archeologii UR/Dr. Rudolf Habelt GmbH, 27-42.

Naroll, R. 1962. Floor Area and Settlement Population. *American Antiquity* 27, 587-589.

Quinn, P.S. 2013. *Ceramic Petrography. The Interpretation of Archaeological Pottery and Related Artefacts in Thin Section*. Oxford: Archaeopress.

Pavúk, J. 1969. Chronologie der Želiezovce-Gruppe. *Slovenská archeólogia* 17, 269-367.

Pavúk, J. 1980. Ältere Linearkeramik in der Slowakei. *Slovenská archeólogia* 28, 7-90.

Pavúk, J. 2004. Early Linear Pottery Culture in Slovakia and the Neolithisation of Central Europe, in: Lukes, A., Zvelebil, M. (eds.). *LBK Dialogues. Studies in the formation of the Linear Pottery Culture*, BAR International Series S1304. Oxford: Archaeopress, 71-82.

Piasecki E. 1990. Cmentarzyska w aspekcie demograficznym. *Przegląd Archeologiczny* 37, 5-51.

Raczak A. 2017. *Dystrybucja surowca i przedmiotów obsydianowych wśród społeczności kultury ceramiki wstęgowej rytej na wschodnim Podkarpaciu. Aspekty ekonomiczne i społeczne.* Rzeszów (unpublished MA thesis stored in the Archive of the Institute of Archaeology, Rzeszów University).

Rauba-Bukowska, A. 2014a. Wyniki badań mineralogiczno-petrograficznych naczyń importowanych kręgu wschodniolinearnego, odkrytych na stanowisku Brzezie 17, gm. Kłaj, in: Czekaj-Zastawny, A. *Brzezie 17. Osada kultury ceramiki wstęgowej rytej*, Kraków: Krakowski Zespół do Badań Autostrad, 459-468.

Rauba-Bukowska, A. 2014b. Rozpoznanie składu mineralnego i petrograficznego mas ceramicznych kultury ceramiki wstęgowej rytej i kultury malickiej ze stan. 10, 11 w Targowisku, pow. Wielicki, in: Zastawny, A. (ed.). *Targowisko, stan, 10, 11. Osadnictwo z epoki kamienia*. Kraków: Krakowski Zespół do Badań Autostrad, 585-606.

Sebők, K. 2014. Bükk-Keramik in Zwięczyca, in: Dębiec, M. (ed.). *Zwięczyca 3. Eine bandkeramische Siedlung am Wisłok*. Rzeszów: Oficyna Wydawnicza ZIMOWIT, 80-85.

Szeliga, M. 2007. Der Zufluss und die Bedeutung des Karpatenobsidians in der Rohstoffwirtschaft der postlinearen Donaugemeinschaften auf den polnischen Gebieten, in: Kozłowski, J. K., Raczky, P. (eds.). *The Lengyel, Polgár and Related Cultures in the Middle/Late Neolithic in Central Europe*. Kraków: Polska Akademia Umiejętności, 295-307.

Szeliga, M. 2014. The Distribution and Importance of Turonian Flints from the North-Eastern Margin of the Holy Cross Mountains in the Flint Raw Material Economy of the Earliest Danubian Communities. *Acta Archaeologica Carpathica* 49, 77-112.

Sztompka, P. 2007. *Socjologia zmian społecznych*. Kraków: Wydawnictwo Znak.

Wacquant, L.J.D. 2001. Wprowadzenie, in: Bourdieu, P., Wacquant, L.J.D. (eds.). *Zaproszenie do socjologii refleksyjnej*, Terminus 21. Warszawa: Oficyna Naukowa, 8-41.

Wuthnow, R. 1987. *Meaning and Moral Order. Explorations in Cultural Analysis*. Berkeley/Los Angeles/London: University of California Press.

Zastawny, A. (ed.) 2014. *Targowisko stan. 10, 11. Osadnictwo z epoki kamienia*. Kraków: Krakowski Zespół do Badań Autostrad.

Zastawny, A., Grabowska, B. 2014. Materiały kultury ceramiki wstęgowej rytej ze st. 10, 11 w Targowisku, pow. Wielicki, in: Zastawny, A. (ed.), *Targowisko stan, 10, 11. Osadnictwo z epoki kamienia*. Kraków: Krakowski Zespół do Badań Autostrad, 63-253.

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# Neolithic pottery innovation in context. A model and case study from the Central and Western Balkans

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## Abstract

Innovation in pottery production and use is understood as a dynamic process, which is related to various different spatial scales and aspects of socio-economic development of human societies. Based on a case study from the central and western Balkans, in this paper, an attempt is undertaken to identify and contextualize innovation processes as seen in an example of pottery production and use. Using research of late Neolithic pottery from Central Bosnia this paper demonstrates how technological and stylistic change, on the one hand, and settlement and population dynamics, on the other hand, are linked, which in turn permits a discussion of the local or micro-regional factors that might be responsible for this development. Furthermore, based on analysis of the spatial range and variability of pottery styles and temper materials, a model explaining which factors affected stylistic and technological choices at meso- and macro-scales is developed.

*Keywords: Neolithic, south-east-Europe, Central Bosnia, Butmir, Vinča, pottery production, boundaries, World System Theory*

## Introduction

The following case study deals with the question of driving factors and socio-economic mechanisms, which caused changes or innovations seen in pottery assemblages. These 'innovations' in a very broadly defined sense, mainly represent regionally differentiated adaptation processes originating elsewhere and earlier as 'inventions', and concern different levels of spatial scale. The mechanisms interlinking local and micro-regional settlement processes, on the one hand, and the distribution of pottery styles and pottery technologies at meso-regional and macro-regional scale, on the other hand, are poorly understood. Thus ethnical displacements and migration until

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recently were wrongly argued as causes for considerable differences and shifts in the distribution areas of certain pottery styles. In contrast, ethnographical and ethno-archaeological research show conclusively that the distribution areas of our 'archaeological cultures' are clearly too large to represent ethnical groups in pre-state societies. They in fact, in many cases, represent distribution areas of pottery styles (*e.g.* Wotzka 1997; Hahn 2005, 153-154). Thus archaeological cultures in this paper are considered purely as pottery style distributions. It is assumed that mechanisms other than ethnicity must exist to explain how local and regional settlement processes are interlinked with each other, which have been under-theorised so far (Porčić 2018).

After a statement regarding the question, how pottery and society can be interlinked with each other, innovation processes at local and micro-regional scale are discussed based on a case study from Neolithic Central Bosnia. The mechanisms that contribute to the shaping of pottery style distributions (alternatively 'archaeological cultures') are discussed at the meso-scale of Central Bosnia and adjacent areas. At the macro-scale, interlinkages are analysed within the western and central Balkan region.

## Interlinking of societies, innovation and pottery

Due to their 'omnipresence' and their use in the context of satisfying daily needs and requirements of household representation pottery are, in particular, suited as source for the reconstruction of the social and socio-economic organisation of ancient societies. For the same reason and also due to their relatively short life-span pottery are an important part of material culture suitable for 'cultural classifications' (or constructions) and chronological differentiation of find assemblages.

The specific way in which stylistic and technological properties of pottery mirror social and economic reality decisively depends on the *relations of production* under which pottery were produced, and the size and composition of the consumer group for whom they were made for. Thus it makes an important difference if somebody produced vessels only for their own household requirements and a few relatives, or if specialised potters satisfied the needs of a much larger group of consumers. In the latter case, it is increasingly likely that the consumer group will include persons with *no* family ties to the potter. Another important aspect is the function of pottery vessels in a society. Are they primarily considered as containers thus as utility objects to which not much attention was paid to? Or vessels had representative purposes in private or public ritual meals? In the latter case, under certain conditions of household production, vessels tend to be 'charged' with symbolic meanings which can, for example, be encoded in decoration styles, elaborated vessel shapes or specially treated surfaces (Wobst 1977; Hegmon 1992; Parkinson 2006a). Under conditions of more specialised pottery production the importance of pottery styles or pottery decoration as a medium of symbolic communication can decline while technical perfection, the standardisation and the investment in more expensive facilities for the production of vessels, such as pottery kilns or potter's wheels, tend to increase. For example, Michael Shanks (2004) using Archaic Greek pottery demonstrated style remained important as a medium of symbolic communication under conditions of specialised production.

Stylistic and technological changes of ceramic vessels and vessel assemblages over time can be the result of multiple causes, and concern different properties and steps of the chaîne opératoire. To be able to interpret such changes it is necessary to analyse precisely the changes themselves, the relations of production of pottery, the production technology, the distribution mechanisms, and also the societal context in the light of other sources. In turn, accelerated stylistic and technological changes in pottery assemblages are probably in principle an indicator for socio-economic change. However, it remains in many cases initially unclear from the transformation of which socio-economic parameters the change in the pottery assemblage result from. Due to incomplete information we don't know in many cases for what rational or irrational reasons prehistoric potters made certain stylistic or technological choices, and what were the triggering parameters or driving forces, and what were the reactions behind such changes. In many cases, a specific need for concrete innovations surely emerged only from a certain socio-economic dynamic. It should be the goal of archaeological reconstructions to identify which of the mentioned aspects are behind changes in pottery assemblages and how they are related to the socio-economic organisation of the evaluated societies.

For the operationalisation of the stated theoretical assumptions, I prefer a very broad definition of the term innovation, which includes not only technical and technological novelties but also organisational changes in the production and distribution of pottery as well as stylistic and functional changes (*e.g.* Schumpeter 1987). Technical innovations concern, for example, firing techniques (*e.g.* pottery kilns dark burnished pottery, painted pottery), temper materials (*e.g.* grog, calcite, organic, un-tempered) or forming techniques (*e.g.* mounting technique, potter's wheel). Organisational innovations comprise of, for example, changes regarding the concentration of production (specialisation processes), the produced amount of pottery or the consumer distribution of the finished products (cf. Costin 1991). Stylistic and functional innovations might concern, for example, the primary purposes of vessels (function and concrete use) but also vessel shapes and the kind of arrangement of decorations as a possible medium of secondary functions.

## Internal socio-economic dynamics with local and micro-regional Scale: late Neolithic in Central Bosnia

Extensive field research recently carried out at Neolithic and early Eneolithic settlements of Central Bosnia have shown a long term perspective of definite coincidences between the developments of pottery, on the one hand, and the local and micro-regional settlement and population dynamics, on the other hand (Müller *et al.* 2013; Hofmann 2013; 2015). The study region is situated in the low middle range of the Dinaric Alps at the interface of regions with different histories of Neolithisation: eastern Adriatic Dalmatia with the pottery sequence of Impresso, Danilo and Hvar on the one hand and the central Balkans with Starčevo/Körös/Criş and Vinča/Sopot on the other hand.

Starting around 5200 BCE, we observe in the study region the emergence of large densely populated settlements, which in the case of Okolište had a size of about 7 ha and temporarily a probable population of more than 2000 people (Hofmann 2013). The inhabitants of these large villages labelled after their characteristic pottery styles as 'Butmir', secured their subsistence with transhumant forms of livestock husbandry (mainly of cattle) that exploited the unsettled high mountain ranges and cultivation of crops, like einkorn, emmer, lentils, and peas, and by gathering wild resources, such as hazelnut, cornel cherry and apple, and to a lesser extent by hunting (Bökönyi 1974; Benecke 2006; Müller 2006; Müller-Scheeßel *et al.* 2010b; Kroll 2013a; Kroll 2013b; Dörfler 2013; Kroll in press).

At Okolište and also other late Neolithic villages in central Bosnia, a spatial layout was maintained over the whole duration of the settlement occupation of 500 years characterised by the arrangement of houses in straight rows (Fig. 1). From an architectural-sociological perspective, this specific layout shows a high degree of axiality and the striking absence of convex spaces for the negotiation of communal concerns. In our interpretation these observations reflect an egalitarian ideology with the endeavour to maintain social balance by means of social control and community-focused rules (Müller-Scheeßel *et al.* 2010a).

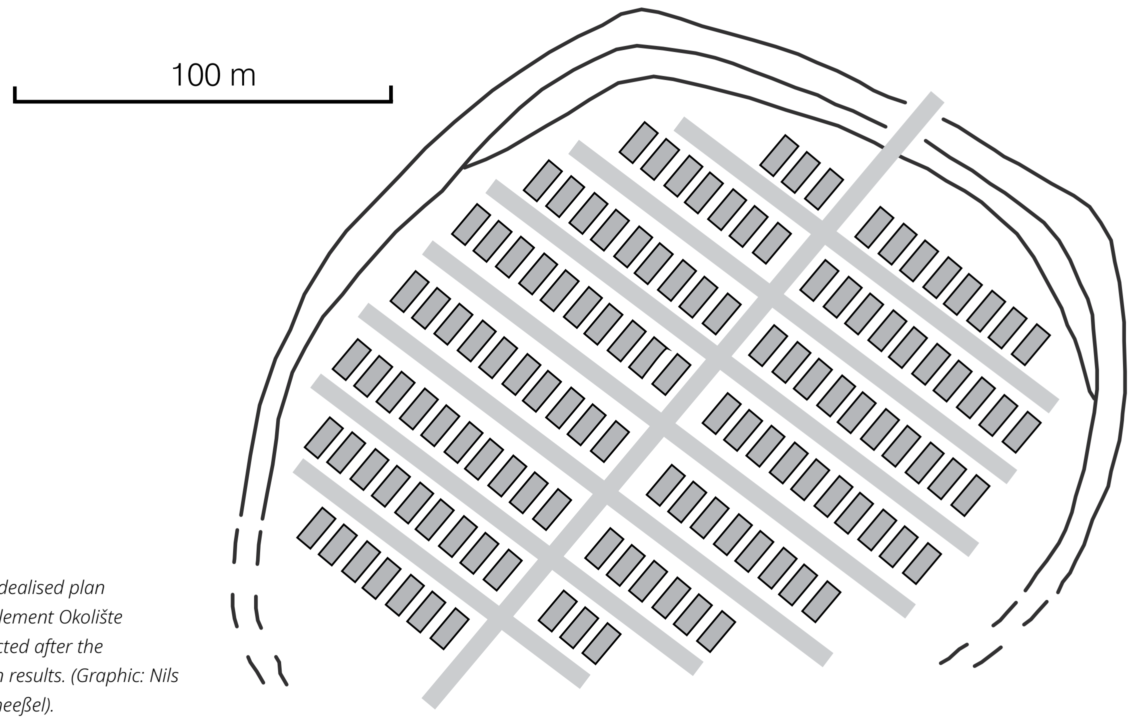



*Figure 1. Idealised plan of the settlement Okolište reconstructed after the excavation results. (Graphic: Nils Müller-Scheeßel).*

On the other hand, we interpret the unequal artefact distributions in adjacent houses (households?) as an indicator for emerging social inequality and contradiction of the egalitarian ideal (Müller *et al.* 2011; Arponen *et al.* 2015). Through intra-site analysis we identified so-called Alpha-households, which were particularly active not only in economic terms but also with regard to ritual activities. The limited availability of arable land and pasture in the catchment of the settlement was identified especially as a possible factor for the development of social inequality (Müller 2006; Bultmann 2012). 'Alpha households', whose members are supposed to represent the political rulers of the village, showed an above average agricultural productivity indicated by frequent grinding stones fits with this interpretation.

Emerging social inequality perhaps formed the starting point and background for internal conflicts and as a consequence the gradual disintegration of the large settlement system that began from around 4850 BCE, which is reflected in substantial local population decline. Starting at the same time, we observe the fission of smaller population groups and the establishment of small settlements in tributaries adjacent to the Visoko Basin and the main Bosna valley.

In the time between around 4850 to 4700 BCE, a dichotomous settlement system became established with larger sites focused on horticulture in the main valley of the Bosna, on the one hand, and very small sites in higher elevated tributaries, on the other. The latter settlements were strongly focused on livestock husbandry and less on horticulture than the settlements in the valleys (Furholt 2013). From an economic point of view, this transformation can be interpreted as an adaptive process to the specific environmental conditions of the Bosnian mountain zone.

The development of the pottery in Okolište has been described in detail elsewhere (Hofmann 2012; 2013). Following a macro-regional trend we observed in the earlier site of Obre, the transition to the production under reducing conditions of fired dark pottery from around 5400 BCE with the continued fabrication of unevenly burnt coarse wares and finer (pre-firing) painted fabrics (cf. Sterud and Sterud 1974; Perić 1995). The surface of the dark fired fabrics initially was unburnished. This was the case in the formative layers of the site Okolište from the time around 5200 BCE (Hofmann 2013).

In the following 150-200 years, until about 5000 BCE, the pottery in Okolište underwent enormous changes reflected, among other things, by significantly increased innovation rates represented by newly emerging decoration motifs and vessel shapes per year (Hofmann 2013, 356-357) (Fig. 2). In this period, we observe an increasing control over the reducing firing technique, the strong increase in the frequency of burnished surface finish and fine fabrics, and the emergence of clearly differentiated vessel categories each with specific technological properties. Newly emerging vessel classes are, for example, partly large and highly decorated necked vessels, bowls with high stands and numerous kinds of bowls made from fine fabrics. Additionally in this period, there is an increase in the number of sherds decorated with geometrical motifs and an overall diversity in decorations and vessel shapes. River sediments as temper are gradually replaced by crushed calcite while fine wares are increasingly un-tempered, with perhaps elutriated fabrics dominating. In terms of functional categories, the percentage of representative serving vessels made of fine fabrics grew rapidly compared to other vessel functions (Hofmann 2012, 198). Accordingly, from phase 2 onwards representative serving vessels dominate the assemblage, while storage vessels are generally poorly represented.

I would like to stress two aspects. Firstly, there is a definite posteriority of the observed changes after the founding of the settlement. Consequently, the changes might represent indirectly the responses of the society to the socio-economic transformations related to the establishment of the large population nucleation. Secondly, the adopted innovations in pottery production originate from different sources. Un-tempered, dark burnished pottery and the division into vessel classes are elements which had already occurred earlier in the central Balkan area (Chapman 2006; Schier 1995). In contrast, tempering with crushed calcite had already been practiced since the early Neolithic in the eastern Adriatic region (Spataro 2002; Spataro and Meadows 2013).

Decisive for our interpretation are also the changes that occurred later. After 4850 BCE, parallel with the disintegration of the population agglomeration, we observe sharply diminishing innovativeness of decorations and vessel shapes, as well as decreasing decoration rates and diversity. In addition, the vessel assemblage gradually lost their regional Butmir-specific style. Instead, in the period between 4850 and 4500 BCE we observe increased percentages of pottery styles of adjacent cultural groups Hvar-Lisičiči, on the one hand, and Vinča, on the other.

Unspecific distribution of pottery styles within the settlement, increased control over the firing process and also the slight increase of metrical standardisation of vessel dimensions are indicators of rising degrees of specialisation in the pottery production (Hofmann in press). However, in Central Bosnia the degree of specialisation was lower compared to the core of the distribution area of Vinča pottery. This is reflected in a low scale of pottery production of on average 1-3 vessels per household a year, which was calculated through 'translation' of the found pottery remains into counts of vessels, and by upscaling of these numbers on the total volume of the settlement mound (Hofmann in press). Lower metrical standardisation of vessels compared to other regions points in the same direction (Hofmann in press; Vuković 2011). So far, it is unclear whether pottery was produced by members of a group of particularly active Alpha households, which probably dominated the village politically (Müller *et al.* 2011). Alternatively, in analogy to many ethnographical observed cases, pottery production might have been an activity of households, which were characterised by underproduction in the field of agriculture (Rice 1987).

In accordance with the above mentioned theoretical considerations, we interpret the coincidence of strong population growth of up to an estimated 0.5 % per year, on the one hand, and increased innovation rates in the pottery production, on the other, as indicators for changing socio-economic conditions in the late

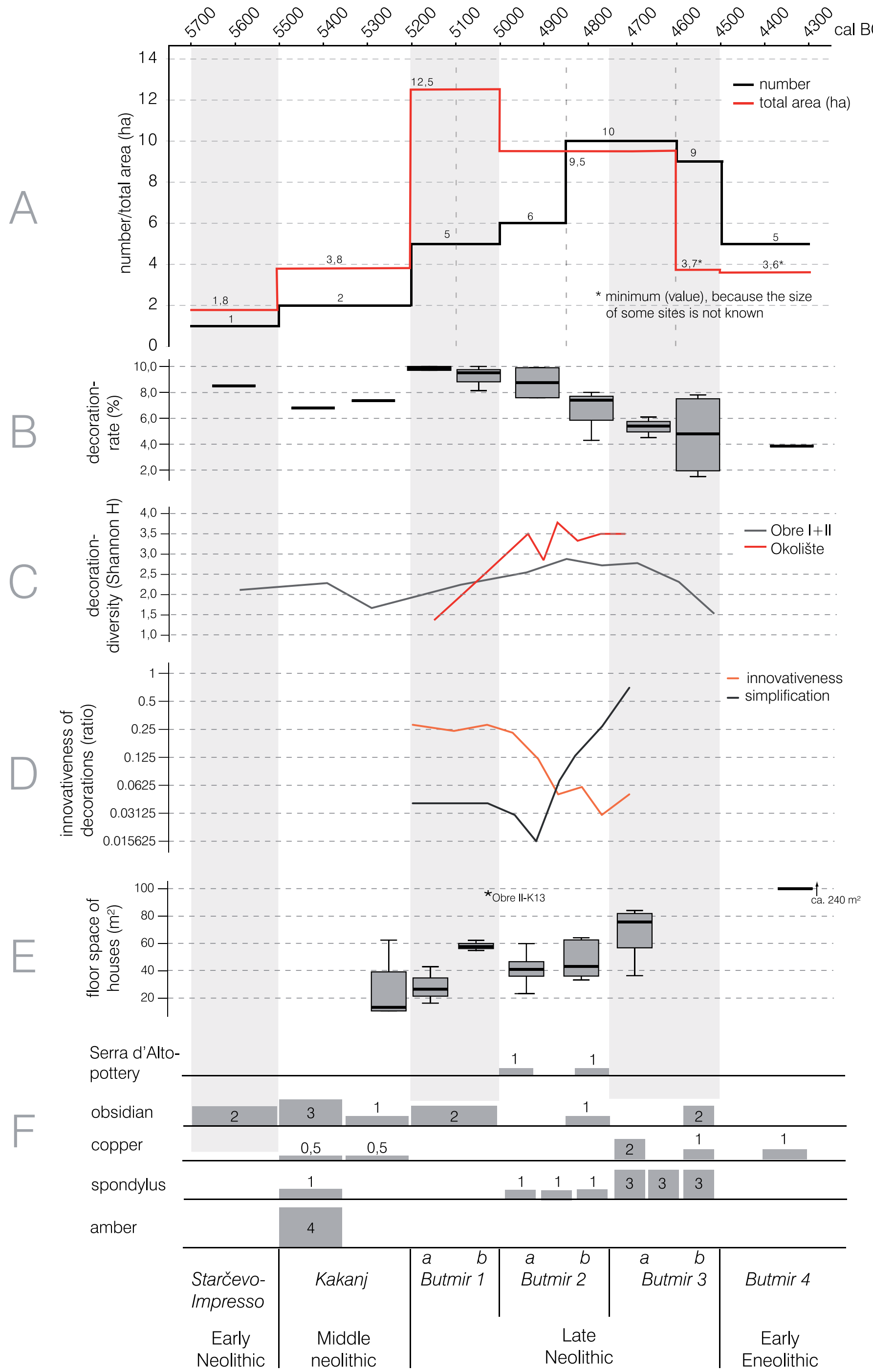



*Figure 2. Development of selected archaeological sources from 5700 to 4300 BCE in Central Bosnia: A) number and total area of settlements in Central Bosnia after Hofmann 2013; B-C) decoration rate and decoration diversity of pottery (B = Okolište, Kundruci, Obre I, Obre II, Zagrebnice, Donje Moštre); D) Innovativeness and simplification quotient of pottery decorations in Okolište after Hofmann 2013, 356; E floor space of houses in Obre I and II, Okolište, Kundruci, Zagrebnice and Donje Moštre; F number of imported goods Obre I, Obre II, Okolište and Donje Moštre.*

Neolithic society of Okolište and the Visoko Basin. The increased frequency of consumption vessels made from representative fine wares and increased decoration rates and diversity, probably results from an increased need for representation within the framework of competitive relationships between households under conditions of an enlarged society and limited resources, such as arable land.

Starting from around 4850 BCE, the decrease of, innovation rates, fine fabrics, decoration rates and diversity indicates also a decreasing need for household representation. Possibly as an adaptation to limited resources of arable land, at the same time as a more dispersed settlement system starts to develop at a micro-re-

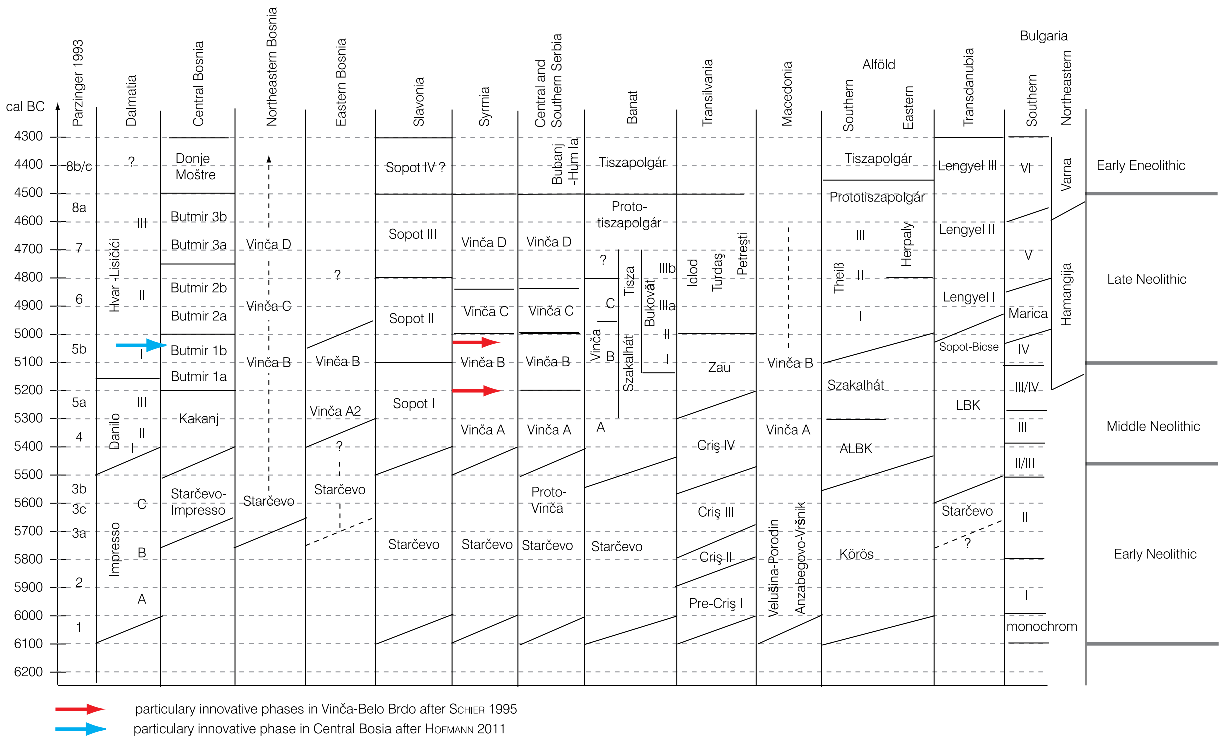



*Figure 3. Comparative chronology of regions in the Balkans. Phases of accelerated cultural change in the central Balkans and in Central Bosnia are marked with arrows.*

gional scale. Settlements situated in the main valley of Bosna River were more focused on gardening while smaller sites in higher elevated tributaries show a stronger emphasis on animal husbandry. During this transformation process, larger and possibly more economically autonomous acting households emerged.

## Regional interaction: the link from micro to meso-scale

During the Neolithic phases of south-east Europe, uniform pottery styles distributed over large territories can be distinguished from periods with stronger regional pottery distribution. This variability can be demonstrated clearly on the basis of the spatial distribution of 'archaeological cultures', which are usually defined based on pottery criterions (Fig. 3).

During the early Neolithic we observe, with the Starčevo-Körös-Criş complex, an extremely large territory with very uniform pottery styles and technology (*e.g.* Parzinger 1993; Spataro 2011) (Fig. 4). Later, around 5500 BCE in the middle Neolithic, a clear trend towards regionalisation with smaller cultural groups began. This trend continued during the late Neolithic until about 4600 BCE. However, the late Neolithic period of the western and central Balkans is also marked by a dichotomy between the huge distribution area of Vinča pottery styles, on the one hand, and significantly smaller surrounding 'style provinces', on the other. A reversal in the trend towards larger distribution areas of pottery styles took place around 4600/4500 BCE is associated with critical developments during the transition to the Copper Age.

Again, the Central Bosnian case study contributes to the understanding of this development. The emergence of pottery styles, which are distributed at meso-regional scale like Kakanj and (later) Butmir, coincided with significant population growth and a population nucleation process. The development of the new pottery styles shows two different aspects: (i) We observe the adaptation and hybrid of new combination of stylistic elements, which had different origins, correspond-

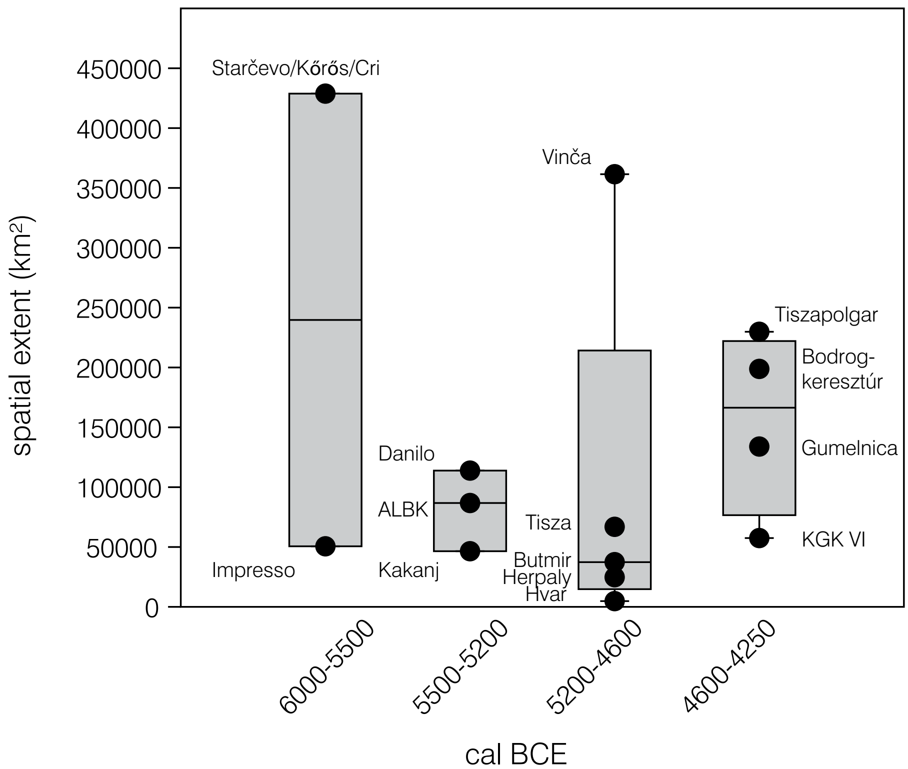



*Figure 4. Boxplot and scatterplot diagram which shows the spatial extension of selected archaeological cultures in the central and western Balkans between about 6000 and 4250 BCE.*

ing to the geographical position at the interface of different cultural complexes; (ii) The above described internal socio-economic processes, which were driven by the novel demographic structure, led to an increase in stylistic diversity and the stylistic effort in the production and decoration of vessels.

A reverse trend towards stronger regional uniformity of pottery styles began around 4850 BCE coinciding with the emergence of a more dispersed and differentiated settlement system. From this point, the Butmir settlements lose more and more of their stylistic significance, and there is an increase in the frequency of vessel units, which show similarities with styles of adjacent regions. Initially, we observe the more or less equal co-occurrence of east Adriatic (Hvar-Lisičići) and central Balkan (Vinča) styles before Vinča elements in the form of channelling started to dominate in the the last phase of the late Neolithic.

The described coincidences between pottery variability and settlement development show that most likely the configuration of regional settlement patterns and related specific interaction patterns are key factors for the spatial range and the distribution of pottery styles. Accordingly, the size of settlements, their economic bases, the social configuration and the micro-regional settlement and population structure are definitive of the type, intensity and range of human interaction. Therefore, it is of crucial importance for the understanding of the observed transformations to identify the concrete changes, which occurred with regard to the regional interaction between agglomerated settlements from around 4900 BCE and more dispersed organised late Butmir societies from 4700 BCE and later.

We need to focus on the fact that the human agents who are responsible for the interaction were most likely integrated in differently directed local and regional communication networks. In our case study, this fact is reflected among other things in the frequency of anthropomorphic and zoomorphic figurines which are mainly a feature of the central Balkan Neolithic. Indeed, anthropomorphic figurines in Butmir settlements are stylistically specific and surely locally produced although they show similar characteristics to central Balkan items, such as distinct size classes and attributes (Hofmann and Hofmann 2012-2013). We therefore assume that they have been made for similar reasons. In societies with Vinča pottery styles, figurines are extremely frequent with on average one figurine per cubic metre of excavated earth. In contrast, in Okolište on average only in every 100 $m^3$ of excavated earth a figurine was found. The construction and use of an average sized house of around 20 $m^3$ of sediment was accumulated in purely arithmetical terms only every fifth house (household?) was associated with such a figurine (Hofmann and Hofmann 2012-2013). Other households might have been integrated into these south-westward interaction networks indicated for instance, by arrow heads, which are widely unknown in the central Balkans. In Okolište, these increased at the same time as Hvar-Lisičići style pottery became more frequent (Müller-Scheeßel 2013).

For the configuration and direction of interaction, an important role was played potentially by the exchange and supply of raw materials. Judging from the point of view of the very sporadic occurrence in the archaeological record, exotic and potentially prestigious materials, such as spondylus from the Aegean, obsidian from Lipari and the Carpathian Basin, painted Serra d'Alto pottery from Italy and copper from the central Balkans probably had only a minor importance (Hofmann 2015, Fig. 17).

In contrast, the supply of non-local raw materials for the production of chipped and polished stone tools was potentially more important, however, concrete provenance is in the most cases an unsolved problem. In the settlement Okolište, in particular between 5000 and 4850 BCE a good supply of raw materials for chipped stones was the case indicated by relatively heavy cores and large blades (Müller-Scheeßel 2013, 268-269). In the later phases of the settlement, between about 4850 and 4700 BCE, smaller blades and the greater exploitation of cores was observed which is interpreted as result of the deterioration of the supply situation.

Accordingly, the trend towards more uniform pottery styles on a larger geographical scale does not in any way mean an intensification of exchange. In our Bosnian case study rather the opposite seems to be the case. In fact, the reorganisation of interacting patterns probably concerned other social and economic spheres, which are archaeologically more difficult to detect. A possible factor might be the shrinking population density at a local and regional scale which probably led to an increase in the frequency of exogamous marriages. A more regionally oriented connectivity (networking) might also be caused by higher overall mobility manifested in clearly shorter-lived settlements. A decisive factor in this case might have been a greater focus on transhumant livestock farming through exploitation of adjacent mountain regions, which without doubt led to numerous intergroup contacts.

A very similar development and dynamic with comparable impact on associated pottery assemblages as in our Bosnian case study was reconstructed by William A. Parkinson for the transition from the late Neolithic to the early Copper Age in the Great Hungarian Plain (Parkinson 2006a; 2006b). He characterised the late Neolithic as a period within those social boundaries which was actively maintained at all spatial levels: at the macro-regional level of the Tisza-Herpály-Csőszhalom cultural complex, at regional levels of spatially separated settlement clusters with sizes between 14-70 $km^2$ and at local scales through the long-living maintenance and fortification of settlement places.

According to the highly explanatory model of Parkinson (2006b), scalar stress resulting from the increase of group size represented a key factor, which at the beginning of the Copper Age increasingly led to fission of large communities and consequently to the reorganisation of the regional settlement systems (cf. Borić 2015; Banffy *et al.* 2016). Scalar stress can occur when large groups of people live together without sufficient political and organisational structure to manage the higher group complexity. In the Great Hungarian Plain, the reorganisation process was accompanied by strongly increased residential mobility, the emergence of numerous clearly smaller settlements with a much lower population, clearly reduced households sizes (nuclear

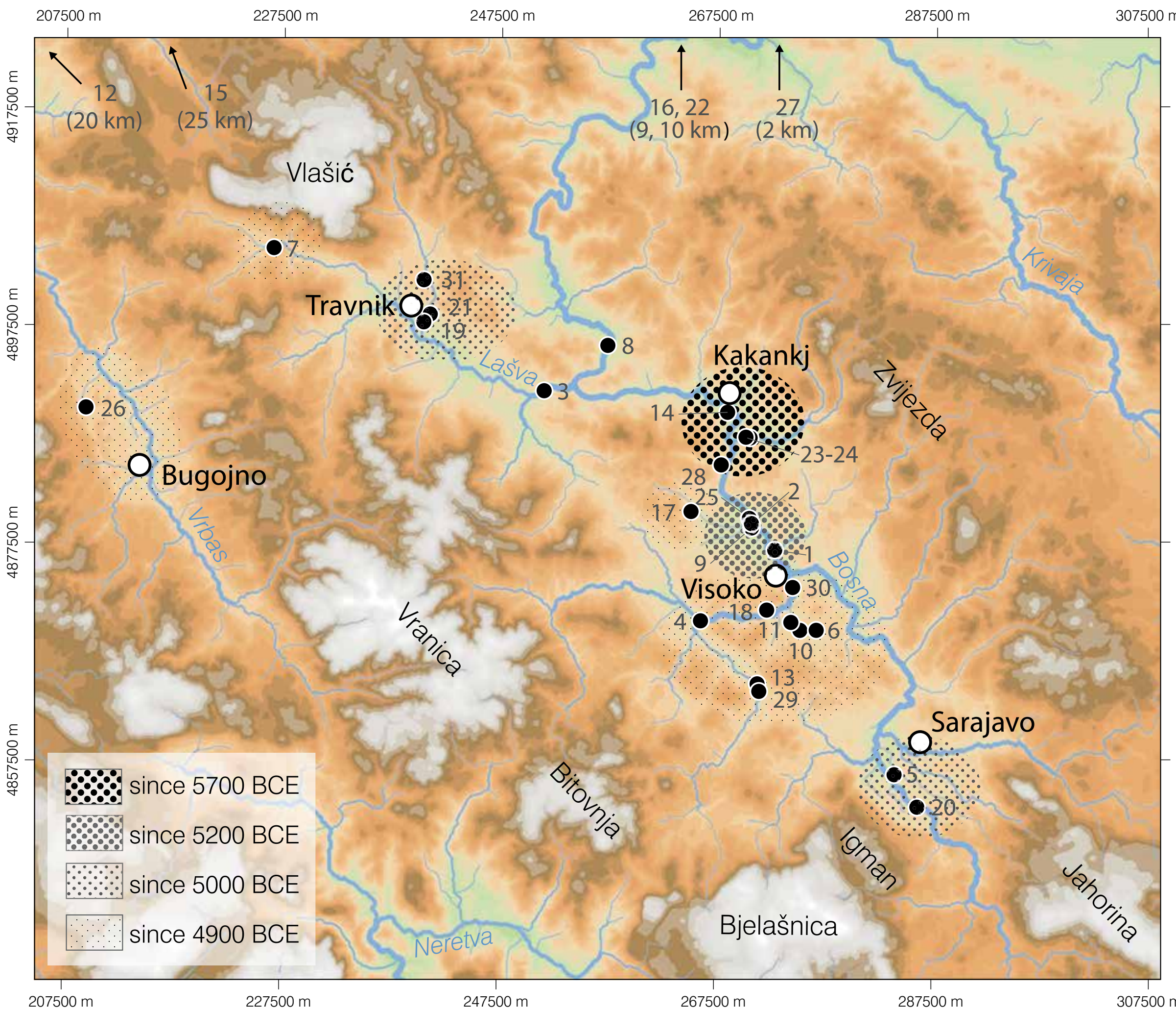



*Figure 5. Separated clusters of Neolithic and early Eneolithic sites in Central Bosnia in the vicinity of the modern towns Kakanj, Visoko, Sarajevo, Travnik and Bugojno and a chronological model of the spatial spread of Neolithic settlements. 1 Arnautovići, 2 Batare, 3 Borak, 4 Brdo, 5 Butmir, 6 Cifluk, 7 Crkvine, 8 Drivuša, 9 Donje Moštre, 10 Dvor, 11 Ginje, 12 Gradina (Bocac), 13 Han Ploca, 14 Kakanj (Plandište), 15 Kovacica, 16 Kraljevine, 17 Kundruci, 18 Lopata, 19 Mujevine, 20 Naklo, 21 Nebo, 22 Novi Šeher, 23 Obre I (Raskršce), 24 Obre II (Gornje Polje), 25 Okolište, 26 Prusac (Biograd), 27 Tuk, 28 Zagrebnice, 29 Zagrebnjaca, 30 Zbilje (Krstac), 31 Gradina (Alihodža).*

families?) and other critical developments, such as significantly increased importance of hunting (cf. Hoekman-Sites and Giblin 2012). Highly increased uniformity of pottery styles over large territories were interpreted as an indicator for increased intensity of social interaction and more relaxed and permeable social boundaries. However, also the precise nature of these shifts in terms of social behaviour is undetermined.

It is extremely difficult to answer the question to what extent regional integration in terms of economical, relational (kinship), historical, political or mythological relations played a role for the configuration and spatial scope of pottery styles. In the described Hungarian case study, a ‘tribal’ socio-political organisation were assumed supposedly to have manifested in large and long-lived supersites as cores of spatially separated settlement clusters and much larger super clusters (Parkinson 2006b). However, the author did not substantiate these conclusions by means of stylistic pottery analysis, which are mainly based on spatial analysis of the settlement itself.

Also in the Bosnian case study spatially separated clusters of settlements exist in basins of the Bosna and Lašva River which are, to a high degree due to the topography and the resulting limited availability of arable land in the zones between of these clusters (Fig. 5). Close physical proximity is very likely to lead to a clearly higher intensity of contacts, and to stronger economic, relational, and political interlinking within such separated micro-regions. On a higher spatial level, the different micro-regions that form together the distribution area of Butmir pottery style within the Central Bosnian low mountain range are interlinked, among other things, through a joint settlement history which had begun near the town of Kakanj (Hofmann 2013, 409-442). Large scaled analysis regarding the question how these different degrees of interconnections might be reflected in pottery assemblages and other categories of material culture has not been carried out.

## Centre-periphery relations: fluctuations at macro-scale

There is considerable evidence that macro-regional factors played an important role in innovation and adaptation processes. To pottery related indicators for that in south-east Europe concern, for example, shifting distribution limits of styles, changing frequencies of styles with different origins in vessel assemblages (*e.g.* Burić and Težak-Gregl 2009; Dammers *et al.* 2014), the spread of dark burnished fabrics (Chapman 2006), but also the introduction and spread of advanced firing technologies, such as the black topped technique (Schier 1995). In contrast to numerous ethnical interpretations of such phenomena by representatives of cultural-historical schools, John Chapman (1981), Timothy Kaiser and Barbara Voytek (1983), and also Wolfram Schier (1995) interpreted the formation of Vinča as result of internal innovation processes which began in different innovative regions situated, for example, in the middle and southern Morava region and the south-eastern part of the Great Hungarian Plain (see also Whittle *et al.* 2016; Tasić *et al.* 2016).

For the explanation of disparities at the spatial macro-level, the World System Theory (WST) of Immanuel Wallerstein and related dependence theories play an important role. There is an intensive discussion about the question of these theories, which were originally developed for capitalistic industrial economies, whether they can be applied to prehistoric societies (*e.g.* Sherratt 1993; Kardulias 1996; Kümmel 2001; Harding 2013). According to the WST, regional disparities can be explained by asymmetric core-periphery relations and mutual economic dependencies between centres, semi-peripheries and peripheries whereby usually centres are profiting at the expense of the peripheries (Wallerstein 1974).

The difficulty in the application of the WST to prehistoric societies is that direct dependencies are in many cases neither detectable nor really probable. Thus, Andrew Sherratt proposed the concept with the third zone or so called '*margin*' (Sherratt 1993). This term describes a zone functionally not differentiated and not dependent on the core but nevertheless related to it through exchange of certain items and the spread of ideas and technologies. However, a reservation should be mentioned about this variant of the WST that the effective processes between the centre and margin remain unprecise and unclear.

Network analysis or mathematical theory of prices, quantities and exchange have been proposed as alternative bottom-up approaches to describe interrelations between regions (cf. Harding 2013; Windler 2017). However, due to the insufficient data, corresponding empirical investigations have not been carried out so far (cf. Porčić and Nešić 2014). Moreover, the strength of these theories mainly consists in the *description* of exchange and communication networks while the explanatory potential of the WST goes further. Thus I tend to give priority to the more explanatory ideas of Kristian Kristiansen, who distinguished *direct* and *indirect* centre-periphery relations in extension of the original WST (Kristiansen 1998, 399 f.).

*Table 1 (overleaf). Data table of temper materials in Neolithic pottery assemblages of the central and western Balkans.*

| site | layer | latitude | longitude | pottery style | dating | shell | calcite | calcite + sand | calcite, chrused + sand | calcite, chrushed | calcite, granular | crushed calcite + coarse sand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blagotin | Blagotin I | 43,811 | 21,140 | Starčevo/Körös/Criş | 5700 | | | | | | | |
| Borđoš | Borđoš A (circular earthwork) | 45,6 | 20,133 | ? | 5000 | | | | | 11,1 | | |
| Borđoš | Borđoš B (flat settlement) | 45,6 | 20,133 | Tisza/Vinča | 4800 | | | | | 0,7 | | |
| Borđoš | Borđoš C (tell upper layer) | 45,6 | 20,133 | Tisza, Vinča, Proto-Tiszapolgár | 4600 | 1 | | | | | | |
| Bregovi nad Bakarama | not differentiated | 45,091 | 18,095 | Starčevo/Körös/Criş | 5750 | | | | | 9,6 | | |
| Bribir | not differentiated | 45,162 | 14,761 | Danilo | 5300 | | | | | | 103,8 | |
| Butmir | not differentiated | 43,826 | 18,316 | Borđoš | 4750 | | | | | 39,8 | 0,8 | |
| Danilo-Bitinj | not differentiated | 43,933 | 15,8 | Danilo | 5300 | | | | | 0,2 | 91,5 | |
| Dobrovac (Čelić) | not differentiated | 44,718 | 18,774 | Vinča | 5200 | | | | | 13,7 | | |
| Donja Tuzla | not differentiated | 44,536 | 18,685 | Vinča | 5000 | | | | | 50 | | |
| Donje Moštre | phase 4 | 44,026 | 18,143 | Donje Moštre | 4350 | | | | 34,7 | | | 9,5 |
| Gornja Tuzla | stratum 6 b | 44,542 | 18,759 | Starčevo/Körös/Criş | 5300 | | | | | 50,2 | 0,5 | |
| Gura Baciului | IB-IC | 46,788 | 23,521 | Starčevo/Körös/Criş | 5950 | | 14 | | | | | |
| Gura Baciului | SC IC-IIA | 46,788 | 23,521 | Starčevo/Körös/Criş | 5900 | | | | | | | |
| Gura Baciului | SC IIA | 46,788 | 23,521 | Starčevo/Körös/Criş | 5850 | | | | | | | |
| Gura Baciului | SC IIA-IIB | 46,788 | 23,521 | Starčevo/Körös/Criş | 5800 | | | | | | | |
| Gura Baciului | SC IV | 46,788 | 23,521 | Starčevo/Körös/Criş | 5300 | | | | | | | |
| Islam Grčki | not differentiated | 44,167 | 15,467 | Hvar-Lisičići | 4300 | | | | | | 90 | |
| Jagnilo | Jagnilo | 43,634 | 18,971 | Vinča | 5300 | | | | | 14,7 | | |
| Jamnina Sredi (Insel Cres) | Jamina Sredi I | 44,663 | 14,497 | Impresso | 5800 | | 7 | | | 90 | | |
| Kakanj-Plandište | not differentiated | 44,121 | 18,111 | Kakanj | 5300 | | | | | 48,4 | | |
| Kraljevina | Kraljevina_unspezifisch | 44,514 | 18,068 | Butmir | 4900 | | | | | 31,8 | | |
| Kulište | not differentiated | 44,989 | 18,458 | ? | 4500 | | | | | 13,5 | | |
| Lepinski Vir | Lepinski Vir 1965 | 44,533 | 22,1 | Starčevo/Körös/Criş | 5750 | | | | | | | |
| Lisičići | not differentiated | 43,683 | 17,887 | Hvar-Lisičići | 4700 | | | | | 93,4 | 1 | |
| Mala Triglavca | older Neolithic layer | 45,673 | 13,957 | Danilo, Vlaska Gruppe | 5450 | | 100 | | | | | |
| Mala Triglavca | Eneolithic layer | 45,673 | 13,957 | ? | 4350 | | 94,5 | 4,8 | | | | |
| Mala Triglavca | younger Neolithic layer | 45,673 | 13,957 | Danilo, Vlaska Gruppe | 5450 | | 97,6 | 2,4 | | | | |
| Markova Špilja | Markovo Špilja I | 43,191 | 16,389 | Impresso | 5750 | | | | | 3,8 | 89,5 | |
| Nebo | not differentiated | 44,193 | 17,765 | Butmir | 4800 | | | | | 45,5 | 0,2 | |
| Nin | not differentiated | 44,244 | 15,193 | Impresso | 5700 | | | | | 2,2 | 95,5 | |
| Obre I (Raskršće) | Obre 1A (I/1) | 44,101 | 18,136 | Starčevo/Körös/Criş | 5650 | | | | | | | |
| Obre I (Raskršće) | Obre 1B (I/2) | 44,101 | 18,136 | Starčevo/Körös/Criş | 5400 | | | | | 0,1 | | |
| Obre I (Raskršće) | Obre 1C (I/3) | 44,101 | 18,136 | Kakanj | 5100 | | | | | | | |
| Obre II (Gornje Polje) | Level 2 | 44,100 | 18,138 | Butmir | 5075 | | | | | 5,3 | | |
| Obre II (Gornje Polje) | Level 3 | 44,100 | 18,138 | Butmir | 4975 | | | | | 60,2 | | |
| Obre II (Gornje Polje) | Level 4 | 44,100 | 18,138 | Butmir | 4900 | | | | | 77,2 | | |
| Obre II (Gornje Polje) | Level 5 | 44,100 | 18,138 | Butmir | 4800 | | | | | 78,6 | | |
| Obre II (Gornje Polje) | Level 6 | 44,100 | 18,138 | Butmir | 4700 | | | | | 96,8 | | |

| organic | organic + coarse sand | organic + sand | organic + sand + coarse sand | organic + sand + stones | coarse sand + organic | quarz | quarz, crushed | mineralic (sand, coarse sand) | sand | sand, coarse | coarse sand + sand | river sediment | steatite | schist | black stones | stone, chrushed | grog | untempered | ? | source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | 83 | | | 7 | | | | | | | | | | | | | 6 | 4 | Vuković 2004 |
| 33,3 | | | | | | | | | 11,1 | | | | | | | | 27,8 | 16,7 | | unpublished |
| 12 | | | | | | | | | 4,2 | | | | | | | | 62,7 | 20,4 | | unpublished |
| 7,9 | | | | | | | | | 11,9 | | | | | | | | 33,7 | 45,5 | | unpublished |
| 42,9 | | | | | | | | | 38,2 | | | | | | | | | 9,6 | | Rasson 1983 |
| | | | | | | | | | 4,5 | | | | | | | | | 4,5 | | Rasson 1983 |
| 0,7 | | | | | | | | | 4,8 | | | | | | | | | 53,9 | | unpublished |
| 21,3 | | | | | | | | | 0,7 | | | | | | | | | | | Rasson 1983 |
| 1,1 | | | | | | | | | 56,9 | | | | | | | | | 28,5 | | Rasson 1983 |
| | | | | | | | | | 10 | | | | | | | | | 22,5 | | Rasson 1983 |
| | | | | | | | | | 35,8 | 8,4 | 6,3 | | | | | | 1,1 | 4,2 | | unpublished |
| 20,7 | | | | | | | | | 11,9 | | | | | | | | | 14 | | Rasson 1983 |
| 58 | | 14 | | | | | | | 7 | | | | | | | | | 7 | | Spataro 2008 |
| 66 | | 17 | | | | | | | 13 | | | | | | | | | 4 | | Spataro 2008 |
| 79 | | 13 | | | | | | | 4 | | | | | | | | | 4 | | Spataro 2008 |
| 75 | | 17 | | | | | | | 8 | | | | | | | | | | | Spataro 2008 |
| 72 | | 14 | | | | | | | | | | | | | | | | 14 | | Spataro 2008 |
| | | | | | | | | | | | | | | | | | | 10 | | Rasson 1983 |
| | | | | | | | 9,8 | | 46,1 | | | | | 18,6 | | | 2 | 8,8 | | unpublished |
| | | | | | | | | | | | | | | | 3 | | | | | Spataro 2002 |
| 1,6 | | | | | | | | | 48,5 | | | | | | | | | 1,6 | | Rasson 1983 |
| 4,5 | | | | | | | | | 22,7 | | | | | | | | | 40,9 | | Rasson 1983 |
| 3,7 | | | | | | | | | 29,5 | | | | | | | | | 53,1 | | Rasson 1983 |
| | 0,5 | 90 | 0,3 | 7,5 | | | | | 1,5 | | | | | | | | | | | Perić/Nikolić 2004 |
| | | | | | | | | | 3,9 | | | | | | | | | 0,7 | | Rasson 1983 |
| | | | | | | | | | | | | | | | | | | | | Gašparič 2004 |
| | | | | | | 0,7 | | | | | | | | | | | | | | Gašparič 2004 |
| | | | | | | | | | | | | | | | | | | | | Gašparič 2004 |
| | | | | | | | | | 2,9 | | | | | | | | | 2,9 | | Rasson 1983 |
| 0,2 | | | | | | | | | 13,5 | | | | | | | | | 34,1 | | Rasson 1983 |
| | | | | | | | | | 4,4 | | | | | | | | | | | Rasson 1983 |
| 48,7 | | | | | | | | | 51,3 | | | | | | | | | | | Rasson 1983 |
| 1,3 | | | | | | | | | 98,6 | | | | | | | | | | | Rasson 1983 |
| 0,3 | | | | | | | | | 99,8 | | | | | | | | | | | Rasson 1983 |
| | | | | | | | | | 91,6 | | | | | | | | | 2,9 | | Rasson 1983 |
| | | | | | | | | | | | | | | | | | | 39,8 | | Rasson 1983 |
| | | | | | | | | | | | | | | | | | | 22,8 | | Rasson 1983 |
| | | | | | | | | | | | | | | | | | | 21,9 | | Rasson 1983 |
| | | | | | | | | | | | | | | | | | | 3,3 | | Rasson 1983 |

| site | layer | latitude | longitude | pottery style | dating | shell | calcite | calcite + sand | calcite, chrused + sand | calcite, chrushed | calcite, granular | crushed calcite + coarse sand |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Obre II (Gornje Polje) | Level 7 | 44,100 | 18,138 | Butmir | 4625 | | | | | 98,7 | | |
| Obre II (Gornje Polje) | Level 8 | 44,100 | 18,138 | Butmir | 4550 | | | | | 99,9 | | |
| Okolište | Phase 7 | 44,034 | 18,140 | Butmir | 4825 | | | | 4 | 38 | | |
| Okolište | Phase 8 | 44,034 | 18,140 | Butmir | 4775 | | | | 10 | 54 | | |
| Okolište | Phase 9 | 44,034 | 18,140 | Butmir | 4725 | | | | 18 | 63 | | |
| Okolište | Phase 1 | 44,034 | 18,140 | Kakanj | 5175 | | | | 13 | 11 | | |
| Okolište | Phase 2 | 44,034 | 18,140 | Butmir | 5120 | | | | 10 | 10 | | |
| Okoliste | Phase 3 | 44,034 | 18,140 | Butmir | 5035 | | | | 10 | 19 | | |
| Okolište | Phase 4 | 44,034 | 18,140 | Butmir | 4960 | | | | 8 | 26 | | |
| Okolište | Phase 6 | 44,034 | 18,140 | Butmir | 4875 | | | | 9 | 27 | | |
| Opovo-Ugar Bajbuk | Layer 1 | 45,05 | 20,417 | Vinča | 4750 | | | | | | | |
| Opovo-Ugar Bajbuk | Layer 2 | 45,05 | 20,417 | Vinča | 4800 | | | | | | | |
| Opovo-Ugar Bajbuk | Layer 3 | 45,05 | 20,417 | Vinča | 4875 | | | | | | | |
| Pokrivenik | not differentiated | 43,733 | 15,717 | Hvar | 4900 | | | | | 6,8 | 93,1 | |
| Selevac, Staro Selo | Selevac S-A I | 44,433 | 20,733 | Vinča | 5200 | | | | | | | |
| Selevac, Staro Selo | Selevac S-A II | 44,433 | 20,733 | Vinča | 5000 | | | | | | | |
| Selevac, Staro Selo | Selevac S-A III | 44,433 | 20,733 | Vinča | 4900 | | | | | | | |
| Selevac, Staro Selo | Selevac S-A IV | 44,433 | 20,733 | Vinča | 4800 | | | | | | | |
| Seusa - La Cararea Morii | level I | 46,041 | 23,634 | Starčevo/Körös/Criş | 5900 | | | | | | | |
| Skarin Samograd | Samograd I | 43,802 | 16,068 | Impresso | 5650 | | 100 | | | | | |
| Smilčić-Barica | Smilčić I | 44,117 | 15,483 | Impresso | 5700 | | 98 | | | | | |
| Trhlovca | horizon F | 45,672 | 13,947 | ? | 4350 | | 79,6 | 19,2 | | | | |
| Trhlovca | horizon G | 45,672 | 13,947 | Danilo | 5450 | | 98,5 | 1,5 | | | | |
| Trhlovca | horizon H | 45,672 | 13,947 | Danilo | 5450 | | 98,5 | 1,5 | | | | |
| Tuk | not differentiated | 44,440 | 18,151 | Kakanj, Vinca | 5150 | | | | | 5,3 | | |
| Vela Špila (Korčula) | Vela Špila IIa | 42,964 | 16,721 | Impresso | 5900 | | 93 | | | | | |
| Vinča-Belo Brdo | phase 1 | 44,669 | 20,725 | Starčevo/Körös/Criş | 5500 | | | | | | | |
| Vinča-Belo Brdo | phase 2a | 44,669 | 20,725 | Vinča | 5300 | | | | | | | |
| Vinca-Belo Brdo | Phase 2b | 44,669 | 20,725 | Vinča | 5275 | | | | | | | |
| Vinca-Belo Brdo | phase 3 | 44,669 | 20,725 | Vinča | 5250 | | | | | | | |
| Vinca-Belo Brdo | phase 4 | 44,669 | 20,725 | Vinča | 5200 | | | | | | | |
| Vinča-Belo Brdo | phase 5a | 44,669 | 20,725 | Vinča | 5150 | | | | | | | |
| Vinča-Belo Brdo | phase 5b | 44,669 | 20,725 | Vinča | 5100 | | | | | | | |
| Vinča-Belo Brdo | phase 5c | 44,669 | 20,725 | Vinča | 5025 | | | | | | | |
| Vinča-Belo Brdo | phase 6 | 44,669 | 20,725 | Vinča | 4950 | | | | | | | |
| Vinča-Belo Brdo | phase 7 | 44,669 | 20,725 | Vinča | 4850 | | | | | | | |
| Visoko Brdo | Visoko Brdo I | 44,932 | 17,918 | Vinča | 4600 | | | | | 61 | | |
| Vizula | Vižula_Impresso + MN | 44,819 | 13,925 | Danilo, Impresso | 5700 | | 3 | | | 50 | | |
| Vrbica (Sibenik) | Vrbica_Impresso | 43,933 | 15,8 | Impresso | 5900 | | 0,4 | | | | 97 | |
| Zelena Pećina | not differentiated | 43,237 | 17,871 | Danilo | 5300 | | | | | 81,5 | 12,7 | |

| organic | organic + coarse sand | organic + sand | organic + sand + coarse sand | organic + sand + stones | coarse sand + organic | quarz | quarz, crushed | mineralic (sand, coarse sand) | sand | sand, coarse | coarse sand + sand | river sediment | steatite | schist | black stones | stone, chrushed | grog | untempered | ? | source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | | 1,2 | | Rasson 1983 |
| | | | | | | | | | | | | | | | | | | 0,1 | | Rasson 1983 |
| | | | | | | | | | 8 | | | | | | | | | 49 | | Hofmann 2013 |
| | | | | | | | | | 3 | | | 3 | | | | | | 29 | | Hofmann 2013 |
| | | | | | | | | | 4 | | | 1 | | | | | 3 | 12,4 | | Hofmann 2013 |
| | | | | | | | | | 14 | | | 59 | | | | | | 2,5 | | Hofmann 2013 |
| | | | | | | | | | 16 | | | 51 | | | | | | 13,1 | | Hofmann 2013 |
| | | | | | | | | | 18 | | | 26 | | | | | 0,1 | 26,5 | | Hofmann 2013 |
| | | | | | | | | | 16 | | | 19 | | | | | 0,2 | 4 | | Hofmann 2013 |
| | | | | | | | | | 14 | | | 18 | | | | | | 32,3 | | Hofmann 2013 |
| 1 | | | | | | | | 3 | | | | | | | | | 50 | 46 | | Tringham *et al.* 1992 |
| | | | | | | | | 3 | | | | | | | | | 29 | 68 | | Tringham *et al.* 1992 |
| | | | | | | | | 5 | | | | | | | | | 35 | 60 | | Tringham *et al.* 1992 |
| | | | | | | | | | 0,8 | | | | | | | | | 0,8 | | Rasson 1983 |
| 1 | | | | | | | | | 82 | | | | | 0,1 | | | | 17 | | Kaiser 1990 |
| | | | | | | | | | 79 | | | | 1 | | | 1 | 0,1 | 19 | | Kaiser 1990 |
| | | | | | | | | | 60 | | | | 5 | | | 9 | 2 | 24 | | Kaiser 1990 |
| | | | | | | | | | 48 | | | | 1 | | | 6 | 4 | 41 | | Kaiser 1990 |
| 36 | | 48 | | | | | | | 4 | | | | | | | | | 12 | | Spataro 2008 |
| | | | | | | | | | | | | | | | | | | | | Rasson 1983 |
| | | | | | | | | | | | | | | | 1 | | | | | Rasson 1983 |
| | | | | | | 1,2 | | | | | | | | | | | | | | Gašparič 2004 |
| | | | | | | | | | | | | | | | | | | | | Gašparič 2004 |
| | | | | | | | | | | | | | | | | | | | | Gašparič 2004 |
| | | | | | | | | | 21,1 | | | | | | | | | 36,8 | | Rasson 1983 |
| | | | | | | | | | | | | | | | | | | | | Rasson 1983 |
| 43 | | | | | | | | | | | | | | | | 4 | | 51 | | Schier 1995 |
| 28 | | | | | | | | | 12 | | | | | | | 15 | 14 | 34 | | Schier 1995 |
| 28 | | | | | | | | | 12 | | | | | | | 15 | 14 | 34 | | Schier 1995 |
| 9 | | | | | | | | | 18 | | | | | | | 8 | 9 | 56 | | Schier 1995 |
| 9 | | | | | | | | | 18 | | | | | | | 8 | 9 | 56 | | Schier 1995 |
| 2 | | | | | | | | | 39 | | | | | | | 12 | 20 | 26 | | Schier 1995 |
| 2 | | | | | | | | | 39 | | | | | | | 12 | 20 | 26 | | Schier 1995 |
| 2 | | | | | | | | | 39 | | | | | | | 12 | 20 | 26 | | Schier 1995 |
| 2 | | | | | | | | | 27 | | | | | | | 18 | 32 | 20 | | Schier 1995 |
| 2 | | | | | | | | | 27 | | | | | | | 18 | 32 | 20 | | Schier 1995 |
| 2,3 | | | | | | | | | 11,2 | | | | | | | | | 25,6 | | Rasson 1983 |
| | | | | | | | | | 42 | | | | | | 6 | | | | | Spataro 2002 |
| | | | | | | | | | | | | | | | | | | | | Spataro 2002 |
| 1 | | | | | | | | | 3,9 | | | | | | | | | 1 | | Rasson 1983 |

While *direct* centre-periphery relations are characterised by commercial relationships in the original sense of the WST *indirect* relations mainly concern other spheres. In the case of such *indirect* relations, peripheries were in fact depending only on the exchange of prestige goods for the social reproduction of the elite but they largely maintained their social and economic systems of which might be in some respects more developed than those of the centres (cf. Frankenstein and Rowlands 1978). The dominant mechanism of trade in such *indirect* centre-periphery relations were based on partnership, personal relations and travels. They included additionally the adaptation of social and ideological values from the core, and changes and imitations in material culture, and also led in part to the 'creation of independent versions' of the centres.

As a starting point for testing the described criterions and to identify potential cores and peripheries, a diachronic dataset from the western and central Balkans was collected and analysed that included information regarding the frequency and distribution of temper materials from 40 settlement sites with 79 occupation layers (Tab. 1). Due to inconsistent criterions for the temper classification, for the mapping it was necessary to simplify the data and to display only main temper components. The temporal resolution was set to 500 years resulting in four time slices (Fig. 6).

In the first phase of the Neolithic between about 6000-5500 BCE we observe a pronounced dichotomy between the Dalmatian coastal zone, where temper is dominated by different kind of calcareous materials, and the continental zone where temper appeared consisting of organic and also increasingly sandy materials. After 5750 BCE, dark burnished un-tempered (perhaps purified) fine pottery occurred for the first time in the central Balkan area.

In the second phase from 5500-5250 BCE we observed the adaptation of calcareous temper materials and partly dark burnished fine wares in the mountain zone of Central Bosnia. In this phase organic temper still dominated the assemblages while in the central Balkan region grog temper is occurring for the first time. According to personal communication with Timothy Kaiser, grog temper and un-tempered fabrics appeared in this period for the first time in Dalmatia.

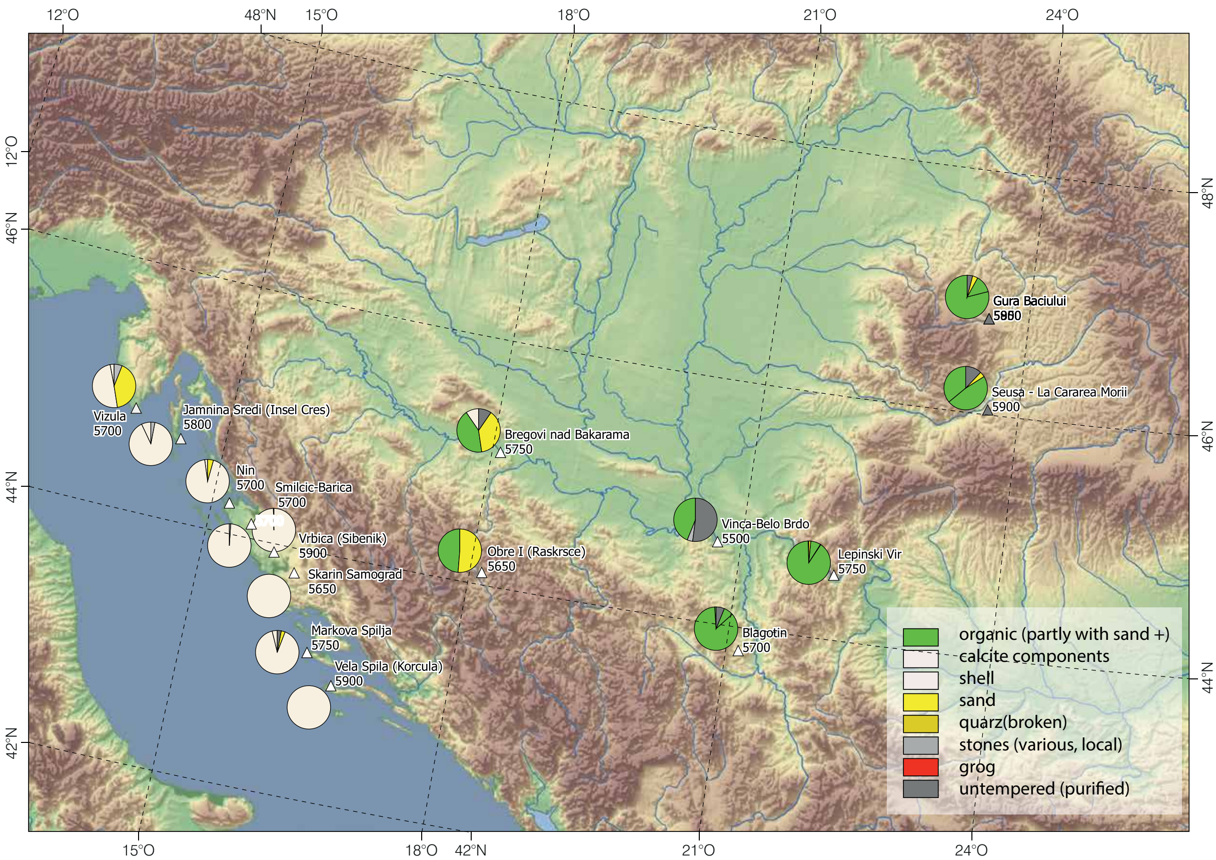
In the third phase between 5250-5000 BCE we see that organic temper largely disappeared and was replaced by sandy/mineral temper materials. Dark burnished wares and calcite temper become more frequent in Central and northern Bosnia.

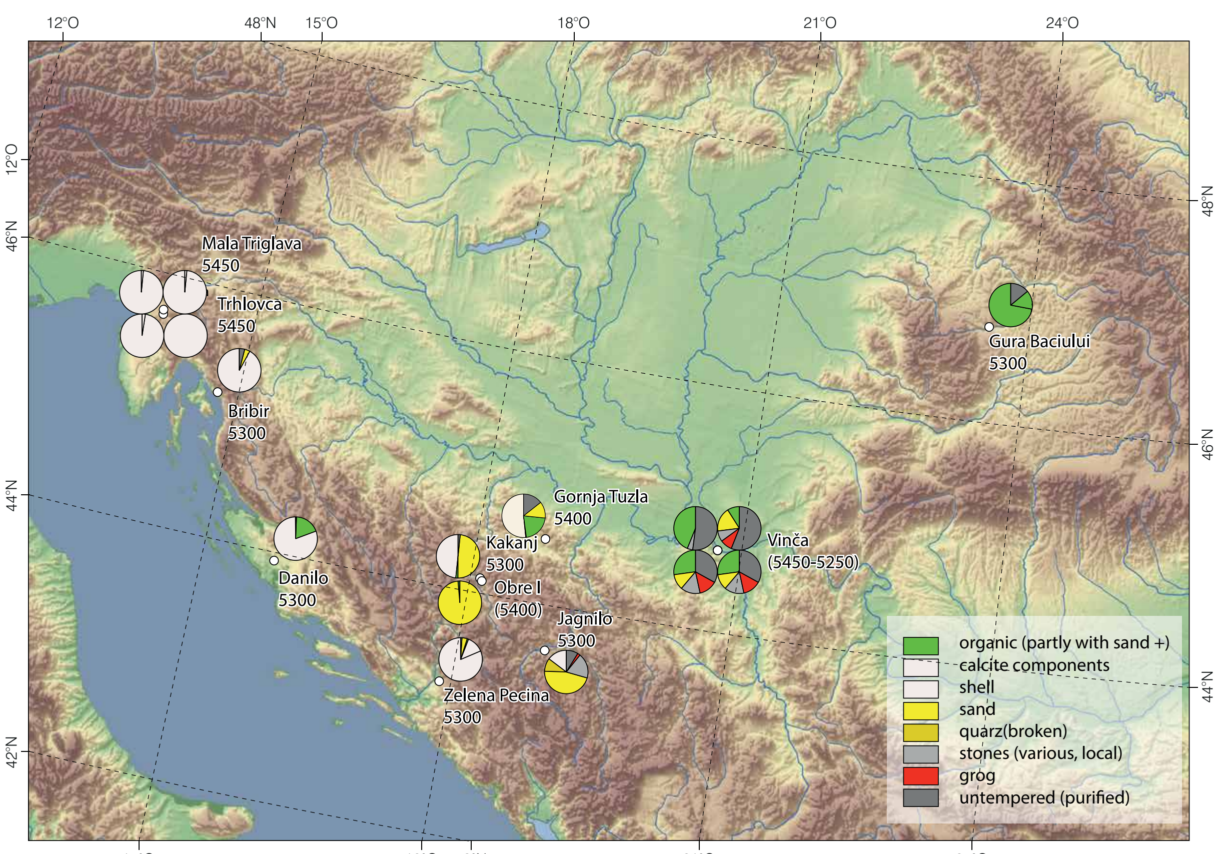
In the fourth phase (5000-4500 BCE) in Central and northern Bosnia calcite temper and dark burnished wares largely prevailed. In the Great Hungarian Plain and the central Balkan low mountain range grog temper dominated the find assemblages as well as of un-tempered fine wares.

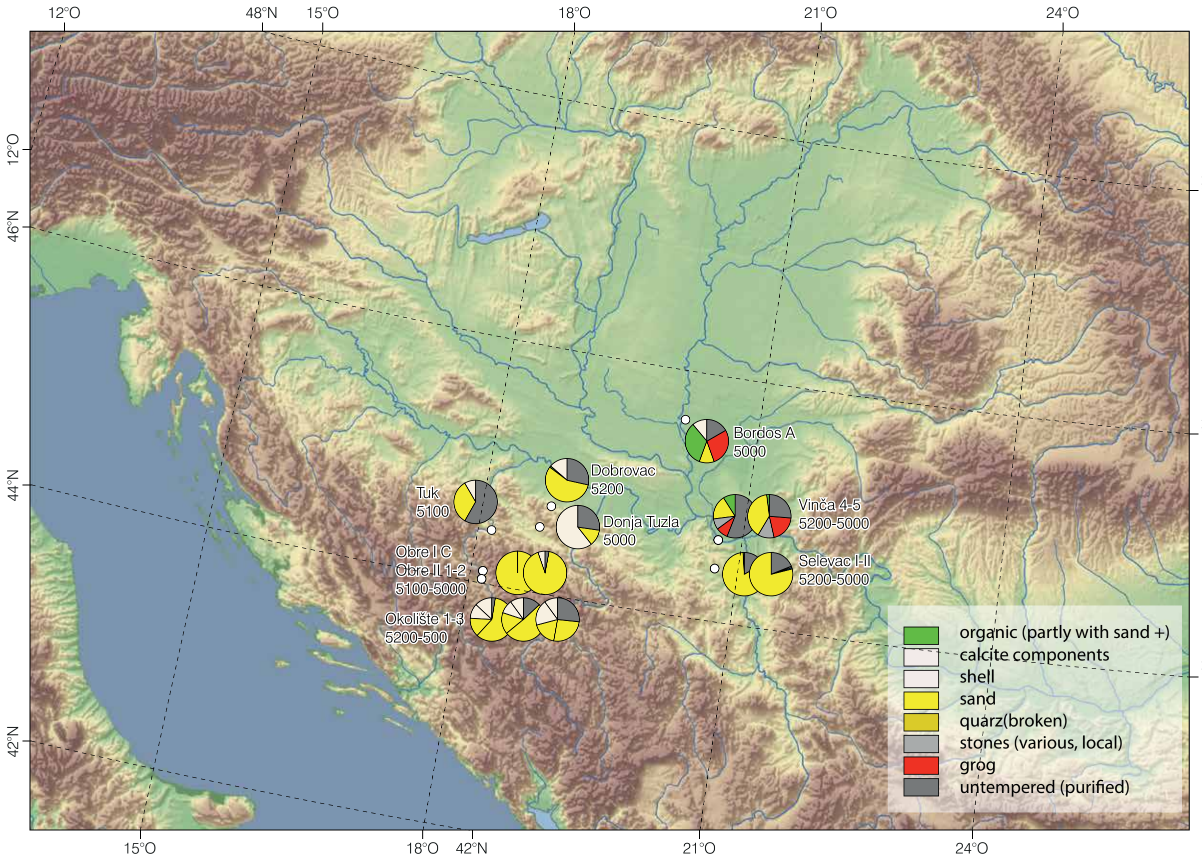
Based on the described map of temper materials within the central and western Balkan region, different zones can be distinguished in consideration of further criteria: (i). In the central Balkan region, the distribution area of societies with Vinča pottery styles, technological innovations, such as dark fired (burnished) pottery and mineral temper, occur earlier than, for example, in the low middle range of the Dinaric Alps. Thus this region might represent an innovative core zone. (ii). Apart from the slightly delayed adoption of dark burnished pottery and mineral temper, we observe in Central and northern Bosnia a specific selective choice of some technological elements from the eastern Adriatic area such as calcareous temper materials. Therefore these regions should be considered as potential peripheral regions.

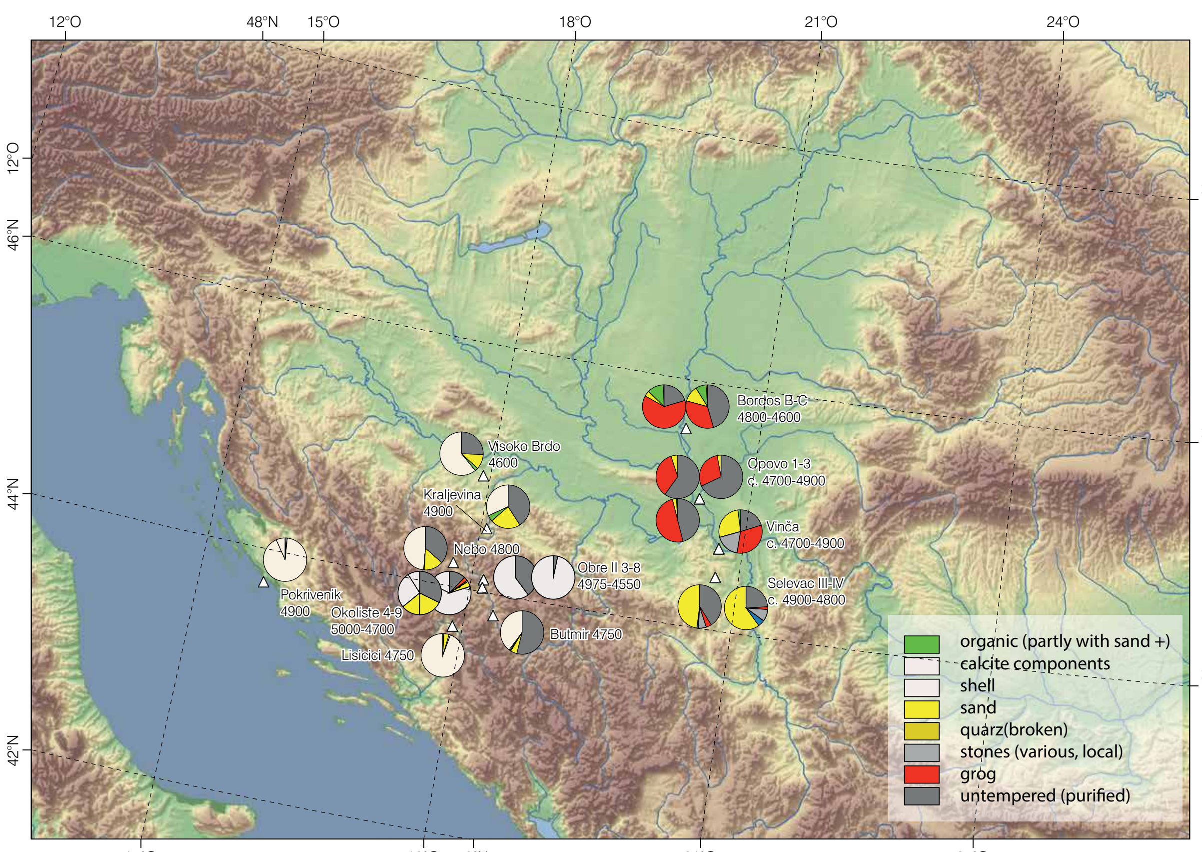
The conclusion that the central Balkan region represents an innovative core zone is also supported by other arguments. We clearly see higher degrees of specialisation in pottery production than in other regions of the Central and western Balkans. This is, for example, indicated by stronger metrical standardisation of vessels (Vuković 2011) and clearly improved firing technologies after 5200/5100 BCE (Kaiser *et al.* 1986; Spataro 2018). Underlying organisational and technological innovations should be considered as closely related to early metallurgical activities which took place in today's eastern Serbia (*e.g.* Pernicka *et al.* 1993; Rosenstock *et al.* 2016; Radivojević and Grujić 2018).

*Figure 6 (opposite and overleaf). Percentages of main temper materials in Neolithic pottery assemblages of the Central and western Balkans displayed in four time slices:*
*a) 6000-5500 BCE;*
*b) 5500-5250 BCE;*
*c) 5250-5000 BCE,*
*and d) 5000-4500 BCE.*
*Underlying data are displayed in Tab. 1.*


Gura Baciului
Seusa - La Cararea Morii
5900
Vizula
5700
Jamnina Sredi (Insel Cres)
5800
Bregovi nad Bakarama
5750
Nin
5700
Smilcic-Barica
5700
Vinča-Belo Brdo
5500
Vrbica (Sibenik)
5900
Obre I (Raskrsce)
5650
Lepinski Vir
5750
Skarin Samograd
5650
Markova Spilja
5750
Blagotin
5700
Vela Spila (Korcula)
5900
organic (partly with sand +)
calcite components
shell
sand
quarz(broken)
stones (various, local)
grog
untempered (purified)


Mala Triglava
5450
Trhlovca
5450
Bribir
5300
Gura Baciului
5300
Gornja Tuzla
5400
Kakanj
5300
Vinča
(5450-5250)
Danilo
5300
Obre I
(5400)
Jagnilo
5300
Zelena Pecina
5300
organic (partly with sand +)
calcite components
shell
sand
quarz(broken)
stones (various, local)
grog
untempered (purified)


12°O
48°N
15°O
18°O
21°O
24°O
46°N
44°N
42°N
Bordos A
5000
Dobrovac
5200
Tuk
5100
Donja Tuzla
5000
Vinča 4-5
5200-5000
Obre I C
Obre II 1-2
5100-5000
Selevac I-II
5200-5000
Okolište 1-3
5200-500
organic (partly with sand +)
calcite components
shell
sand
quarz(broken)
stones (various, local)
grog
untempered (purified)


12°O
48°N
15°O
18°O
21°O
24°O
46°N
44°N
42°N
Bordos B-C
4800-4600
Visoko Brdo
4600
Opovo 1-3
c. 4700-4900
Kraljevina
4900
Vinča
c. 4700-4900
Nebo 4800
Obre II 3-8
4975-4550
Selevac III-IV
c. 4900-4800
Pokrivenik
4900
Okoliste 4-9
5000-4700
Butmir 4750
Lisicici 4750
organic (partly with sand +)
calcite components
shell
sand
quarz(broken)
stones (various, local)
grog
untempered (purified)

The special role of the Vinča territory as particular innovative core zone could explain the extremely large size of the distribution area of Vinča pottery compared to adjacent 'style provinces'. Other potential factors probably influenced the central role of the Vinča distribution area in comparison to other regions due to its centrality in geographical terms based on its proximity to large rivers, such as the Danube, Sava, Tisza, Morava and Timiš. Furthermore in comparison to the Central Bosnian region, there was greater agricultural potential (Sherratt 1972; Chapman 1981, 84-115), which potentially would have permitted increased population densities, larger settlements and triggered higher innovation rates.

Environmental factors are likely to have played an important role in suspected peripheral areas. Limited agricultural opportunities would have restricted the potential for population growth. This leads to lower regional population densities and smaller settlement sizes and in the consequence less innovation. In geographical terms peripheral areas can be more isolated than core ones. One of the most characteristic traits of peripheral regions seems to be their ability to interlink with different core zones or interaction spheres. This is reflected in pottery assemblages, for example, through the selective new combinations of technological elements and the joint appearance or even hybrid combinations of geographically differently oriented pottery styles. Something that should be mentioned is, for example, the adaptation of calcareous temper materials for medium and coarse fabrics, and the common presence of Vinča and Hvar-Lisičići stylistic elements in the same contexts. All these aspects are described in pottery assemblages of our Central Bosnian case study (*e.g.* Hofmann 2013; 2015).

This multiple directed characteristic of finds assemblages in peripheral regions becomes understandable in the light of certain quantifications and material evidence. In Okolište, on average only every fifth household were using anthropomorphic figurines that were in central Balkan settlements extremely frequent (Hofmann and Hofmann 2012-2013). On the other hand, in Bosnian Neolithic settlements imported items from different origins were infrequent and also the occurrence of arrow heads show they most likely reflect individuals integrated from differently oriented contact networks.

In view of the described evidence we are able to identify with a certain probability a large 'world system' following the model of Kristiansen (1998) in the Central and western Balkan region. This includes a core zone that is at least partly congruent with the distribution area of Vinča pottery and an adjacent much smaller peripheral zone to which belong the distribution areas of pottery styles like Kakanj, Butmir, Sopot and certain associations, for example, of Szakálhát, Vinča and Tisza, (Fig. 7).

Elements connecting these central and peripheral areas are, for example, a specific settlement behaviour, which led to the emergence of settlement mounds (cf. Rosenstock 2009), the production and consumption of dark burnished pottery with clear differentiated vessel categories and common (but changing) decoration principles, and the application signs, which were after firing, mainly incised into bowls and perhaps identify the owner of the vessel (Starović 2004; Hofmann, 2013).

Aspects of pottery can be used as proxies to delimit the described central Balkan 'world system' and 'interaction sphere' from each other. Similar to the sequence of pottery styles, such as Impresso-Danilo-Hvar in the eastern Adriatic region or Starčevo-LBK or LBK-Lengyel in Transdanubia and Moravia. Another example concerns the Great Hungarian Plain and Transylvania where an uninterrupted tradition exist of producing oxidized fired painted pottery since the early Neolithic of which can be considered as indicative for another world system. This tradition probably contributed in the fifth millennium BCE decisively to the emergence of new centres and trajectories with painted pottery, such as Petreşti and Cucuteni-Tripolye.

However, as the gradual spread of settlement mounds into the Great Hungarian Plain (Raczky 2015) or the adoption of dark burnished fine fabrics in Dalmatia (Danilo) shows, also in these regions innovations from the Vinča core area were adopted temporarily. These 'anomalies' remind us that the addressed centre-periphery relations should

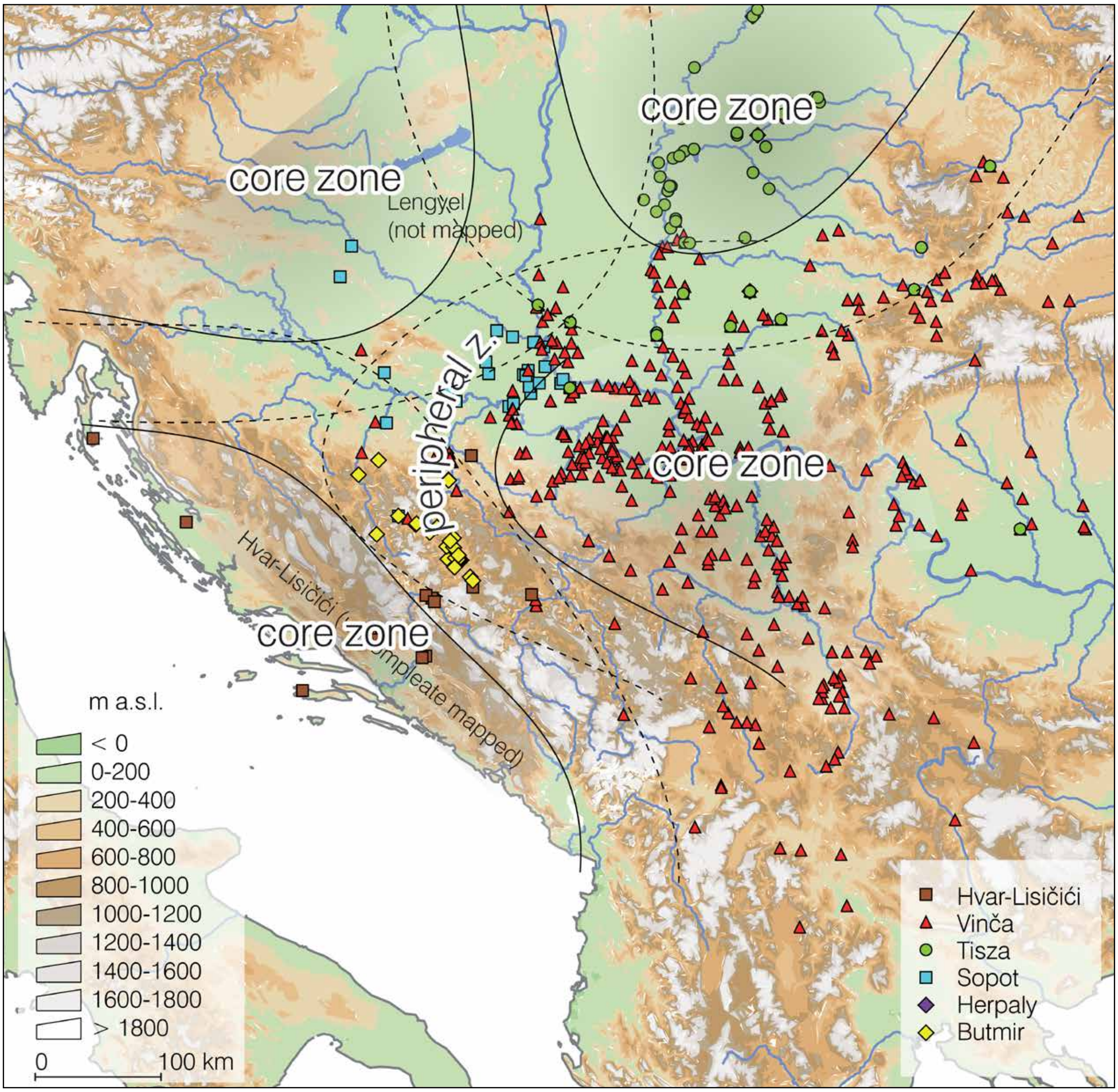



*Figure 7. Spatial distribution of world systems in the Central and western Balkans.*

not be understood as static but as subject of considerable spatial-temporal dynamics. This dynamic is visible, for example, in changes in the range of stylistic characteristics. The underlying mechanisms of these dynamics, and related innovation processes, are to greater extent population processes of boom and bust (cf. Müller 2013).

In peripheral regions, the multi-regional orientation lead to different intensities of contacts in one or another direction depending on the 'gravity' of the particular centres. In the finds assemblages of peripheral zones we observe 'shifts' in the main orientation throughout the whole Neolithic. In Central Bosnia this is relatively well understood. Initially, around 5700 BCE, the majority of connections existed in the central Balkans from where the Central Bosnian low middle range was potentially colonised. After 5500 BCE and accelerated after 5200 BCE until about 4850 BCE contacts to the east Adriatic region increased until they began to dominate between 4850 and 4750 BCE. Afterwards, until 4300 BCE, again connections to central Balkans increasingly dominated the archaeological record that were marked with, for example, indicators for trade with salt and copper, the dominance of pottery decorated by channelling and the adoption of very specific multi-family houses (Hofmann 2015).

## Conclusions

In this paper, an attempt is made to show that the innovative dynamic evident in Neolithic pottery assemblages of the central and western Balkans are the result of a complex interplay of factors at different spatial scales. These factors are only partly of an economic nature but also concern sociological, ideological and settlement-historical dimensions. The presented model regarding the reasoning of social and political boundaries relies mainly on communication networks of which occurred through the movement of individuals from place to place, motivated by myriad of intentions. However, the model does not need permanent migration or other sustainable kinds of human mobility. These should not be excluded, but I believe they require a separate analysis with suitable methods.

It seems indirectly demographical processes and their consequences, on the one hand, and environmental constrains, on the other, are crucial regulating factors of innovation processes (cf. Shennan *et al.* 2013; Müller 2013). Accordingly, in the study area there are in particular phases of innovative boom observed, which can be alternatively understood as phases of accelerated cultural change that follow or apparently coincide with phases of rapid population growth (Hofmann 2013). In tell settlements of south-east Europe this is, among other things, reflected in the formative layers of tell sites contain frequently pottery assemblages of the prior periods as shown, for example, at Uivar (Dammers *et al.* 2014), and Okolište (Hofmann 2013).

At a local, micro-regional and meso-regional scale, the configuration of the settlement systems, local population size and spatial distribution of populations in terms of density plays central roles. For the spatial scope and dynamic of innovation processes there is a fundamental difference between agglomerated and dispersed settlement behaviour (Tab. 2) where higher innovative potential primarily in agglomerated settlement systems.

On the other hand, environmental factors, such as the agricultural potential or raw material resources of a region are important, since they can represent limiting factors for population growth in a given territory under certain technological conditions. They potentially represent important factors at the spatial macro-scale and can contribute to the emergence of centre-periphery relations.

The Neolithic settlement dynamic in the study area is characterised by a process of pronounced population processes those led to the emergence of more agglomerated settlements starting by the latest 5500 BCE. In the study region, high levels of social complexity during the Neolithic were perhaps never reached (Porčić 2018). Pottery temporarily became a medium of representation and symbolic communication in the context of growing social complexity that actively maintained traditions and social balance that represent the other side of the coin, which are not addressed here (Kaiser and Voytek 1983; Rasson 1983; Hofmann 2015). The trend towards regionalisation of styles, further diversity of pottery assemblages and the increased effort for the production of vessels are material expressions of innovation processes in a very broad sense. Greater societal complexity triggered specialisation processes which led to increased technical perfection and certain standardisations, and changes in the distribution mechanisms of pottery.

A regional differentiated degree of specialisation in pottery production is only one aspect of indirect centre-periphery relations on a macro-scale have been rarely discussed due to the lack of a suitable theoretical foundation. Accordingly, in the central Balkan region, the distribution area of the Vinča culture, from the middle of the 6$^{th}$ millennium BCE at the latest, established an extensive and innovative core zone of a Neolithic 'world-system'. Due to certain innovative deficits, peripheral societies copied selected material aspects from the centre and assimilated certain ideological values.

Undoubtedly, here the sketched model requires much stronger empirical substantiation, which can be obtained through consequent quantifications of different aspects

| | agglomerated settlement behaviour | dispersed settlement behaviour |
|---|---|---|
| population size | local: high<br>regional: moderate–high | local: low<br>regional: low–moderate |
| innovative potential | high | low |
| Interaction (e.g. intermarriage, exchange) | predominantly local–micro regional | predominantly micro–meso-regional |
| economic organisation | predominantly local–micro regional | predominantly micro–meso-regional |
| degree of specialisation | moderate–high | low |
| exchange | low–moderate | low |
| pottery styles | local, micro- and meso-regional | macro-regional |
| Importance of material culture in communication | moderate –high | low |

*Table 2. Comparison regarding the spatial scope of selected aspects in agglomerated and dispersed settlement systems in the Central and western Balkans during the Neolithic and Early Eneolithic.*

of material culture. Due to their specific embedment in central spheres of human life, pottery represents a superb source, among other things, for the illumination of innovation processes. Beyond conventional cultural classifications, which are certainly useful but can also mask the true facts, it needs further investigation of production and distribution of pottery and analysis regarding their variability at all spatial levels.

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## References

Arponen, V. P., Müller, J., Hofmann, R., Furholt, M., Ribeiro, A., Horn, C., Hinz, M. 2015. Using the Capability Approach to Conceptualise Inequality in Archaeology: the Case of the Late Neolithic Bosnian Site Okolište c. 5200-4600 BCE. *Journal of Archaeological Method and Theory* 23 (2), 1-20.

Bánffy, E., Osztás, A., Oross, K., Zalai-Gaàl, I., Marton, T., Nyerges, É. Á. 2013 (2016). The Alsónyék story: towards the history of a persistent place. *Bericht der Römisch Germanischen Komission* 94, 283-318.

Benecke, N. 2006. Archäozoologische Untersuchungen. *Bericht der Römisch Germanischen Komission* 87, 159-161.

Bökönyi, S. 1974. The vertebrate fauna. *Wissenschaftliche Mitteilungen des Bosnisch-Herzegowinischen Landesmuseums* 4A, 55-154.

Borić, D. 2015. The end of the Vinca world: Modelling the Neolithic to Copper Age transition and the notion of archaeological culture, in: Hansen, S., Raczky, P., Anders, A. Reingruber, A. (eds.). *Neolithic and Copper Age Between the Carpathians and the Aegean Sea: Chronologies and Technologies from the 6th to 4th Millennia BCE*. Rahden: Verlag Marie Leidorf GmbH.

Bultmann, U. 2012. Putting Sites in their Chatchment Areas, in: Hofmann, R., Moetz, F.-K., Müller, J. (eds.). *Tells: Social and Environmental Space,* Proceedings of the International Workshop Socio-Environmental Dynamics over the Last 12,000 Years: The Creation of Landscapes II, 14 – 18 March 2011 Kiel, Universitätsforschungen zur Prähistorischen Archäologie 207. Bonn: Dr. Rudolf Habelt GmbH, 221-230.

Burić, M., Težak-Gregl, T. 2009. Bapska. A Late Neolithic settlement in eastern Croatia – A new project, in: Draşovean, F., Ciobotaro, D.L., Maddison, M. (eds.). *Ten years after: The Neolithic of the Balkans, as uncoverd by the last decade of research,* Proceedings of the conference held at the museum of Banat, 09-10 November 2007 Timişoara. Timişoara: Editura Marineasa, 85-99.

Chapman, J. 1981. *The Vinča culture of South-East Europe. Studies in chronology, economy and society*, BAR International Series S117. Oxford: BAR Publishing.

Chapman, J. 2006. Dark Burnished Ware as sign: ethnicity, aesthetics and categories in the later Neolithic of the Central Balkans, in: Tasić, N., Grozdanov, C. (eds.). *Homage to Milutin Garašanin*. Belgrade: Serbian Academy of Science and Arts, 295-308.

Costin, C.L. 1991. Craft Specialization: Issues in Defining, Documenting, and Explaining the Organization of Production. *Archaeological Method and Theory* 3, 1-56.

Dammers, B., Franz, A., Sobott, R.G., Bente, K. 2014. Keramiktechnologie und kulturelle Identität am Beispiel von Uivar, in: Schier, W., Meyer, M. (eds.). *Vom Nil bis an die Elbe. Forschungen aus fünf Jahrzehnten am Institut für Prähistorische Archäologie der Freien Universität Berlin*. Rahden/Westf.: Verlag Marie Leidorf GmbH, 25-46.

Dörfler, W. 2013. Prokoško Jezero: an environmental record from a subalpine lake in Bosnia-Herzegovina, in: Müller, J., Rassmann, K., Hofmann, R. (eds.). *Okolište 1 – Untersuchungen einer spätneolithischen Siedlungskammer in Zentralbosnien*. Bonn: Dr. Rudolf Habelt GmbH, 311-340.

Frankenstein, S., Rowlands, M. 1978. The internal structure and regional context of Early Iron Age society in south-western Germany. *Bulletin of the Institute of Archaeology London* 15, 73-112.

Furholt, M. 2013. Abseits des Weges – Prospektion und Ausgrabungen in Kundruci, in: Müller, J., Rassmann, K., Hofmann, R. (eds.). *Okolište 1. Untersuchungen in einer spätneolithischen Siedlungskammer in Zentralbosnien*, Neolithikum und Chalkolithikum in Zentralbosnien 1, Universitätsforschungen zur prähistorischen Archäologie 228. Bonn: Dr. Rudolf Habelt GmbH, 173-206.

Gašparič, A.Ž. 2004. Archaeometrical Analysis of Neolithic Pottery from the Divača region, Slovenia. *Documenta Praehistorica* 31, 205-220.

Hahn, H.P. 2005. *Materielle Kultur. Eine Einführung.* Ethnologische Paperbacks. Berlin: Dietrich Reimer Verlag GmbH.

Harding, A. 2013. World Systems, Cores and Peripheries in Prehistoric Europe. *European Journal of Archaeology,* 16 (3), 387-400.

Hegmon, M. 1992. Archaeological research on style. *Annual Review of Anthropology* 21, 517-536.

Hoekman-Sites, H., Giblin, J.I. 2012. Prehistoric animal use on the Great Hungarian Plain: A synthesis of isotope and residue analysis from the Neolithic and Copper Age. *Journal of Anthropological Archaeology* 31 (4), 515-527.

Hofmann, R. 2012. Style and Function of Pottery in Relation to the Development of Late Neolithic Settlement Patterns in Central Bosnia, in: Hofmann, R., Moetz, F.-K., Müller, J. (eds.). *Tells: Social and Environmental Space*, Proceedings of the International Workshop Socio-Environmental Dynamics over the Last 12,000 Years: The Creation of Landscapes II, 14 – 18 March 2011 Kiel, Universitätsforschungen zur Prähistorischen Archäologie 207. Bonn: Dr. Rudolf Habelt GmbH, 181-202.

Hofmann, R. 2013. *Okolište 2 – Spätneolithische Keramik und Siedlungsentwicklung in Zentralbosnien*, Neolithikum und Chalkolithikum in Zentralbosnien 2, Universitätsforschungen zur prähistorischen Archäologie 243. Bonn: Dr. Rudolf Habelt GmbH.

Hofmann, R. 2015. The Bosnian Evidence: The New Late Neolithic and Early Copper-Age Chronology and Changing Settlement Patterns, in: Hansen, S., Raczky, P., Anders, A., Reingruber, A. (eds.). *Neolithic and Copper Age between the Carpathians and the Aegean Sea. Chronologies and Technologies from the 6th to the 4th Millenium BCE*, International Workshop Budapest 2012. Bonn: Dr. Rudolf Habelt GmbH, 219-241.

Hofmann, R. (in press). Specialisation in pottery production in the Late Neolithic Okolište? A case study from Central Bosnia.

Hofmann, R., Hofmann, A. 2012-2013. Anthropomorphe und zoomorphe Figurinen des Spätneolithikums aus Okolište und der Butmirgruppe in Zentralbosnien: Darstellungsmodi, Herstellungstechniken, Datierungen, Häufigkeiten und Fundkontexte. *Offa* 69/70, 439-459.

Kaiser, T. 1990. Ceramic Technology, in: R. Tringham, D. K. (ed.). *Selevac. A Neolithic Village in Yugoslavia.* Los Angeles: Institute of Archaeology University of California, 255-288.

Kaiser, T., Voytek, B. 1983. Sedentism and economic change in the Balkan Neolithic. *Journal of Anthropological Archaeology* 2 (4), 323-353.

Kaiser, T., Franklin, U., Vitali, V. 1986. Pottery and pyrotechnology in the late Neolithic of the Balkans, in: Olin, J.S., Blackman, M.J., (eds.). *Proceedings of the 24th International Archaeometry Symposium.* Washington D.C.: Smithsonian Press, 85-94.

Kardulias, N.P. 1996. Multible levels in the Aegean Bronze Age World-System. *Journal of World-Systems Research* 2 (1), 378-408.

Kristiansen, K. 1998. *Europe before history.* New studies in archaeology. Cambridge (England)/New York: Cambridge University Press.

Kroll, H. 2013a. Bericht über die Pflanzenfunde aus Okolište Haus 38, in: Müller, J., Rassmann, K., Hofmann, R. (eds.). *Okolište 1 – Untersuchungen einer spätneolithischen Siedlungskammer in Zentralbosnien*, Neolithikum und Chalkolithikum in Zentralbosnien 1, Universitätsforschungen zur prähistorischen Archäologie 228. Bonn: Dr. Rudolf Habelt GmbH, 113-122.

Kroll, H. 2013b. Die Wirtschaft des Umfelds von Okolište: Zagrebnice, Kundruci und Donje Moštre, in: Müller, J., Rassmann, K., Hofmann, R. (eds.). *Okolište 1 – Untersuchungen einer spätneolithischen Siedlungskammer in Zentralbosnien*, Neolithikum und Chalkolithikum in Zentralbosnien 1, Universitätsforschungen zur prähistorischen Archäologie 228. Bonn: Dr. Rudolf Habelt GmbH, 231-237.

Kroll, H. (in press). Die Pflanzenfunde von Okolište, in: Müller, J., Rassmann, K. (eds.). *Okolište – Umwelt, materielle Kultur und Gesellschaft in einer spätneolithischen und chalkolithischen Siedlungskammer in Zentralbosnien.*

Kümmel, C. 2001. *Frühe Weltsysteme. Zentrum und Peripherie-Modelle in der Archäologie*, Tübinger Texte Materialien zur Ur- und frühgeschichtlichen Archäologie 4. Rahden/Westf.: Verlag Maria Leidorf GmbH.

Müller-Scheeßel, N. 2013. Die geschlagenen Steinartefakte aus dem Visoko-Becken I – Die geschlagenen Steinartefakte aus Okolište, in: Müller, J., Rassmann, K., Hofmann, R. (eds.). *Okolište 1 – Untersuchungen einer spätneolithischen Siedlungskammer in Zentralbosnien*, Neolithikum und Chalkolithikum in Zentralbosnien 1, Universitätsforschungen zur prähistorischen Archäologie 228. Bonn: Dr. Rudolf Habelt GmbH, 241-286.

Müller-Scheeßel, N., Hofmann, R., Müller, J., Rassmann, K. 2010a. Entwicklung und Struktur des spätneolithischen Tells von Okolište (Bosnien-Herzegowina) unter architektursoziologischen Gesichtspunkten, in: Trebsche, P., Müller-Scheessel, N., Reinhold, S. (eds.). *Der gebaute Raum. Bausteine einer Architektursoziologie vormoderner Gesellschaften*. Münster: Waxmann Verlag GmbH, 171-192.

Müller-Scheeßel, N., Hofmann, R., Müller, J., Rassmann, K. 2010b. The Socio-Political Development of the Late Neolithic Settlement of Okolište/Bosnia-Hercegovina: Devolution by Transhumance?, in: Kiel Graduate School "Human Development in Landscapes" (ed.). *Landscapes and Human Development: The Contribution of European Archaeology*, Proceedings of the International Workshop Socio-Environmental Dynamics over the last 12,000 Years: The Creation of Landscapes, 01-04 April 2009 Kiel, Universitätsforschungenzur prähistorischen Archäologie 191. Bonn: Dr. Rudolf Habelt GmbH, 181-191.

Müller, J. 2006. Demographische Variablen des Bosnischen Spätneolithikums – zur Frage der Bevölkerungsrekonstruktion im südosteuropäischen Neolithikum, in: Tasić, N., Grazdanov, C. (eds.). *Homage to Milutin Garašanin*. Belgrade: Serbian Academy of Sciences and Arts, 367-378.

Müller, J. 2013. Demographic traces of technological innovation, social change and mobility: from 1 to 8 million Europeans (6000-2000 BCE), in: Kadrow, S., Włodarczak, P. (eds.). *Environment and subsistence – forty years after Janusz Kruk's „Settlement studies…"*. Rzeszów, Bonn: Dr. Rudolf Habelt GmbH, 1-14.

Müller, J., Hofmann, R., Müller-Scheeßel, N., Rassmann, K. 2011. Zur sozialen Organisation einer spätneolithischen Gesellschaft in Südosteuropa (5200-4500 v. Chr.), in: Hansen, S., Müller, J. (eds.). *Sozialarchäologische Perspektiven: Gesellschaftlicher Wandel 5000-1500 v. Chr. zwischen Atlantik und Kaukasus, Internationale Tagung 15-18 Oktober 2007 Kiel*. Mainz: Verlag Phillip von Zabern, 81-106.

Müller, J., Rassmann, K., Kujundžić-Vejzagić, Z. 2013 (eds.). *Okolište 1 – Untersuchungen einer spätneolithischen Siedlungskammer in Zentralbosnien, Neolithikum und Chalkolithikum in Zentralbosnien 1*, Universitätsforschungen zur prähistorischen Archäologie 228. Bonn: Dr. Rudolf Habelt GmbH.

Parkinson, W.A. 2006a. Tribal boundaries: Stylistic variability and social boundary maintenance during the transition to the Copper Age on the Great Hungarian Plain. *Journal of Anthropological Archaeology* 25, 33-58.

Parkinson, W.A. 2006b. *The Social Organization of Early Copper Age Tribes on the Great Hungarian Plain*, BAR International Series S1573. Oxford: Archaeopress.

Parzinger, H. 1993. Studien zur Chronologie und Kulturgeschichte der Jungstein-, Kupfer- und Frühbronzezeit zwischen Karpaten und Mittlerem Taurus. *Römisch-Germanische Forschungen* 52. Mainz a. Rhein: Verlag Phillip von Zabern.

Perić, S. 1995. *Butmirska kultura. Geneza i razvoj. Butmir culture. Origin and development*, Posebna Izdanja Arh. Inst. 29. Belgrad: Arheolški Institute, Beograd.

Perić, S., Nikolić, D. 2004. Stratigrafic, cultural and chronological characteristics of the pottery from Lepinski Vir. 1965 excavations, in: Perić, S. (ed.). *The central Pomoravlje in Neolithization of South East Europe*. Belgrad: Arheološki Institute Beograd, 157-217.

Pernicka, E., Begemann, F., Schmitt-Strecker, S. 1993. Eneolithic and Early Bronze Age copper artefacts from the Balkans and their relation to Serbian copper ores. *Prähistorische Zeitschrift* 68, 1-54.

Porčić, M. 2018. Evaluating Social Complexity and Inequality in the Balkans Between 6500 and 4200 BC. *Journal of Archaeological Research* 27 (3), 335-390.

Porčić, M., Nešić, M. 2014. Simulating cultural transmission: preliminary results and their implications for the study of formal variability in the Central Balkan Neolithic. *Documenta Praehistorica* 41, 137-148.

Raczky, P. 2015. Settlements in South-east Europe, in: Fowler, C., Harding, J., Hofmann, D. (eds.). *The Oxford Handbook of Neolithic Europe*. Oxford: Oxford University Press, 235-253.

Radivojević, M., Grujić, J. 2018. Community structure of copper supply networks in the prehistoric Balkans: An independent evaluation of the archaeological record from the 7th to the 4th millennium BC. *Journal of Complex Networks* 6, 106-124.

Rasson, J.A. 1983. *Interaction Spheres as Adaptive Mechanisms. Bosnian-Dalmatian Relations in the Neolithic.* Thesis (PhD) at the State University of New York at Binghamton.

Rice, P.M. 1987. *Pottery analysis. A sourcebook*. Chicago/London: The University of Chicago Press.

Rosenstock, E. 2009. *Tells in Südwestasien und Südosteuropa. Untersuchungen zur Verbreitung, Entstehung und Definition eines Siedlungsphänomens*, Urgeschichtliche Studien 2. Remshalden: B.A. Greiner.

Rosenstock, E., Scharl, S., Schier, W. 2016. Ex oriente lux? – Ein Diskussionsbeitrag zur Stellung der frühen Kupfermetallurgie Südosteuropas, in: Bartelheim, M., Horejs, B., Krauß, R. (eds.). *Von Baden bis Troja. Ressourcennutzung, Metallurgie und Wissenstransfer. Eine Jubiläumsschrift für Ernst Pernicka*. Rahden/Westf.: Verlag Marie Leidorf GmbH, 59-122.

Schier, W. 1995. *Vinča-Studien. Tradition und Innovation im Spätneolithikum des zentralen Balkanraumes am Beispiel der Gefäßkeramik aus Vinča-Belo Brdo.* Habilitation at the Ruprecht-Karls-Universität Heidelberg.

Schumpeter, J. A. 1987. *Theorie der wirtschaftlichen Entwicklung : eine Untersuchung über Unternehmergewinn, Kapital, Kredit, Zins und den Konjunkturzyklus.* Berlin: Duncker und Humblot.

Shanks, M. 2004. *Art and the Early Greek State*. Cambridge: Cambridge University Press.

Shennan, S., Downey, S.S., Timpson, A., Edinborough, K., Colledge, S., Kerig, T., Manning, K., Thomas, M.G. 2013. Regional population collapse followed initial agriculture booms in mid-Holocene Europe. *Nature Communications* 4, 2486.

Sherratt, A. 1972. Socio-economic and demographic models for later prehistoric Europe, in: Clarke, D.L., (ed.). *Models in Archaeology*. London: Methuen (Reprinted in Sherrat 1997), 477-542.

Sherratt, A. 1993. What would a Bronze Age world system look like? Relations between temperate Europe and the Mediterraneum in later prehistory. *Journal of European Archaeology* 1 (2), 1-57.

Sherratt, A. 1997. *Economy and Society in Prehistoric Europe. Changing Perspectives.* Edinburgh: Edinburgh University Press.

Spataro, M. 2002. *The first farming communities of the Adriatic: Pottery production and circulation in the Early and Middle Neolithic*, Società per la Preistoria e Protostoria della Regione Friuli-Venezia Giulia, Quaderno 9. Trieste: Edizioni Svevo Trieste.

Spataro, M. 2008. Early Neolithic pottery production in Romania: Gura Baciului and Şeuşa La-Cărarea, in: Bailey, D.W, Whittle, A., Hofmann, D. (eds.). *Living well together? Settlement and materiality in the Neolithic of South-East and central Europe*. Oxford: Oxbow Books, 91-100.

Spataro, M. 2011. A comparison of chemical and petrographic analyses of Neolithic pottery from South-eastern Europe. *Journal of Archaeological Science* 38 (2), 255-269.

Spataro, M. 2018. Origins of Specialization: The Ceramic Chaîne Opératoire and Technological Take-off at Vinča-Belo Brdo, Serbia. *Oxford Journal of Archaeology* 37 (3), 247-265.

Spataro, M., Meadows, J. 2013. Bringing Pottery to Life: Ceramic Temper as Cultural Identitity. *Diadora* 26/27, 59-76.

Starović, A. 2004. *Signs of Civilistion*, Exhibition catalogue. Novi Sad: Institute of Archaeomythology and Serbian Academy of Sciences and Arts.

Sterud, L., Sterud, A.-K. 1974. A quantitative analyses of the material remains. *Wissenschaftliche Mitteilungen des Bosnisch-Herzegowinischen Landesmuseums* 4A, 155-355.

Tasić, N., Miroslav, M., Filipović, D., Penezić, K., Dunbar, E., Reimer, P., Barclay, A., Bayliss, A., Gaydarska, B., Whittle, A. 2016. Interwoven strands for refining the chronology of the Neolithic Tell of Vinča-Belo Brdo, Sebia. *Radiocarbon* 58 (4), 1-37.

Tringham, R., Brukner, B., Kaiser, T., Borejević, K., Bukvić, L., Šteli, P., Russell, N., Stevanović, M., Voytek, B.1992. Excavations at Opovo 1985-1987: Socioeconomic Change in the Balkan Neolithic. *Journal of Field Archaeology* 19, 351-386.

Vukocić, J. 2004. Statistic and typological analyses of the Early Neolithic pottery excavated in the structure 3 at the site of Blagotin near Trstenik, in: Perić, S. (ed.). *The Central Pomoravlje in Neolithization of South East Europe*. Belgrad: Archaeological Institute Belgrade, 83-155.

Vuković, J. 2011. Late Neolithic Pottery Standardization: Application of Statistical Analyses. *Starinar* 61, 81-100.

Wallerstein, I. 1974. *The Modern World System I. Capitalist Agriculture and the Origin of the European Word Economy in the Sixteenth Century*, Stud. Social Discontinuity. New York/San Diego/London: Academic Press.

Whittle, A., Bayliss, A., Barclay, A., Gaydarska, B., Bánffy, E., Borić, D., Draşovean, F., Jakucs, J., Marić, M., Orton, D., Pantović, I., Schier, W., Tasić, N. & Vander Linden, M. 2016. A Vinča potscape: formal chronological models for the use and development of Vinča ceramics in south-east Europe. *Documenta Praehistorica* 43, 1-60.

Windler, A. 2017 From the Aegean Sea to the Parisian Basin: Spondylus shell exchange in Europe during the process of Neolithisation, in: Eisenach, P., Stöllner, T., Windler, A. (eds.). *The RITaK conferences 2013-2014, Raw Materials, Innovation, Technology of Ancient Cultures RITaK 1*. Bochum: Verlag Marie Leidorf GmbH, 95-110.

Wobst, H.M. 1977. Stylistic behaevior and information exchange, in: Cleland, C.E. (ed.). *For the director: Research in Honor of B. Griffin.* Ann Arbor: Museum of Anthropology/University of Michigan.

Wotzka, H.-P. 1997. Maßstabsprobleme bei der ethnischen Deutung neolithischer "Kulturen". *Das Altertum* 43, 163-76.

## Notes on contributor

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# Technological innovation and social change. Early vs. late Neolithic pottery production of the Central Balkans

*Jasna Vuković*

## Abstract

The earliest pottery of the Central Balkans (Starčevo culture), characterized by organic inclusions, round, spherical shapes, and oxidized firing conditions, usually lacking traces of use, is usually seen as pottery typical for partly mobile communities. On the other hand, late Neolithic (Vinča) pottery features (mineral inclusions, and reduced firing atmosphere, among others) indicate major changes in manufacturing sequence, conditioned by more elaborate technical knowledge, suggesting the different needs of the consumers, which also affected changes in pottery demand. In this paper, innovation in Neolithic pottery production is considered through several distinct aspects of technology: the standardisation analyses which may reveal social innovation (almost random in the early vs. partly specialized production in the late Neolithic), the shift from organic to mineral inclusions in ceramic paste, as a consequence of changed needs for particular performance of pottery, and the change in the chaîne opératoire in the manufacture of vessels with roughened surfaces, an innovation that led to the adoption of less time-consuming manufacturing procedure. The processes that led to transformation of pottery technology and craft organisation from the early to the late Neolithic are still unknown. They may be traced during the early to late Neolithic transitional period, and may be explained by contact between two different technological traditions, changes in knowledge transmission mechanisms, and lack of social pressure in the practicing of the craft, leading to the emergence of specialized artisans.

*Keywords: pottery, technology, early Neolithic (Starčevo), late Neolithic (Vinča), innovation*

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## Introduction: innovation and technological change

Issues within innovation and technology are widely discussed in archaeological and anthropological literature. Technology may be broadly defined as "the processes and practices associated with production and consumption, including distribution, use, and disposal, from design to discard" (Miller 2007, 4). Technology may also be seen as set choices depending on many factors (Lemonnier 2002 a, b), but it is based on certain knowledge, which constitutes "a bridge between the techniques and society" (Lemonnier 1986). According to Schiffer and Skibo (1987), technological knowledge is comprised of several components: recipes for action, teaching frameworks, and techno-science, which includes the awareness of how the finished product will perform its function(s). On the other hand, the concept of technological style, defined as a way of doing something (Hegmon 1992) or a way an artefact was made (Chilton 1999, 50), thus representing expression of social behaviour or shared understanding of how the things have to be done (Stark 1999, 5), and so reveals the presence of technological traditions. These are defined as patterned ways of doing things that exist in identifiable form over a period of time, and they are transmitted vertically – from parents to their offspring (O'Brien and Shennan 2010, 6). Technological styles exhibit high temporal durability, they are extremely conservative (Nicklin 1971, 26) and ensured by social control through learning and teaching frameworks, and even by the presence of social sanctions which ensure existing traditions are maintained (*e.g.* Gosselain 1992; Stark 1999, 41).

Despite the long temporal continuity of technological styles, changes do occur. The factors that trigger technological change, although discussed in the literature still challenge the researchers. Technological change is caused by the presence of innovation, usually defined as a process that includes both invention and adoption (van der Leeuw and Torrence 1989; Hegmon and Kulow 2005), or the process during which a new idea or technique becomes widely accepted (for overview see: O'Brien and Shennan 2010). Invention, therefore, occurs at the level of the individual while adoption occurs on the collective scale (Roux 2010, 217). The long-lasting process of technological change also includes the processes of development and replication (Schiffer 2010). In the archaeological record, technological change can be traced by defining changes and quantities of certain features on a temporal scale in a particular area. However, these processes are of unequal visibility in the archaeological record: only adoption stands out, as it includes high frequencies of archaeological examples. Other processes are very hard to determine. As it was argued, the dominant pattern of technological change over time is increasing formal variation, and this pattern can be attributed to the process of invention (Schiffer 2010).

The spreading of innovation is mainly conditioned by the mechanisms of cultural transmission. They can be vertical – from cultural ancestor to cultural descendant, or horizontal (between cultural groups) (O'Brien and Shennan 2010, 6). As it was mentioned earlier, technological traditions are conservative, so the first one tends to prevent innovation and to maintain the existing way of doing things. Innovation is, however, possible, but under different conditions. From an actor-network perspective, the process of diffusion of cultural traits can be traced through the models relating individual actions, the social network structure and the sociological regularities, stressing the non-linear nature between individual actions and social dynamics and the presence of mediating mechanisms that explain how individual actions generate some macro-social regularities (after Roux and Manzo 2018). Innovation and its adoption are therefore possible within favourable social structures. It may be triggered by some stressful conditions, for instance changed needs of consumers, but also by increased demand for specific products (see below). It may include contacts, interactions, and mixing between different social groups enabling a decrease in social pressure within learning frameworks, making it possible to experiment and apply new techniques, thus increasing variability, including the hybridization of different technological styles.

Technological change also causes changes in social organisation, so social innovation should be distinguished from technical innovation (cf. Schubert 2014). In another words, technological change is also a behavioural change, which includes alterations in activities (Schiffer 2010, 236) which further affect other aspects of social relations. This is especially important regarding the organisation of production, and the position of the artisans within the society.

## Pottery as a new technology

Pottery as a new technology was introduced very early on, and the emergence of such new technology among the hunter-gatherer societies was seen as a "prestige" technology used for special foods (Craig 2016), or as containers used for communal feasts in order to display rare and desirable food, therefore stressing the special status of some individuals (Hayden 1990). Another explanation is so-called "architectural hypothesis", *i.e.* the view that the process of innovation in pottery technology was carried out in two steps – the first one included the production of unfired, sun-dried pottery, and the second introduced firing when pottery-making became a real pyrotechnic craft (Vandiver 1987). So-called "culinary hypotheses" (Rice 1999, 6) consider the emergence of pottery as a way to introduce a variety of "new foods" into the diet, making inedible food edible (detoxifying toxic foods or making inedible food digestible by thermal processing) (Arnold 1985, Tab. 6.1); the adoption of pottery enabled new techniques of food processing (*i.e.* soaking, fermentation, cooking and roasting) and storing. Another explanation is a more complex economic approach based on the principle of supply and demand (cf. Rice 1999, 41-42; Skibo and Schiffer 2008, 40-41): ceramics are adopted when other kinds of containers could not withstand increased demand caused by the new ways of food preparation and storing, and when food became important as a social expression.

In the Central Balkans[1] pottery was introduced as a part of the Neolithic package, during the early Neolithic Starčevo tradition, at the beginning of the sixth millennium BCE. The differences between two chronological extremes – Early Starčevo, namely Blagotin (6430-6260 cal BCE – 6220-6020 cal BCE) (Thissen 2009; Whittle *et al.* 2002) and Lepenski Vir (the end of VII and the beginning of the VI millennium) (for discussion of radiocarbon dates see: Budja 2009; Bonsall *et al.* 2015; Perić and Nikolić 2016), and the final phases of late Neolithic Vinča, around 4500 BCE (Tasić *et al.* 2015) can be summarized as follows: organic inclusions, namely chaff in the early (Spataro 2007; 2011), and mineral inclusions in the late Neolithic; round shapes vs. predominantly biconical shapes, and most importantly, the differences in firing procedure: oxidized, which results in reddish, brownish, and orange colours, and reduced, with grey and black finished products of the late phases of Vinča. The differences can also be observed in some other features, such as surface finishing and decoration, most of all impresso vs. channelled ornaments, and the appearance of the motifs. During this long temporal sequence, many innovations in pottery technology occurred followed by changes in social relations. How can they be explained and what caused them? Was it experimentation? Are they conditioned by the needs of the consumers, such as changing food habits, by some external stress, or by changes in the patterns

1 The term "Central Balkans" refers to the areas south of the Danube and Sava rivers. Its western borders go along with the rivers of Drina and Ibar, and the mountains of Šara and Prokletije while its eastern border is marked by the mountains Suva planina and Osogovo. It includes the territory of central modern-day Serbia and parts of Kosovo and North Macedonia (Garašanin 1979, 79). In this paper, only pottery from the sites analysed by the author is included.

of knowledge transfer? How are these factors interrelated? In this paper, only some of the aspects of technological change in the Neolithic pottery of the Central Balkans are going to be examined, and possible answers will be presented.

## Social innovation: organisation of pottery production in the Neolithic of the Central Balkans

The organisation of pottery production for the earliest pottery-making communities was rarely considered in archaeological literature. According to all of the proposed models of production organisation (Balfet 1965; van der Leeuw 1977; Rice 1981; Peacock 1982; Sinopoli 1988; Santley *et al.* 1989; Costin 1991; Blackman *et al.* 1993; Costin and Hagstrum 1995), the simplest organisation, present in the egalitarian societies can be related to low intensity of production, part-time involvement in the craft, and the production for the needs of artisan's household. The calculation of the values of coefficient of variation – CV (Eerkens and Bettinger 2001) of the metric parameters of ceramic vessels is considered to be one of the most reliable tools for the determination of the presence of product uniformity and high level of routine and motor skills of the artisans. In order to explore the level of product standardisation, CV values were calculated for the pottery assemblages from two early Neolithic Starčevo sites – Blagotin in central Serbia and Lepenski Vir in the Danube Gorges. Pottery assemblages from both sites exhibit extremely high morphological and dimensional variability. In the Blagotin assemblage, higher frequency of fine pottery, decorated specimens and high variety in shape repertoire were confirmed. Nevertheless, three main morphological groups for standardisation analysis of the pottery from both sites were established: large conical dishes, hemispherical bowls, and S-profiled vessels. CV values were calculated for several metric parameters. However, due to high fragmentation of the material, the rim diameter and wall thickness were the only metric parameters that could be measured on all of the specimens. The results (Tab. 1) revealed relatively high CV values. They indicate non-standardized, almost random production for both sites, especially for the classes of S-profiled pots and conical bowls, which are going to be further examined in this paper. They indicate a large number of producers, and the simplest form of production: household-based and non-specialised, intended to fulfil the needs of the members of the potter's household. This kind of production was also of low intensity and was probably taking place seasonally (Vuković 2017a).

In contrast, late Neolithic Vinča pottery exhibits considerably lower CV values (Vuković 2011), revealing reduced variability. This is especially visible when early and late Neolithic assemblages are compared. Scatter-dot diagram (Fig.1) clearly shows that best-fit regression line for Vinča pottery tends to be lower and closer to the x-axis, revealing considerably more standardized production. However, the late Neolithic low values occur on only one class of ceramic vessels – two types of bowls, indicating the presence of partial standardisation. Some other properties of Vinča pottery must also be mentioned: reduced variability in shape repertoire, but at the same time, the presence of elaborated, "luxurious" vessels made by skilled artisans (Vuković and Miloglav 2018), as well as uniform paste composition originating from a single raw material source (Spataro 2017; 2018). Moreover, the simplification of manufacturing technique is assumed for the late Neolithic standardized bowls and the usage of molds have been assumed (Vuković 2014a). All these aspects indicate the presence of specialisation, probably still household-based, but meant for the consumption outside the potters' household (Vuković and Miloglav 2018).

These differences between early and late Neolithic pottery production clearly show that pottery-making went through a series of changes – from the meeting of one's own needs to the emergence of skilled, probably specialised artisans. These

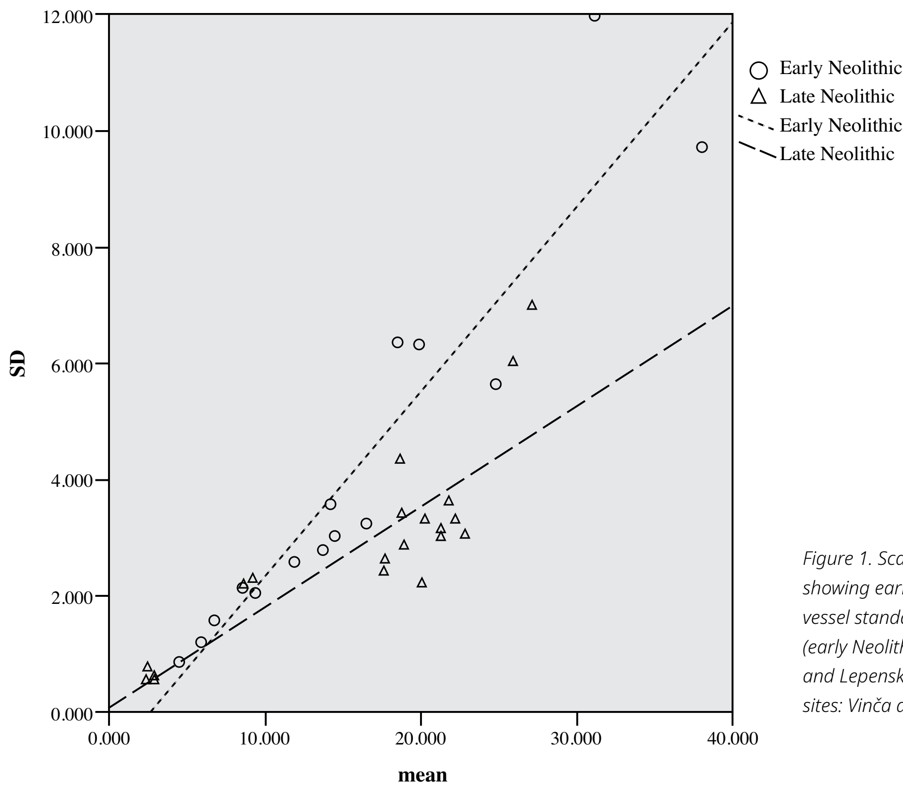


*Figure 1. Scatter-dot diagram showing early vs. late Neolithic vessel standardisation level (early Neolithic sites: Blagotin and Lepenski Vir; late Neolithic sites: Vinča and Drenovac).*

| functional/morphological class | Rim diameter | | Wall thickness | |
|---|---|---|---|---|
| | Blagotin | Lepenski Vir | Blagotin | Lepenski Vir |
| Mean<br>SD<br>CV (%) | n=60<br>18.45<br>6.36443<br>34.50 | n=136<br>19.9081<br>6.31465<br>31.72 | n=62<br>6.73<br>1.57<br>23.32 | n=136<br>8.57<br>2.139<br>24.96 |
| Mean<br>SD<br>CV (%) | n=22<br>13.6818<br>2.78408<br>20.35 | n=35<br>14.1714<br>3.56441<br>25.15 | n=22<br>4.5<br>0.859<br>19.08 | n=35<br>5.89<br>1.207<br>20.5 |
| Mean<br>SD<br>CV (%) | n=68<br>30.0588<br>12.69020<br>42.22 | n=183<br>38.0000<br>9.72521<br>25.6 | n=57<br>9.3<br>2.044<br>21.98 | n=183<br>11.87<br>2.584<br>21.77 |

*Table 1. CV values for metrical parameters of the early Neolithic pottery vessels.*

changes can be considered as social innovation, but they might have been conditioned by many factors: population pressure, the shift in food habits, supply, and demand. Intensification of pottery production is also a consequence of less-time consuming and therefore improved production sequence, resulting in higher output of finished products.

## The consequence of innovation: adoption of mineral inclusions in ceramic paste

Fine pottery is a good example of the changes in pottery function and consumption in the Neolithic traditions of the Central Balkans. Bowls of small sizes of both Neolithic traditions share formal properties: thin walls, finely finished surfaces (slipped in the early and burnished/polished in the late Neolithic) and fine fabric with no macroscopically visible coarse inclusions, but they exhibit remarkable differences in function and frequency within the assemblages. In the early Neolithic Starčevo tradition they occur rarely: 7% at Kovačke njive (Vuković *et al.* 2016), 6% at Blagotin (Vuković 2004), around 1% at Lepenski Vir (Perić and Nikolić 2004; cf. Vuković 2010), whereas in the late Neolithic fabric with finely grained mineral inclusions mostly predominate: for instance, around 70% percent in late phases of Vinča – Belo Brdo (Vuković 2010), and Grivac (Nikolić 2004).[2] According to the use-alteration analyses of the Blagotin assemblage, it is evident that fine pottery was used for different purposes – for food processing in the absence of water, but also for storage (Vuković 2010; 2012). In contrast, with the exception of mechanical damage, *i.e.* abrasion, mostly present on the exterior surfaces of the base, other use-wear traces are lacking on the late Neolithic Vinča bowls. Moreover, their high frequency indicates frequent manipulation and exposure to the risks of breakage, suggesting that they were probably used for serving and consuming food or drink. These differences indicate a dynamic role for fine bowls in the late Neolithic, their frequent use, and consequently high breakage and replacement rates, therefore suggesting higher demand and more intensive production (Tab. 2).

Fine fabric and the absence of macroscopically visible, coarse organic inclusions in ceramic paste are directly related to one of most remarkable technological changes that occurred during the Neolithic sequence. The transition to production of pottery with mineral inclusions and complete abandonment of the practice of adding coarse organic admixtures is a general feature of Vinča pottery. The differences in performance characteristics between two types of ceramics are well-known: high vs. low porosity, low vs. high hardness, strength, and mechanical stress resistance, and low. vs. high efficiency in thermal conductivity. If we accept the explanation that pottery with organic temper characterized partly mobile communities, whose technological choices were focused on the production of lighter vessels with high transportability, we may assume that the fine pottery was made occasionally and for special purposes (Vuković 2019; cf. Thissen 2005; Schiffer and Skibo 1987). With the beginning of fully sedentary life, going along with population increase, the need for organic tempered pottery ceased, as it could not fulfil a higher efficiency in thermal food processing for a larger population. The need for preparation of larger quantities of food, as well as dry storage of grains, conditioned a wider adoption of mineral temper. As a consequence, it became generally accepted for all functional classes of pottery.

## Innovation and labour investment: impresso vs. barbotine

One of the most noteworthy features of early Neolithic pottery and a significant chronological marker is surface finishing (and/or decoration) in the form of roughened or textured surfaces. According to all chronological schemes (Aranđelović-Garašanin 1954; Dimitrijević 1974; Garašanin 1979) of Starčevo pottery, impresso (made by impressing fingers, fingertips or tools on a still plastic surface) is typical for earlier phases, while barbotine (applying wet clay on the walls of the vessel; this layer can further be processed by finger-dragging, and it's usually called organized barbotine) predominates in late phases, and is still present in the early phases of Vinča tradition. Does this gradual prevalence of barbotine reflect a process of innovation and why did it occur?

These two kinds of surface finishing occur on most frequent morphological classes of vessels in Starčevo assemblages: large conical bowls and S-profiled

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2 It must be noted that some of the late Neolithic assemblages contain considerably lower frequencies of fine pottery, for instance Kovačke njive (Vuković *et al.* 2016).

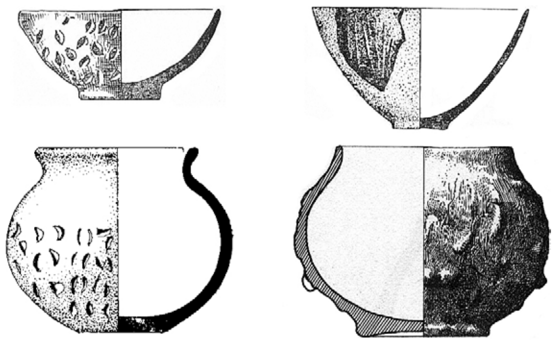

*Figure 2. early Neolithic conical bowls and S-profiled vessels with roughened surfaces (after Dimitrijević 1974).*

| | Early Neolithic | Late Neolithic |
|---|---|---|
| Frequency in the assemblage | 6% | 71% |
| Use-life | long | short |
| Breakage rate | low | high |
| Replacement rate | low | high |
| Use frequency | infrequent | extremely frequent |
| Typical for: | storage | serving |

*Table 2. Differences in use-lives, breakage and replacement rates between early and late Neolithic vessels with mineral inclusions inferred from the analyses of Blagotin and Vinča assemblages (after Vuković 2014b, 10).*

vessels (Fig. 2), the classes that exhibit extremely high variability in metrical parameters and high CV values suggesting random production. Conical bowls are usually of large dimensions, with a slipped interior and textured exterior surfaces. The slip on the interior surfaces suggests the need for reducing porosity, indicating the storage of liquids. However, the openness of their profile also suggests ease of access to contents, excluding long-term storage and long-distance transport. Bearing in mind their high frequencies in the assemblages, these vessels were frequently used, and obviously have been exposed to risks of breakage. In the Blagotin assemblage, use-alteration traces are lacking, and they are attributed to the functional class of short-term storage of water for the daily needs of the household. However, it seems that on other sites these vessels were also used for thermal food processing (Vuković 2012). The S-profiled pots also often have slipped or burnished interior surfaces, while their exterior surfaces are roughened, or two different kinds of surface finishing are present: burnishing or slip on the upper parts and texturing on their lower parts. Carbon deposits, as indicators of thermal food-processing, are identified on a limited number of specimens. Textured surfaces provide desirable performance characteristics that affect thermal properties: they increase thermal shock resistance (Skibo *et al.* 1989; Schiffer *et al.* 1994), and because of the larger surface area they are effective in preventing boil-over (Pierce 2005). At the same time, textured surfaces provide a better grip, making the pot easier to carry (Rice 1987, 140-141), and suitable for transport (for more detail see Vuković 2019). It seems that these two classes of vessels could have been multifunctional: for cooking and storage/transport, and specific performance characteristics caused the need for textured surfaces. But, the manufacturing processes of impresso and barbotine pots significantly differ from each other. So, why did barbotine gradually becomes the predominant surface roughening technique? The production sequence *i.e.* chaîne opératoire may provide answers.

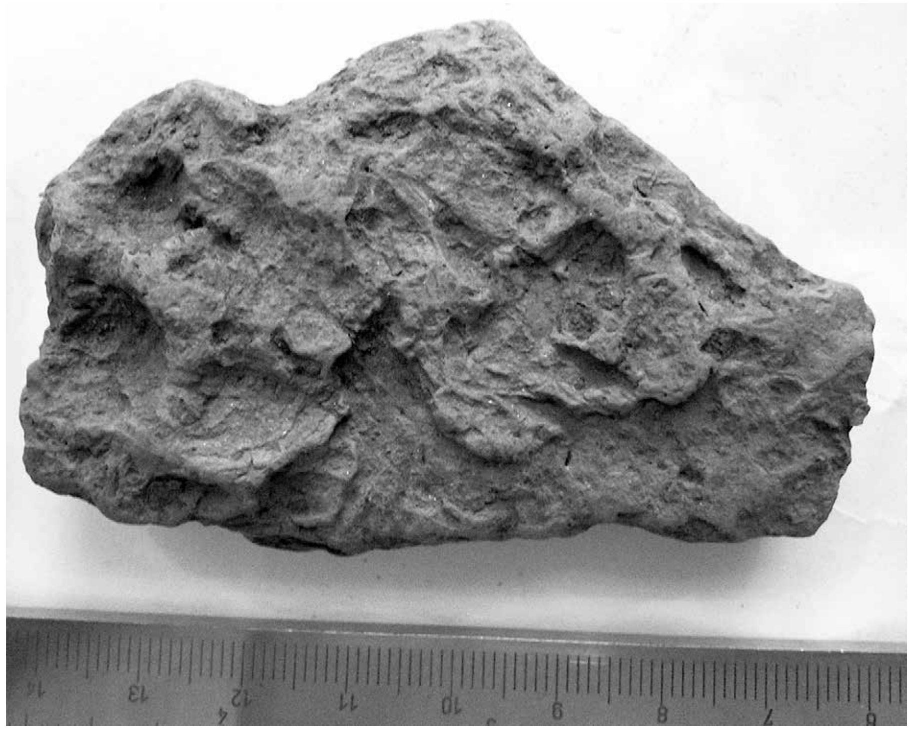

*Figure 3. Hybrid between impresso and barbotine – Blagotin (after: Vuković 2013, Fig. 3).*

Impresso is made on a still wet vessels' wall. The pressing of an instrument (or fingers) on still plastic surfaces is time-consuming. At the same time, during the procedure the vessel is under the constant risk of collapse, due to a strong force applied to weak and soft vessel's walls, thus requiring more attention from the potter. In contrast, barbotine can be applied on a (partly) dried surface, and then dragged with fingers. The procedure is simpler, less time-consuming, requires less attention, and the risk of collapse is diminished. At the same time, bearing in mind that less effort was needed, this change in chaîne opératoire enabled higher output *i.e.* more vessels produced during the same time interval. It should also be noted that the simplification of manufacturing techniques is seen as one of the most prominent features suggesting craft specialisation (Rice 1981).

The issue of impresso-to-barbotine transformation reveals the processes of invention and adoption of new technological solutions. It perfectly fits with the view that the process of invention leads toward less human energy investment in production (Roux 2010, 218). It has been argued that invention can be seen as a gradual modification and combination of earlier existing elements (Lemonnier 2002b; Schiffer 2005): barbotine is known almost from the beginning of Starčevo tradition, but it became dominant in the later phases. The process of invention, archaeologically visible in higher variability in the material record, in this case is, however, much harder to detect, as these issues were highly neglected in the archaeology of the Neolithic of the Central Balkans. However, several finds can lead us to a better understanding of this phenomenon: the hybrids between impresso and barbotine, so far identified only in the Blagotin assemblage (Vuković 2013). According to the still unpublished results of pottery analyses, it seems that some architectural structures on this site belong to later Starčevo phases.[3] The first example exhibits application of a layer of clay over the vessel's walls, but pressed with fingers, similarly to impresso-technique (Fig. 3). The second – a fragment of an S-profiled pot, is far more interesting. At the first sight, it appears as typical organized (channelled) barbotine,

3 Analysis was conducted by the author.

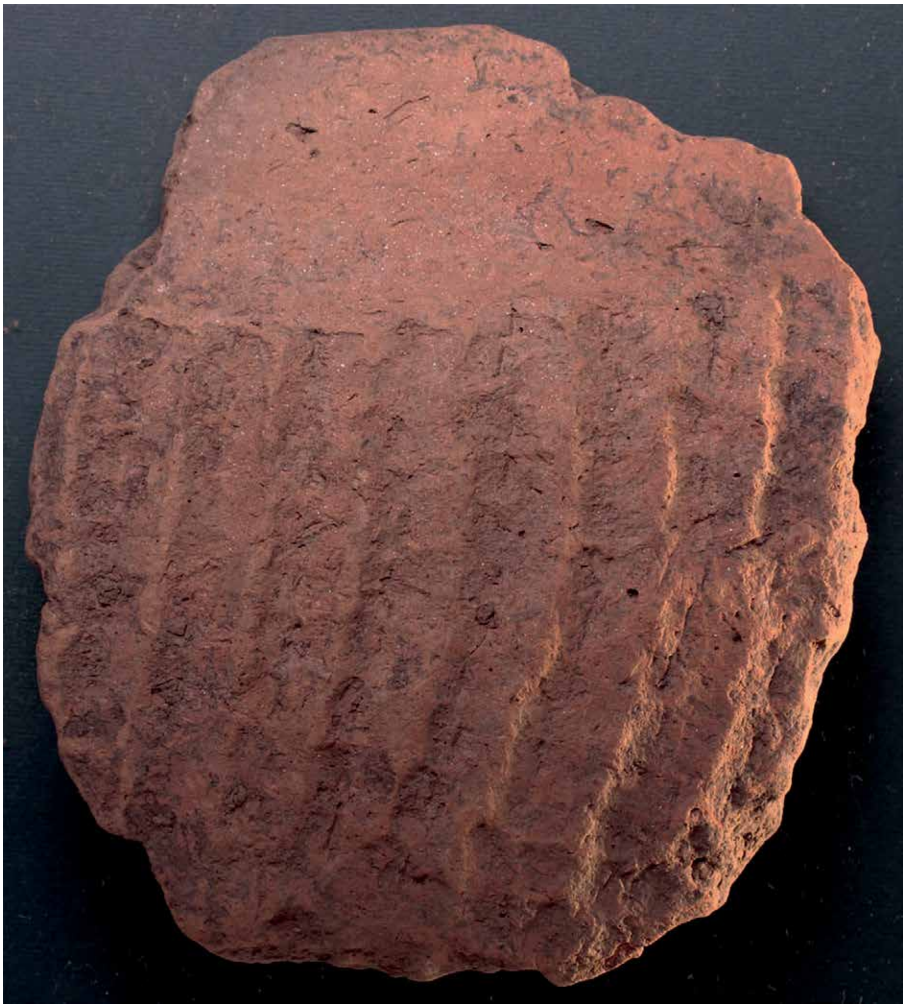

*Figure 4. Hybrid between impresso and barbotine – Blagotin (after: Vuković 2013, Fig. 4, height of the fragment: 15 cm).*

with parallel vertical ribs (Fig. 4). However, a closer look revealed that these ribs were made by producing fine and shallow finger impressions in a still wet clay. It may be assumed that these examples are not isolated, and more effort should be made in identifying similar specimens within other Starčevo assemblages. Nevertheless, hybridization, as a form of increased variability must be emphasized as a possible clue for assessing the process of invention.

## Innovation and social groups: mixing of technological traditions

Some of the very important differences in pottery technology between two chronologically distant points in the Neolithic sequence have been presented so far. Remarkable differences were identified, possibly as a consequences of the changing needs of the consumer and some economic aspects, such as demand and consumption, which resulted in intensification of production. However, the main question – how is the process of technological change related to social relations and social transformation is still unanswered. In the case of the Neolithic of the Central Balkans, the key is the transitional period from the early (Starčevo) to the late Neolithic (Early

Vinča).[4] In modern-day Serbia, there are a number of archaeological sites belonging to the transitional period (Vuković 2015). Their main characteristic is the presence of so-called mixed assemblages – assemblages that contain specimens belonging to different technological traditions. Usually, they occur in the zones of contact between contemporary populations (or "cultures" in traditional archaeology), for instance, between Vinča and Tisza in Vojvodina. It is far more difficult to interpret the case of mixed assemblages consisting of features typical for different periods or chronological phases established in traditional archaeology based on culture history.

The presence of pottery belonging to Starčevo and Vinča traditions in the same occupational layers indicate several important points. Technological traditions, being conservative, actually represent group identities, because they include not only procedures themselves, but also distinct behavior, learned techniques and organisation of labour (Lechtman 1977) or recipes for action (Schiffer and Skibo 1987). Because it involves practical knowledge of techniques, particular operations and behaviours, and social interactions it is indicative of group identities, revealing distinct technological styles. If two different technological styles occur in pottery assemblage, it is reasonable to assume that two different social groups existed in the same settlement.

As it was stressed earlier, high variability in the material record may reveal the process of invention. Undoubtedly, mixed assemblages exhibit variability, but there is also one other very important feature that affects it: technological hybrids. Within the pottery from Pavlovac-Čukar in Southern Serbia many examples were found (Vuković 2017b): vessels in Starčevo fabric with slipped surfaces, but morphologically typical for Vinča and vice versa. Especially interesting is one example of a conical lid – typical of the late Neolithic, but completely unknown in Starčevo. However, it was made in Starčevo fabric with organic inclusions and with red-slipped surfaces. Moreover, it is also decorated in a Starčevo manner, with rough, deep incised lines and with no structured motif. Also, rough, careless manufacture was identified on one distinct group of pottery objects, so-called altars belonging to the Starčevo tradition. It was argued that this kind of poorly made ceramics is not related to the works of novices in the craft, but rather to the mature potters belonging to a different technological tradition, whose inexperience can be explained by their lack of awareness of the symbolic meaning of these objects and socially accepted practices.

The mixed assemblages, that include technological hybrids and imperfect products, therefore may indicate mixing of people as well. The presence of hybrids suggests the change in learning frameworks: from the rigid knowledge transmission patterns which do not encourage experimentation and innovation (cf. Wallaert-Pêtre 2001; Thissen 2017) to the allowance of choices originated from different traditions, suggesting lack of control and social pressure. The process of innovation may be related to the processes of direct interaction between different social groups (Stark *et al.* 1995), and the possibility of integration of potters into new communities (Stark 1999, 30). In the case of the Central Balkans, in the current state of research, it may be assumed that the peaceful coexistence of two social groups existed in the transitional period. Innovation was enhanced by the allowance of technological solutions from different social groups. Moreover, as it was recently argued, the integration of potters can occur in cases of intermarriage, which enhances a specific form of cultural transmission in pottery production, resulting with the presence of hybrids. The hybrids in this sense can be considered as "boundary objects" –

4 The term "middle Neolithic", i.e. late Starčevo, was intentionally avoided. Traditionally, Starčevo culture is attributed both to the early and the middle Neolithic, and these two "phases" are identified by some pottery features (dark painting, reduced firing atmosphere, the presence of biconical shapes, and the prevalence of barbotine surface roughening, among others). According to the existing data and due to the absence of new radiocarbon dates, which could shed some new light on the transitional period, it is highly possible that features identified as characteristics of the middle Neolithic existed simultaneously with the earliest phases of Vinča, therefore putting the validity of the term "middle Neolithic" in question (Vuković 2015).

"the things that cross social boundaries, not demarcate them", or in other words objects produced according to specific learning traditions but at the same time in a nonconformist mode (Mills 2018). It is also worth noting that a "secondary apprenticeship", *i.e.* the re-education of potters after being married and integrated into new communities, implies the performing of all steps in an operational sequence, not partial adoption of some of the technological features (Wallaert 2013). These observations further confirm the possibility of the presence of potters belonging to different traditions in the Pavlovac-Čukar assemblage. In traditional archaeology, it was assumed that Vinča population belongs to the "younger Balkan-Anatolian cultural complex", whose carriers gradually migrated to the areas inhabited by the Starčevo people (Garašanin 1979; cf. Vuković 2015). Recent studies on Neolithic Demographic Transition however, revealed a significant population bust at the end of the early Neolithic, and the beginning of Vinča coincides with increase in population size culminating *c.* 4800 cal BCE (Porčić *et al.* 2016). This shift could be explained as a consequence of a population bottleneck, *i.e.* drift, when certain material culture variants – pottery features – become dominant by chance, but also by the migration of a new population around 5300 cal BCE. Although the radiocarbon dates are still lacking for the Pavlovac-Čukar, its pottery evidence suggesting the presence of different technological styles may contribute to solving this problem.

## Instead of a conclusion: innovation and the issues for further research

In the case of Neolithic pottery production, the process of innovation is still elusive, and processes affecting the technological change are diverse and dependent on a number of interrelated factors. Changes in ceramic recipes from organic to mineral inclusions were possibly triggered by changes in the needs of the population, for example, a full sedentary lifestyle and the need for more suitable vessels for cooking and storing. These changes were conditioned by population pressure and increased demand, resulting with an increase in the number of serving vessels. In the Neolithic transitional period, when contact between populations with different technological styles occurred, conservative and long lasting technological traditions were subject to changes triggered by new social interactions, resulting in more flexible knowledge transfer patterns, which enabled less rigid control in pottery production. Finally, in the case of impresso-barbotine transformation, the changes were a consequence of the need for more efficient manufacture, which resulted in higher output of products.

However, the process of technological change is still to a great extent unknown. So, instead of a conclusion it seems more appropriate to address the reasons for further research. To trace innovation we must seek for hybrids, as a cause of increased formal variability in pottery assemblages – the ones that represent mixing of different technological styles, but also the ones that suggest mixing of different procedures leading to the emergence of more simple manufacturing techniques. Identification of the potter's skill level by the presence of imperfect products, as another cause of high variability, and an identification of possible teaching methods also should be emphasized. Another line of research is to analyse the changes that occur in pottery recipes, thus indicating a more complex knowledge of suitability of specific raw materials to specific functions and performance of pottery. One of the most important technological changes in pottery production – the shift from oxidized to reduced firing is still a puzzling issue, since firing locations and firing facilities have not yet been identified in the archaeological record on the Neolithic sites of the Central Balkans. Finally, studying of painted designs, and the differences between light (white) vs. dark (black or red) painted ornaments may reveal the connection between technological change and symbolic expression and behaviour. Only by comparing these data from a number of assemblages can more accurate conclusions be made.

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## References

Aranđelović-Garašanin, D. 1954. *Starčevačka kultura*. Ljubljana: Univerza v Ljubljani.

Arnold, D.E. 1985. *Ceramic Theory and Cultural Process*. Cambridge: Cambridge University Press.

Balfet, H. 1965. Ethnographical observations in North Africa and archaeological interpretation: The Pottery of the Magreb, in: Matson, F.R. (ed.). *Ceramics and Man*. Chicago: Aldin Publishing Co., 161-177.

Blackman, J.M., Stein, G.J., Vandiver, P.N. 1993. The Standardization Hypothesis and Ceramic Mass Production: Technological, Compositional, and Metric Indexes of Craft Specialization at Tell Leilan, Syria. *American Antiquity* 58 (1), 60-80.

Bonsall, C., Cook, G., Manson, J.L., Sanderson, D. 2015. New AMS dates for human remains from Stone Age sites in the Iron Gates reach of the Danube, Southeast Europe. *Radiocarbon* 57 (1), 33-46.

Budja, M. 2009. Early Neolithic pottery dispersals and demic diffusion in Southeastern Europe. *Documenta Praehistorica* XXXVI, 117-137.

Chilton, E.S. 1999. One Size Fits All: Typology and Alternatives for Ceramic Research, in: Chilton, E.S. 1999. (ed.). *Material Meanings: Critical Approaches to the Interpretation of Material Culture*. Salt Lake City: The University of Utah Press, 44-60.

Costin, C.L. 1991. Craft Specialization: Issues in Defining, Documenting, and Explaining the Organization of Production, in: Schiffer, M.B. (ed.), *Archaeological Method and Theory*. Tucson: The University of Arizona Press, 1-56.

Costin, C.L., Hagstrum, M.B. 1995. Standardization, Labor Investment, Skill, and the Organization of Ceramic Production in Late Prehispanic Highland Peru. *American Antiquity* 60 (4), 619-639.

Craig, O.E. 2016. The innovation and development of pottery in the Japanese archipelago, in: Lozovskaja, O.V., Mazurkevich, A.N., Dolbunova, E.V. (eds.). *Traditions and innovations in the study of earliest pottery*, Materials of the International conference, 24-27 May 2016 St. Petersburg, Russia. St. Petersburg: Russian Academy of Science/Institute for the History of Material Culture/The State Hermitage Museum/Samara State Academy of Social Sciences and Humanities/UMR 8215, Trajectoires CNRS, Université Paris 1, 179-182.

Dimitrijević, S. 1974. Problem stupnjevanja starčevačke kulture s posebnim obzirom na doprinos južnopanonskih nalazišta rešavanju ovih problema. *Materijali* X, 59-122.

Eerkens, J.W., Bettinger, R.L. 2001. Techniques for Assessing Standardization in Artifact Assemblages: Can We Scale Material Variability? *American Antiquity* 66 (3), 493-504.

Garašanin, M. 1979. Centralnobalkanska zona, in: Benac, A. (ed.). *Praistorija jugoslavenskih zemalja* II. Sarajevo: Svijetlost i Akademija nauka i umjetnosti Bosne i Hercegovine, 79-212.

Gosselain, O. 1992. Technology and Style: Potters and Pottery among Bafia of Cameroon. *Man* (N.S.) 27, 559-586.

Hayden, B. 1990. Nimrods, Piscators, Pluckers, and Planters: The Emergence of Food Production. *Journal of Anthropological Archaeology* 9 (1), 31-69.

Hegmon, M. 1992. Archaeological Research on Style. *Annual Review of Anthropology* 21, 517-536.

Hegmon, M., Kulow, S. 2005. Painting as Agency, Style as Structure: Innovations in Mimbres Pottery Designs from Southwest New Mexico. *Journal of Archaeological Method and Theory* 12 (4), 313-334.

Lechtman, H. 1977 Style in technology - Some early thoughts, in: Lechtman, H., Merill, R. (eds.). Material Culture: Styles, Organization, and Dynamics of Technology, Proceedings of the American Ethnological Society. St. Paul: West Publushing, 3-20.

Lemonnier, P. 1986. The Study of Material Culture Today: Toward an Anthropology of Technical Systems. *Journal of Anthropological Archaeology* 5 (2), 147-186.

Lemonnier, P. 2002a. Introduction, in: Lemmonier, P. (ed.). *Technological Choices: Transformation in Material Cultures since the Neolithic*. London: Routledge, 1-35.

Lemonnier, P. (ed.). 2002b. *Technological Choices: Transformation in Material Cultures since the Neolithic*. London: Routledge.

Miller, H.L. 2007. *Archaeological Approaches to Technology.* London: Elsevier.

Mills, B.J. 2018. Intermarriage, Technological Diffusion, and Boundary Objects in the U.S. Southwest. *Journal of Archaeological Method and Theory* 25 (4), 1051-1086. DOI: https://doi.org/10.1007/s10816-018-9392-0

Nicklin, K. 1971. Stability and Innovation in Pottery Manufacture. *World Archaeology* 3 (1), 13-48.

Nikolić, D. 2004. Keramičko posuđe, in: Bogdanović, M. (ed.). *Grivac – naselja protostarčevačke i vinčanske kulture*. Kragujevac: Centar ua naučna istraživanja SANU/Narodni muzej, 203-313.

O'Brien, M.J., Shennan, S.J. 2010. Issues in Anthropological Studies of Innovation, in: O'Brien, M., Shennan, S.J. (eds.). *Innovation in Cultural Systems: Contributions from Evolutionary Anthropology*. Cambridge: MIT Press, 2-17.

Peacock, D.P. S. 1982. *Pottery in the Roman World: An Ethnoarchaeological Approach*. London and New York: Longman.

Perić, S., Nikolić, D. 2004. Stratighraphic, Cultural and Chronological Characteristics of the Pottery from Lepenski Vir – 1965 Excavations, in: Perić, S. (ed.). *The Neolithic in the Middle Morava Valley.* Beograd: Archaeological Institute/Regional Museum Jagodina/Regional Museum Paraćin, 157-217.

Perić, S., Nikolić, D. 2016. *Lepenski Vir: Stratigraphy, Chronology and Periodization*. Excavations 1966. Belgrade: Institute of Archaeology.

Pierce, C. 2005. Reverse Engineering the Ceramic Cooking Pot: Cost and Performance Properties of Plain and Textured Vessels. *Journal of Archaeological Method and Theory* 12 (2), 117-157.

Porčić, M., Blagojević, T., Stefanović, S. 2016. Demography of the Early Neolithic Population in Central Balkans: Population Dynamics Reconstruction Using Summed Radiocarbon Probability Distributions. *Plos one* 11 (8): e0160832. DOI: https://doi.org/10.1371/journal.pone.0160832

Rice, P.M. 1981. Evolution of Specialized Pottery Production: A Trial Model. *Current Anthropology* 22 (3), 219-240.

Rice, P.M. 1987. *Pottery Analysis: A Sourcebook*. Chicago: The University of Chicago Press.

Rice, P.M. 1999. On the Origins of Pottery. *Journal of Archaeological Method and Theory* 6 (1), 1-54.

Roux, V. 2010. Technological Innovations and Developmental Trajectories: Social Factors as Evolutionary Forces, in: O'Brien, M., Shennan, M.J. (eds.). *Innovation in Cultural Systems: Contributions from Evolutionary Anthropology*. Cambridge: MIT Press, 219-233.

Roux, V., Manzo, G. 2018. Social Boundaries and Networks in the Diffusion of Innovations: A Short Introduction. *Journal of Archaeological Method and Theory* 25 (4), 967-973. DOI: https://doi.org/10.1007/s10816-018-9395-x

Roux, V., Bril, B., Karasik, A. 2018. Weak Ties and Expertise: Crossing Technological Boundaries. *Journal of Archaeological Method and Theory* 25 (4), 1024-1050. DOI: https://doi.org/10.1007/s10816-018-9397-8

Schiffer, M.B. 2010. Can Archaeologists Study Processes of Invention?, in: O'Brien, M., Shennan, S.J. (eds.). *Innovation in Cultural Systems: Contributions from Evolutionary Anthropology*. Cambridge: MIT Press, 235-249.

Schiffer, M.B., Skibo, J.M. 1987. Theory and Experiment in the Study of Technological Change. *Current Anthropology* 28 (5), 595-622.

Schiffer, M.B., Skibo, J.M., Boelke, T.C., Neupert, M.A., Aronson, M. 1994. New Perspectives on Experimental Archaeology: Surface Treatments and Thermal Response of the Clay Cooking Pot. *American Antiquity* 59 (2), 197-217.

Schubert, C. 2014. *Social Innovations, Highly Reflexive and multi-referential phenomena of today's innovation society? A report on analytical concepts and social science initiative,* Technology Studies Working Papers, TUTS-WP-2-2014. Berlin: Technical University.

Skibo, J.M., Schiffer, M.B., 2008. *People and Things: A Behavioral Approach to Material Culture*. Brooklyn: Springer.

Sinopoli, C.M. 1988. The Organization of Craft Production at Vijayanagara, South India. *American Anthropologist, New Series* 90 (3), 580-597.

Skibo, J.M., Schiffer, M.B., Reid, K.C. 1994. Organic-Tempered Pottery: An Experimental Study. *American Antiquity* 54 (1), 122-146.

Spataro, M. 2007. Everyday Ceramics and Cult Objects: A Millennium of Cultural Transmission, in: Spataro, M., Biagi, P. (eds.). *A Short Walk through the Balkans: the First Farmers of the Carpathian Basin and Adjacent Regions*, Quaderno 12. Trieste: Società Preistoria Protostoria Friuli-V.G., 149-160.

Spataro, M. 2011. A comparison of chemical and petrographic analyses of Neolithic pottery from South-eastern Europe. *Journal of Archaeological Science* 38, 255-269.

Spataro, M. 2017. Innovation and regionalism in the middle/late Neolithic of south and south-eastern Europe (ca. 5,500-4,500 cal. BC): a ceramic perspective, in: Burnez-Lanotte, L. (ed.). *Workshop "Matières à Penser": Raw Materials Acquisition and Processing in Early Neolithic Pottery Productions*, Proceedings of the Workshop of Namur (Belgium), 29-30 May 2015 University of Namur, Séances de la Société Préhistorique Française 11. Paris: Société préhistorique, 61-80.

Spataro, M. 2018. Origins of Specialization: The Ceramic *Chaîne Opératoire* and Technological Take-off at Vinča-Belo Brdo, Serbia. *Oxford Journal of Archaeology* 37 (3), 247-265.

Stark, M.T. 1999. Social Dimensions of Technical Choice in Kalinga Ceramic Traditions, in: Chilton, E.S. (ed.). *Material Meanings: Critical Approaches to the Interpretation of Material Culture*. Salt Lake City: The University of Utah Press, 24-43.

Stark, M.T., Clark, J.J., Elson, M.D. 1995. Causes and Consequences of Migration in the 13th Century Tonto Basin. *Journal of Anthropological Archaeology* 14, 212-246.

Tasić, N., Marić, M., Penezić, K., Filipović, D., Borojević, K., Russell, N., Reimer, P., Barclay, A., Bayliss, A., Borić, D., Gaydarska, B., Whittle, A. 2015. The end of the affair: formal chronological modelling for the top of the Neolithic tell of Vinča-Belo Brdo. *Antiquity* 89 (347), 1064-1082.

Thissen, L. 2005. The role of pottery in agropastoralist communities in early Neolithic southern Romania, in: Bailey, D., Whittle, A., Cummings, V. (eds.). *(Un)settling the Neolithic*. Oxford: Oxbow books, 71-78.

Thissen, L. 2009. First ceramic assemblages in the Danube catchment, SE Europe – A Synthesis of the radiocarbon evidence. *Buletinul muzeului jedetean Teleorman. Seria arheologie* 1, 9-30.

Thissen, L. 2017. The First Balkan Neolithic in the Lower Danube Plain and the Making of a Pottery Tradition, in: Reingruber, A., Tsirtsoni, Z., Nedelcheva, P. (eds.). *Going West? The Dissemination of Neolithic Innovations between the Bosporus and the Carpathians*, Proceedings of the EAA Conference, 11 September 2014 Istanbul. London/New York: Routledge, 79-90.

van der Leeuw, S.E., Torrence, R. (eds.) 1989. *What's New? A Closer Look at the Process of Innovation*, One World Archaeology 14. London: Allen and Unwin.

van der Leeuw, S.E. 1977. Toward a study of the economics of pottery making, in: Van Beek, B.L. (ed.). *Ex Horreo*. Amsterdam: University of Amsterdam, 68-76.

Vandiver, P. 1987. Sequential Slab Contruction; A Conseravtive Southwest Asiatic Ceramic Tradition, ca. 7000-3000 B.C. *Paléorient* 13 (2), 9-35.

Vuković, J. 2004. Statistic and typological analyses of the Early Neolithic pottery excavated in the structure 03 at the site of Blagotin near Trstenik, in: Perić, S. (ed.). *The Neolithic in the Middle Morava Valley.* Beograd: Archaeological Institute/ Regional Museum Jagodina/Regional Museum Paraćin, 101-168.

Vuković, J. 2010. Neolithic Fine Pottery: Properties, Performance, and Function. *Journal of Serbian Archaeological Society* 26, 7-23.

Vuković, J. 2011. Late Neolithic Pottery Standardization: Application of Statistical Analyses. Старинар LXI, 81-100.

Vuković, J. 2012. Early Neolithic Pottery form Blagotin, Central Serbia: A Use-Alteration Analysis, in: Krauss, R. (ed.). *Beginnings: New Research in the Appearance of the Neolithic between Northwestern Anatolia and the Carpathian Basin*, Papers of the International Workshop, 08 – 09April 2009 Istanbul, Menschen – Kulturen – Traditionen, Studien aus den Forschungsclusterndes Deutschen Archäologischen Instituts 1. Rahden/Westf.: Verlag Marie Leidorf GmbH, 205-211.

Vuković, J. 2013. Deskripcija nasuprot interpretaciji: odnos tradicionalne i savremene arheologije prema problemu impreso-barbotin ranog neolita. *Etnoantropološki problemi* 8 (3), 657-679.

Vuković, J. 2014a. Archaeological Evidence of Pottery Forming Sequence: Traces of Manufacture in Late Neolithic Vinča Assemblage, in: Vitezović, S., Antonović, D. (eds.). *Archaeotechnology: studying technology from prehistory to the Middle Ages*. Belgrade: Srpsko arheološko društvo, 177-198.

Vuković, J. 2014b. Pottery ethnoarchaeology and archaeology of the Neolithic, in: Đorđević, B. (ed.). *Traditional Pottery Making from the Ethnoarchaeological Point of View. Scientific Research and Safeguarding of Intangible Heritage*, Proceedings of the First International Conference. Belgrade: National Museum, 6-19.

Vuković, J. 2015. Izgubljeni u tranziciji: problem prelaza ranog/srednjeg u kasni neolit centralnog Balkana u jugoslovenskoj/srpskoj arheologiji druge polovine XX veka. *Etnoantropološki problem*i 10 (3), 652-673.

Vuković, J. 2017a. Popravke i produžena upotreba keramičkih posuda: primer ranoneolitske zdele s Kovačkih njiva. *Zbornik Narodnog muzeja* XXIII-1, 123-133.

Vuković, J. 2017b. Erasing boundaries or changing identities? The transition from Early/Middle to Late Neolithic, new evidence from Southern Serbia, in: Gori, M., Ivanova, M. (eds.). *Balkan dialogues: Negotiating Identity between Prehistory and the Present*. London: Routledge, 240-253.

Vuković, J. 2019. Technology and Function: Performance Characteristics and Usage Aspects of the Neolithic Pottery of the Central Balkans, in: Amicone, S., Radivojević, M., Quinn, P., Marić, M., Mirković, N. (eds.). *Tracing pottery making recipes in the Balkans, 6th – 4th millennium BC*. Oxford: Archaeopress, 172-181.

Vuković, J., Miloglav, I. 2018. Part-time Labor and Household Production: Emergence of Specialized Potters in the Late Neolithic Vinča (Serbia) and Late Eneolithic Vučedol (Croatia) Societies, in: Miloglav, I., Vuković, J. (eds.). *Artisans Rule: Product Standardization and Craft Specialization in Prehistoric Society*. Newcastle: Cambridge Scholars Publishing, 120-136.

Vuković, J., Vitezović, S., Milanović. D. 2016. Pavlovac-Kovačke njive – Neolithic layers, in: Perić, S., Bulatović, A. (eds.). *Archaeological Investigations along the Highway Route E-75 (2011-2014)*. Belgrade: Institute of Archaeology, 167-204.

Wallaert-Pêtre, H. 2001. Learning How to Make the Right Pots: Apprenticeship Strategies and Material Culture, a Case Study in Handmade Pottery from Cameroon. *Journal of Anthropological Research* 57 (4), 471-493.

Wallaert, H. 2013. Apprenticeship and the confirmation of social boundaries, in: Wendrich, W. (ed.). *Archaeology and apprenticeship: body knowledge, identity, and communities of practice.* Tucson: University of Arizona Press, 20-42.

Whittle, A., Bartosiewicz, L., Borić, D., Pettit, P.B., Richards, M. 2002. In the beginning: new radiocarbon dates for the Early Neolithic in northern Serbia and south-east Hungary. *Antaeus* 25, 63-117.

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# Technological changes and innovations in the osseous industries in the early and late Neolithic in the Balkans

*Selena Vitezović*

## Abstract

The Neolithic period is marked with numerous and dramatic changes in all aspects of life. Changes in subsistence, namely domestication of plants and animals and introduction of agriculture and animal herding, are the most important, but not the only changes; different mode of subsistence affected different aspects of daily life – shelter making, tool production, technologies, as well as the perception of the environment, and many more.

In this paper, traditions, changes and innovations will be analysed among osseous industries in the south-eastern Europe within the early Neolithic Starčevo and the late Neolithic Vinča culture. Osseous industries went through considerable changes in the Neolithic: introduction of domestic animals brought in modifications in raw material choices and methods of acquiring; changes in economy – new crafts and new activities, which influenced the typological repertoire. Furthermore, we may note some new manufacturing techniques, connected with changes in lithic industries, such as the introduction and wider use of abrasion techniques. Finally, we may observe differences in the cultural attitude towards these raw materials – they are no longer used for the figurines, objects of art, *etc*., although they remain the most important raw materials for personal ornaments.

*Keywords: osseous industry, Starčevo-Körös-Criş cultural complex, Vinča culture, south-eastern Europe*

## Introduction

Osseous raw materials were among the most important raw materials throughout prehistoric times, along with stone and wood. They were used from the lower Palaeolithic, and, especially from the upper Palaeolithic, bone industries constitute an important part of the material culture – osseous raw materials

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were used for weapons, tools, and ornaments, as well as for making portable art (cf. Schibler 2007 and references therein). Because of their long, continuous presence in almost all prehistoric societies and their frequency, osseous artefacts are important for studying long-term traditions and innovations in technology, and they are also convenient for studying regional diversity.

For a long time, osseous artefacts were neglected in analyses; some researchers perceived them as simply, *ad hoc* used kitchen debris, while the choices regarding selection of the skeletal elements, manufacturing technique and final shape were often interpreted as being determined by environmental factors and following the "easiest", "simplest", "ergonomic" solutions (cf. Vitezović 2016a and references therein). Some of the technological choices within osseous industries are partially dependent on the environment, such as the availability of certain animal species and skeletal elements. However, osseous industry, like other technologies, is also a cultural phenomenon and approach concentrated on its technological aspects and is needed for a complete, comprehensive analysis of its place within a given community (cf. Vitezović 2011a; 2013a).

Technology is a conceptual approach to material culture studies. Derived from the Greek word τέχνη, meaning skill, technology implies all human actions upon a given material (Miller 2007). The concept of technology as a culture-driven phenomenon has become more widely accepted in recent decades, largely influenced by the technological approach from the French anthropological and archaeological school (cf. Lemonnier 1992; Greene 2006). Technologies must be considered in a general anthropological perspective as social productions that are compatible with other social phenomena. All technologies within a given community constitute technological systems, and individual technologies, including osseous, are mutually dependent (Lemonnier 1992).

The features of technologies and technological systems are not simply a result of physical constraints, either those internal to technologies themselves, or constraints arising from the natural environment, and the question of the influence of social choices has to be taken into account. According to P. Lemonnier (1992), there are more subtle informational or symbolic aspects of technological systems that involve arbitrary choices of techniques, physical actions, materials, *etc.*, which are not dictated by their function.

According to B. Hayden (1998), there are different kinds of constraints operating in the development of solutions for each problem and trade-offs between constraints make it unlikely that there will be any single optimal solution to a problem, but rather, a number of more or less equally acceptable solutions. Among the most powerful of these constraints are functional requirements, material properties, availability, and production costs. Once a field of acceptable solutions for a given problem has been identified, the choice of the solution that will be adopted may largely be a matter of cultural tradition, ideological values, style, *etc.* These constraints have an important role in the case of practical technologies. On the other hand, prestigious technologies, used not to perform a practical task, but to solve a social problem, to display wealth, success, and power, have fundamentally different logic and strategy than those used for creating practical artefacts. Prestige technologies employ as much surplus labour as possible to create objects that will appeal to others and attract people to the possessor of those objects due to admiration for his/her economic, aesthetic, technical, or other skills (Hayden 1998).

The analysis of technological choices must include all steps in the manufacturing process, from raw material selection, to episodes of repair, until the final discard. André Leroi-Gourhan proposed the concept of chaîne opératoire (Leroi-Gourhan 1964; 1965; 1971), which aims to describe and understand all the cultural transformations that a specific raw material had to go through and to reconstruct the organization of a technological system. It is a chronological segmentation of the actions and mental processes required in the manufacturing of an artefact and its maintenance in the technical system of a prehistoric group (Inizan *et al.* 1995, 14; cf. also Sellet 1993).

When it comes to bone technologies analyses, important research questions are why bones were chosen for the production of certain objects in the first place, why specific species and skeletal elements were chosen or avoided, why a specific manufacturing technique was used, and why some bone objects had been used for a long time and often repaired (cf. Choyke 2010; 2013; also Vitezović 2011a; 2013a; 2016a, and references therein).

With the changes that the introduction of the Neolithic way of life brought – namely, domesticated plants and animals, and associated subsistence patterns and other activities, all the technologies changed, including the osseous technology. New animal species and changes in economy affected the raw material choices, changes in other technologies had impact on the manufacturing procedures, and new tasks and new activities influenced the need for some tool types; some disappeared, some new types emerged and the frequency and morphological variations of some types decreased or increased.

In this paper, bone industries from the Neolithic period in the areas of the central Balkans and southern Carpathian basin will be analysed – from the early /middle Neolithic Starčevo culture and from the late Neolithic Vinča culture. Analyses followed the approach and the criteria for typological classification outlined by the French archaeological school (cf. Camps-Fabrer 1966; 1979; Camps-Fabrer ed. 1990; 1991; 1998; Ramseyer ed. 2004), adapted for Balkan prehistoric assemblages (Bačkalov 1979; Beldiman 2007; Vitezović 2011c; 2016a). Analytical criteria for the technological and functional interpretation of manufacture and use wear traces were established upon the previous work and experimental results from different authors (Newcomer 1974; Semenov 1976; Peltier 1986; Campana 1989; Christidou 1999; Maigrot 2003; Christidou, Legrand 2005; Van Gijn 2005; Legrand 2007, *inter al.*). Special focus will be put on the innovations and traditions within the Starčevo culture bone industries (*vs.* Mesolithic bone industry, known in this area only from the Iron Gates region – cf. Bačkalov 1979; Beldiman 2007; Vitezović 2011b; Mărgărit and Boroneanţ 2017) and on the innovations and traditions within the Vinča culture bone industry (*vs.* Starčevo culture).

## Archaeological background

The region of the central Balkans and southern Carpathian basin during the Neolithic was marked by the phenomena labelled as Starčevo and Vinča cultures. The Starčevo culture, part of the Starčevo-Körös-Criş cultural complex, was widespread in present-day Serbia, eastern Croatia, Bosnia and Herzegovina, and northern Montenegro. The Vinča culture encompassed more/less the same territory, and also expanded into the territories of Oltenia and Transylvania in present-day Romania (cf. Garašanin 1979; Srejović *ed.* 1989). Absolute dates place the Starčevo culture in the period between 6200 and 5500 BCE (Whittle *et al.* 2002), and the Vinča culture in the period 5400/5300-4500/4450 BCE (Borić 2009; Tasić *et al.* 2015).

The communities of the Starčevo culture represent the earliest agriculturalists in the region. The subsistence of both Starčevo and Vinča communities were based on the cultivation of different plant resources and animal herding, although gathering, fishing and hunting were practiced as well (cf. Bökönyi 1988; Filipović and Obradović 2013; Marinova *et al.* 2013; Greenfield 1986; 2008; Orton 2008; *inter al.*). Domestic animal species included sheep, goats, cattle and pigs, and wild species included red deer, aurochs, wild pigs, roe deer, different fish, birds, *etc.* As a general trend, the predominance of sheep/goats in the Starčevo culture may be noted and the increasing importance of cattle in the Vinča culture. However, there are differences between sites / regions within both Starčevo and Vinča communities regarding the predominant species, as well as regarding the domestic / wild ratios (for details for specific sites, cf. Bökönyi 1988; Bulatović 2012; 2018; Clason 1982; Greenfield 1986; 2008; Orton 2008).

The Starčevo culture brought in an important new technology – ceramic, now used not only for production of cooking, storage and consumption vessels, but also for utilitarian items such as weights or spindle whorls, or non-utilitarian objects such as altars or figurines. The ceramic production in the Vinča culture is even more prominent and certain levels of specialization and standardisation are observed (cf. Vuković 2011). Changes are noted in the lithic industry as well; woodworking tools are more common and more diverse, abrasive stone artefacts, such as querns, whetstones, grindstones, increase in frequency and diversity, and so on (cf. Antonović 2003).

Diversity in technologies, production of goods which are not purely utilitarian and production of goods which are time, labour and skill demanding, as well as a certain level of standardization, show that craft production was diverse, rich and important and that elaborated associated social and economic relations existed. Osseous industries constitute an important part of the material culture in both Starčevo and Vinča cultures. The analyses are connected with numerous methodological problems, though. Some sites were excavated on a limited surface, faunal material was not always carefully collected nor examined by specialists, taphonomic conditions for preservation were not always favourable, and also stratigraphic position on multi-layered sites were not always certain. However, several assemblages analysed in detail from technological viewpoint so far offer interesting results on traditions and innovations in the Neolithic.

## Osseous industry in the Starčevo culture

Osseous industry in the Starčevo culture was analysed from the following sites (Fig. 1): Ludaš-Budžak, Nosa-Poroš, Nosa-Biserna Obala, Golokut-Vizić, Obrež-Baštine, Donja Branjevina, Starčevo-Grad, Ušće Kameničkog Potoka, Knjepište, Velesnica, Zmajevac, Divostin, Grivac, Drenovac, Međureč, Anište-Bresnica, Bubanj-Novo Selo and Pavlovac-Kovačke Njive (Vitezović 2007; 2011c; 2011d; 2013b; 2013c; 2017a; in prep; Vuković *et al.* 2016; cf. also Vitezović 2012a; 2014). The quality and quantity of the information obtained from these assemblages differs considerably. At some of these sites, the faunal remains were not carefully collected, and some the preservation was not very good, while some sites were either excavated on a small area or the stratigraphy was mixed. This is why some of these assemblages only consist of several artefacts, while some of the assemblages are rich in both quantity and quality. Numerous excavations carried out in the first half and mid-20$^{th}$ century did not practice careful collection of faunal material, and only selected bone artefacts were collected. In particular, from sites of Ludaš-Budžak, Nosa-Poroš, Nosa-Biserna Obala and Anište-Bresnica only complete objects are stored today in the museums and it is reasonable to assume that there were more bone objects in the excavated area, but were not noticed or considered not worthy of being collected. Problems with the interpretation of the stratigraphy and discerning of Starčevo and Vinča culture layers, caused by inadequate excavation technique of mechanical "spits", exist at the sites of Divostin, Grivac and Pavlovac, and within these assemblages it is not clear to which period some artefacts belong. The information obtained from these sites are those regarding the presence of certain techniques and artefact types, while the absence of some traits is taken with caution.

Fortunately, some assemblages have sample bias reduced to a minimum. The site of Starčevo-Grad is very important, because it is relatively rich and there are no problems related to the interpretation of the stratigraphic sequence. In this case, it is obvious from the collection itself that faunal material was carefully collected during the excavations in the 1930's, today in the National museum there are stored not

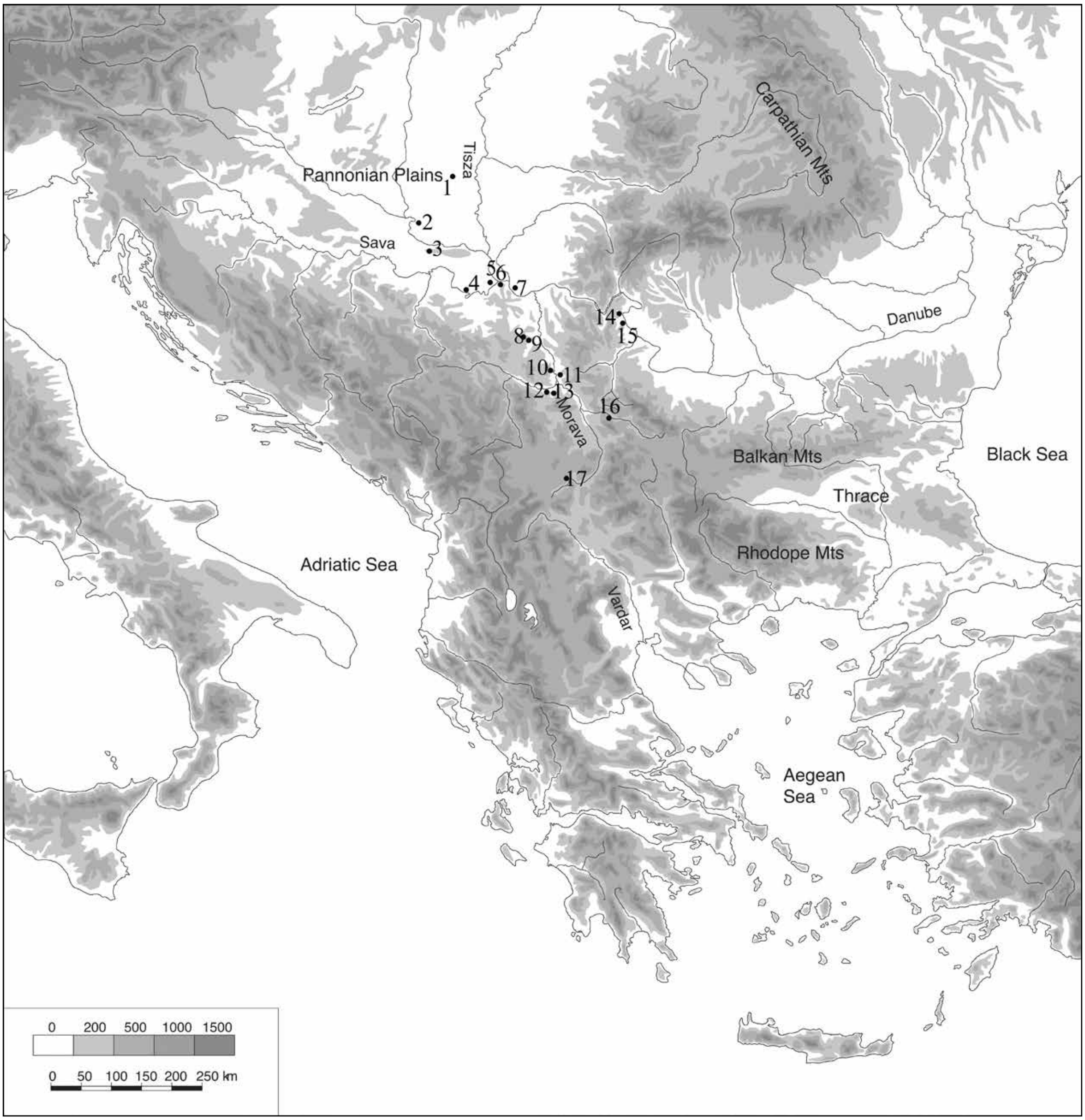


*Figure 1. The most important Starčevo and Vinča culture sites mentioned in the text: 1. Ludaš-Budžak, 2. Donja Branjevina, 3. Golokut-Vizić, 4. Obrež-Baštine, 5. Jakovo-Kormadin, 6. Vinča-Belo Brdo, 7. Starčevo-Grad, 8. Grivac, 9. Divostin, 10. Međureč, 11. Drenovac and Slatina-Motel, 12. Stragari, 13, Vitkovo, 14. Velesnica, 15. Ušće Kameničkog Potoka and Knjepište, 16. Bubanj, 17. Pavlovac-Kovačke Njive.*

only complete objects, but also fragments, manufacture debris, unworked faunal remains, *etc.* Furthermore, excavations carried out in the 21st century yielded collection with same technological and typological traits. Also, assemblages from sites of Međureč, Knjepište, Velesnica, Ušće Kameničkog Potoka were recovered and collected following the modern standards of archaeological excavations, and recent excavations at sites of Bubanj and Drenovac provided representative assemblages, with sample bias reduced to a minimum (see references for each of the sites for more details on the history of excavations, stratigraphy, preservation, *etc.*).

Osseous raw materials were used for producing a variety of objects: everyday tools (awls, needles, heavy points, scrapers, burnishers, chisels, wedges, hammers, small percussion tools, retouching tools, *etc.*), diverse utilitarian objects (such as handles or hafts), weapons (projectile points) and ornaments (beads, pendants, buckles, bracelets).

In the osseous technology of the Starčevo culture some traits may be noted that can be linked with the Mesolithic traditions, but also numerous innovations, linked with changes in subsistence, economy, and other technologies, as well as with culture-driven changes. Some of these innovations are shared with other early Neolithic communities in Anatolia and south-eastern Europe, and they are usually considered to be the result of the Near-Eastern influences (cf. Sidéra 1998), however, they were not simply transmitted, but modified through the process of adoption (cf. Vitezović 2011c for more details on the Starčevo culture bone industry and Vitezović 2016b for a more detailed discussion on innovations and Near-Eastern influences).

## Raw material management and selection

Osseous raw materials could be acquired from animals killed for food or could be collected (for example, shed antlers or mollusc shells) (cf. Vitezović 2016a and references therein). They could be obtained directly and locally, or acquired through trade and exchange (for example, mollusc shells from distant regions). In prehistoric communities, locally and directly acquired osseous raw materials usually prevail. However, this does not imply that all the available skeletal elements were used unselectively – certain choices among available raw materials were made, directed by their physical and mechanical traits as well as by cultural preferences (cf. Isaakidou 2003; Choyke 2010; 2013).

In the Starčevo culture, a strict selection of both skeletal elements and species was present. The main raw materials were sheep/goat and cattle long bones (mainly metapodial bones, tibiae) and ribs, followed by red deer antlers (Vitezović 2011c; 2014). Other skeletal elements were used only occasionally and in small quantities – such as roe deer antlers, boar tusks, other teeth and mollusc shells. Some skeletal elements were almost never used, such as cranial bones or pig bones. Reasons for such a choice are only partially technological – ungulate metapodial bones are very convenient for tool production because of their straight shaft and thick walls, and therefore widely used in prehistory (cf. Schibler 2013); however, the presence of pig bones in other cultures / periods shows their properties can be well exploited. We can also note that certain techno-types have a strict, exclusive choice of skeletal element and species, partially linked with their physical and mechanical properties (for example, use of antlers for percussion tools – cf. Vitezović 2014 and references therein).

There are some regional differences in the ratio of certain skeletal elements; especially when it comes to the usage of antlers, which are very frequent at some sites (especially Divostin and sites in the Iron Gates region, but also Starčevo-Grad), while almost completely missing at others – at Međureč, for example, not a single antler object was found (cf. Vitezović 2014). Antlers were not widely used in the early Neolithic in the region; they were rare or almost non-existent in the Körös culture (cf. Tóth 2013) or among early Neolithic communities in Greece (Perlès 2001). Somewhat more frequent use of antlers on Starčevo and Criş sites (cf. Vitezović 2014 and Beldiman 2007 respectively) could be a reflection of Mesolithic traditions, – namely, antler industry was important and diverse among the Mesolithic communities in the Iron Gates (Bačkalov 1979; Beldiman 2007; Vitezović 2011b). Antlers were mainly shed and so obtained by collecting, and this shows that Starčevo communities possessed the necessary knowledge about the environment, as the red deer tend to shed their antlers at the same place every year (cf. Clutton-Brock 1984).

Mollusc shells used for artefacts were only marine shells, mainly acquired fresh, although there is a possibility that some of the *Dentalium* shells were fossilised ones (cf. Dimitrijević 2014). Deliberate modification of freshwater *Unio* shells is not confirmed thus far. The quantities of mollusc shells encountered on different sites varies, in fact, they are quite rare and found in small numbers at only a few sites. Few shell ornaments come from Divostin, Međureč and Drenovac, while only at Starčevo-Grad the assemblage is somewhat richer and includes several *Spondylus* bracelets and three *Dentalium* beads (cf. Vitezović

2016c). These are only exotic, marine shells, acquired through some sort of exchange, and valued as prestige goods (cf. Vitezović 2012a).

The predominance of cattle and sheep/goat bones shows that the skeletal elements of domestic animals were already fully accepted as adequate raw material, and also that their physical and mechanical properties were well known. The study of raw material choices in the Natufian, PPNA (Pre-Pottery Neolithic A) and PPNB (Pre-Pottery Neolithic B) assemblages from Levant showed that a certain time is needed for domestic animals to be fully adopted and included into all segments of life and into diverse aspects of consumption (Le Dosseur 2010). During the Natufian and PPNA, gazelle bones were predominant both in faunal record and as a raw material. Caprinae increased in the fauna during the middle PPNB and even predominate, but the gazelle were still the preferred raw material choice. Goat and especially sheep bones became the main raw material choice during the late PPNB. This suggests that the frequency and easy access are not the determining reasons for the choice of species, and this shift in preferred raw materials from gazelle to sheep/goats also included changes in attitude towards the newly introduced animals.

## Manufacturing techniques

Most of the manufacturing techniques encountered within the Starčevo culture have much in common with techniques practiced throughout prehistoric Europe, although some technological traits are more culture- and chronologically specific.

One of the most prominent innovations of Neolithic osseous technology was the widespread use of abrasion, directly linked with the introduction and widespread use of stone abrasive tools (cf. Antonović 2003; Antonović and Vitezović 2014). Abrasive stone tools became particularly abundant and diverse and include querns, static and portable whetstones and grindstones, *etc.* Their function was usually related to food processing, but some of these artefacts were used in the later stages of shaping objects from osseous raw materials, for repairing / re-sharpening cutting edges, pointed ends, as well as for more decorative polishing of mesial and basal surfaces.

A particularly interesting method of shaping concerns the production of pointed tools from small ruminant metapodials. This tool type was widespread in Europe throughout the Neolithic period (*e.g.* Bačkalov 1979; Beldiman 2007; Camps-Fabrer ed. 1990; Makkay 1990; Sidéra 2005; Stratouli 1998). Three distinctive manufacturing methods were recognised: (i) manufacture using abrasion only; (ii) manufacture by first sawing the metapodia in half and then abrading them; and (iii) manufacture by first abrading and then by sawing (cf. Murray 1979, Sidéra 2005). In the first and the third method, metapodial bone was first ground with an abrasive stone from both sides (dorsal and ventral) until it became flat. It may have been further shaped then by abrasion only, or by a combination of cutting with a flint tool and abrasion. The result are very thin, fine points. The distal epiphysis, preserved at the base, is often reduced to a very small, almost flat knob or simply ground from all sides, thus obtaining a more or less regular square shape. This method allowed more precise shaping, but restricted the number of artefacts which could have been fashioned from a single piece of raw material (Fig. 2).

The second method could enable the maximum of four tools from a single bone and, also, the results were not so fine, but more resilient, stronger awls. All three techniques for shaping were used within the Starčevo-Körös-Criş culture and the early and middle Neolithic in the region (cf. Beldiman 2007; Beldiman and Sztancs 2011; Makkay 1990; Stratouli 1998; Tóth 2012). In later periods, methods that included abrasion as the first step disappeared, and the second technique became predominant (cf. Bačkalov 1979; Russell 1990; Vitezović 2007; also see below). Unfortunately, at this moment it is not clear whether the abrasion-only technique existed

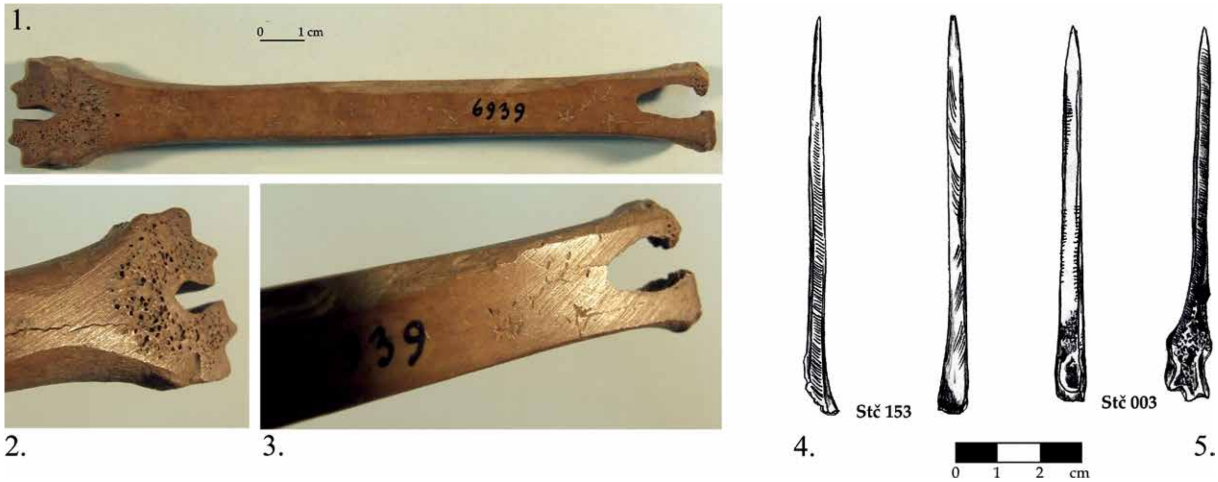


*Figure 2. Method of manufacture of pointed artefacts by abrasion only: 1. manufacture debris – abraded metapodial bone, 2. and 3. details, 4. and 5. final products – awls, all from Starčevo-Grad.*

in the early phases of the Vinča culture or if it disappeared with the final periods of the Starčevo culture, since the stratigraphy is uncertain for some of the finds.

The usage of technique for transversal division of long bones can also be considered as specific for the Starčevo culture. It is easier to divide large, thick long bones from large mammals into segments longitudinally than transversally due to the anisotropic traits of the long bones (Christensen 2004). In order to obtain segments that have full circumference and original width of the bone, a groove was made along the circumference of bone with a chipped stone tool and/or with abrasive fibre and the bone was either completely cut through or the final millimetre or so of the bone was just snapped or broken off. This method enabled obtaining blanks with predetermined dimensions, of regular shape and more or less straight edges, which was not possible with breaking or chopping.

A similar method of transversal division, grooving with a chipped stone tool and use of wet abrasive fibre, was also applied on antlers. Again, antlers, especially when fresh, are very resilient, and this technique, labelled *débitage by segmentation* (*débitage par tronçonnage*) or *cut-and-break technique*, enabled obtaining regular blanks (cf. Averbouh 2000, 186; Averbouh and Pétillon 2011, 41). Another technique was used for extracting elongated, flat blanks from beam segments, called *débitage by extraction* (*débitage par extraction*) or *groove-and-splinter technique* (cf. Averbouh 2000, 186; Averbouh and Pétillon 2011, 41). Usually, two parallel grooves were incised longitudinally and then a blank was extracted with a wedge (cf. Averbouh 2000; Averbouh and Pétillon 2011; Rigaud 2004).

Within the Starčevo culture, three distinct methods for making perforations on bones were noted. The most widespread method of making perforations was by drilling with a perforated chipped stone tool (with sand added), used to obtain smaller holes – usually 5-8 mm in diameter and circular in shape. This technique is generally applied to ornaments; perforated tools are very rare. The second method, scraping out the bone, which produced elongated, more oval perforations, was noted on a single example, on one bone needle from Pavlovac-Kovačke Njive (Vuković *et al.* 2016, t. VI/2).

The third technique was used to make larger holes, 1-1.5 cm in diameter and circular in shape. They were made with a hollow tool (perhaps some sort of a reed tube or something similar), with an abrasive substance added (*e.g.* sand) and are encountered on decorative items. These large perforations leave distinctive debris, in the shape of small circles, discovered at several sites so far, including a large amount at the site of Kremenjak-Čoka (cf. Vitezović 2013e). This technique is characteristic for the Starčevo-Körös-Criş cultural complex (cf. Beldiman and Sztancs 2011; Makkay 1990; Tóth 2012; see also Vitezović 2013e and references therein).

## Typological repertoire

Some of the Neolithic osseous tools are not culturally or chronologically specific; they have simple shapes, which follow the natural shape of bones and were widespread across Europe – *e.g.*, awls from long bone splinters, scrapers from ribs, *etc.* Most of the characteristic techno-types actually display certain Near-Eastern influences. According to I. Sidéra (1998), Anatolian influences visible in the osseous industries in south-eastern Europe included the presence of some or all of the following techno-types: pointed tools with a cutting edge from small ruminant tibiae, antler sickles, elaborated fishhooks, needles with perforation made by incising, buckles, crude axes, spoons, and beads from bird bones.

These techno-types were not simply taken over by the Starčevo communities, but were modified through the process of adoption (Near-Eastern influences are discussed in more detail elsewhere – cf. Vitezović 2016b). The presence and quantity of these techno-types vary; some were not identified thus far (such as beads from bird bones or crude axes), some were found in small numbers (such as elaborated fish hooks or antler sickles), while some techno-types are relatively frequent. The types that are more common are spatula-chisels from caprinae tibiae, spatula-spoons from large ungulate metapodials and buckles and ring-shaped ornaments from large long bone segments.

Spatulae-chisels from caprinae tibiae were produced from almost the entire tibia bone; the proximal epiphysis is removed and bone obliquely ground to obtain a working edge. Sometimes, basal parts are additionally smoothed (Fig. 3). They were discovered at sites such as Grivac, Divostin, Rudnik near Srbica and Pavlovac-Kovačke Njive (Vitezović 2011c; Vuković *et al.* 2016). Their frequency varies and they are generally not as important as, for example, in the Bulgarian Karanovo I-II culture (cf. Lang 2005; Zidarov 2014). Also, in the eastern Balkans, tibia tools are still produced in the late Neolithic, while in the central Balkan area the usage of entire tibia bones disappears in later stages.

Spatula-spoons take a very special place in several Anatolian (*e.g.* Dekker 2014; Özdoğan 2011; Russell 2006; 2016) and south-eastern European osseous industries, including the Starčevo-Körös-Criş cultural complex (cf. Beldiman 2007; Beldiman and Sztancs 2011; Makkay 1990; Nandris 1972; Tóth 2012; Vitezović 2011c; 2011d; 2013b; 2016d) and the Karanovo I-II culture (cf. Lang 2004; Zidarov 2014). They are considered by M. Özdoğan (2011) as part of the "Neolithic package", while J. Nandris (1972) singled them out as the key bone artefact for the "First Temperate Neolithic".

Spatulae-spoons were made almost exclusively from large ungulate metapodial bones. Although it was suggested by Nandris (1972) that only bones of wild *Bos primigenius* were in use, *Bos taurus* metapodials prevail or were even exclusively used in the Starčevo culture. Spatula-spoons are particularly meticulously made, with very high skill, time and labour investment. According to the experimental results, approximately 25 hours of work were needed for one spoon (Sidéra 2011). They were produced from an entire metapodial bone through several stages of cutting, scraping, burnishing and polishing. They have elongated handles of cylindrical or oval cross-sections, straight or gently curved, and a bowl (spoon-part) at the distal end, usually completely flat or slightly concave. Bowl shapes vary – they may be elongated, leaf-shaped, or shorter, triangular, or, rarely, oval (Fig. 4). Zoomorphic handles, known from Anatolian sites (Mellaart 1961, pl. 4/c; 1965) and occasionally encountered in Bulgaria, have not been discovered thus far (cf. Vitezović 2016d and references therein). However, it should be noted that one projectile-shaped artefact from Donja Branjevina, probably a re-worked spoon, had a zoomorphic base (Vitezović 2011d, 31). Also from Donja Branjevina, one fragmented piece has a peculiar base – decorated with two rows of incisions (Vitezović


*Figure 3. Spatula-chisels from caprine tibiae, 1. Divostin and 2. Pavlovac-Kovačke Njive.*

2011d, 37, Fig. 18/2), and one example from Tečić may be mentioned with incisions on both sides at basal part of the bowl (Vitezović 2016d, 192, Fig. 3).

Very intensive, long use is another important feature of these artefacts. High polish and shine from use, worn bone tissue is visible on all of them; sometimes they have broken or damaged edges, and we may observe how they continued to be in use even after the breakage. Their function is still enigmatic; the intensive use-wear, especially damages, was interpreted as being related to contact with either clay or stone (cf. Georgiev 1967; Nandris 1972). They may have been used on special occasions, and their original purpose may have been related to the processing of different plants, perhaps "special" plants, such as medicines or spices. They might have served as cosmetic tools as well (cf. also Dekker 2014; Russell 2006; 2012). In the Starčevo culture, they were used for long periods of time and often repaired; therefore, it may be assumed that their original function was rather important (Vitezović 2011c). Their final function was probably as some sort of burnishers, as suggested by the presence of a high level of polish and shine, consistent with the prolonged contact with soft, organic materials, such as leather, hide and plant fibres (cf. Peltier 1986; Maigrot 2003; Legrand 2007; also cf. observations by Tóth 2012, 175). Perhaps one of their functions included processing pigments (for a more detailed analysis of spatula-spoons in the Starčevo culture, cf. Vitezović 2016d).

All these traits, their relative frequency (over forty examples were discovered at sites such as Donja Branjevina or Starčevo – cf. Vitezović 2011d; 2016d), important skill and labour investment in their production and long use often with repairs show that this techno-type was an important segment of the Starčevo material culture.

Another culture-specific bone item should be mentioned, namely one subtype of projectile points. Projectile points made from bones were relatively frequent in the Starčevo culture (unlike chipped stone projectiles) (Vitezović 2012b; 2018a). They were presumably used for hunting and fishing, and they were carefully made, suggesting that they were valued objects. Three subtypes were noted, and one of them is made from metapodial bones by using the very same manufacturing procedure as for spatula-spoons, furthermore, some are actually modified handles of broken spatula-spoons. So far, they have been discovered within Körös (Makkay 1990), Criş (Beldiman) and Starčevo culture sites (cf. Vitezović 2012b; 2018a).

New artefact types also include several decorative items. One of them being buckles in the shape of an open bracelet, all made from long bones of considerable

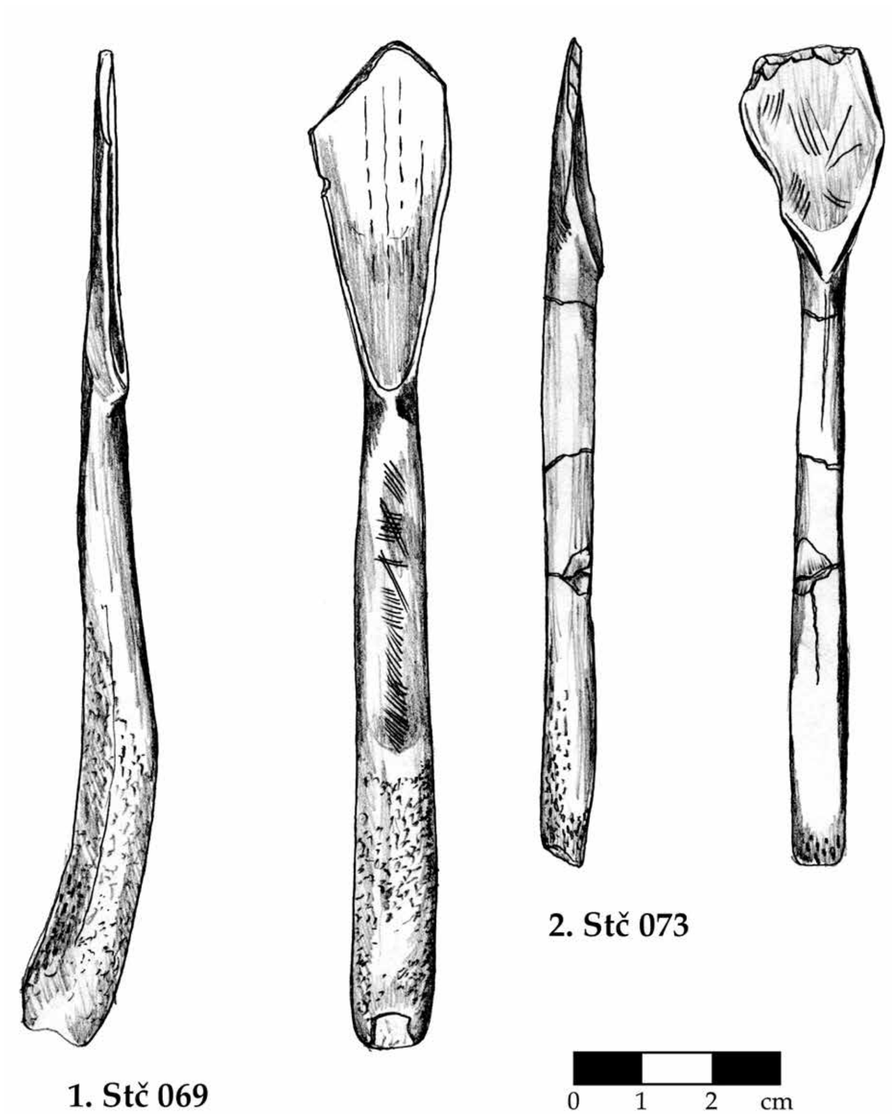


*Figure 4. Spatula-spoons made from Bos metapodial bones, Starčevo-Grad.*

size, from large ungulates, probably *Bos.* Bones were cut transversally by making a groove with abrasive fibre; and then by cutting the bone with a flint tool. All these objects have carefully shaped heads, made by cutting with a flint tool, and all the surfaces were carefully polished with some fine-grained stone. However, their original shape is unknown – whether they were in the shape of a half-circle or almost full circle, as they are all broken in the middle. This breakage is probably due to use – these peculiar artefacts may have been used as some sort of belt buckle or clasp for clothing pieces (Vitezović 2012a).

Among the region and culture specific decorative items, rings, disks and rectangular plates with large holes may also be included, all of similar morphology with slight variations. They were obtained by using the above-mentioned specific techniques, either by transversal cutting of large long bones (ring-shaped pieces), or from diverse flat pieces of bones, mainly from diaphyses of large long bones, by cutting, burnishing and polishing and by making large holes with a hollow tool (disks and rectangular perforated plates) (Vitezović 2012b; 2013e).

## Osseous industry in the Vinča culture

The study of technological changes is based on assemblages from the following sites, partially or completely analysed by the author: Jakovo-Kormadin (Vitezović 2010; Krištofić 2016; 2017), Vinča-Belo Brdo (Srejović and Jovanović 1959; Bačkalov 1979; Cristiani *et al.* 2016; unpublished work by the author), Drenovac, Slatina-Motel (Vitezović 2007), Vitkovo (Vitezović 2011e), Stragari (Vitezović 2007; 2009; 2011f), Belovode, Pločnik (Vitezović in press a; in press b), Grivac and Divostin (Vitezović 2013c; 2013d) (cf. also Vitezović and Bulatović 2013; Vitezović 2017b) (Fig. 1). Also, the osseous industry from the site of Selevac is extensively published (Russell 1990). Again, sample bias is present, thus making it difficult to measure and quantify some of the observed features; for example, over 300 objects were discovered at Drenovac within a single trench, while a rescue excavation campaign at Slatina-Motel yielded only approximately 60 artefacts (cf. Vitezović 2007). On the other hand, some of these assemblages are quite abundant, in fact, providing more detailed information on variations within assemblages, but also creating distorted images for underrepresentation of some raw materials or techno-types on other sites. This especially refers to the site of Vinča-Belo Brdo, where excavations first started in 1908 and, with some pauses, are still on-going. At this site an impressive 9m-thick cultural layer was discovered and a substantial quantity of portable finds also comes from the large area that was investigated, including osseous artefacts (cf. Bačkalov 1979; Nikolić *ed.* 2008). Also, as mentioned above, the stratigraphic situation is not always clear in case of the sites of Divostin and Grivac. Fortunately, some of these assemblages come from meticulous, careful excavations – recent campaigns at Drenovac, Belovode, Pločnik, Vitkovo and Jakovo-Kormadin (see references for each of the sites for more details on the history of excavations, stratigraphy, preservation, *etc.*).

In the Vinča culture, as in the Starčevo culture, the osseous raw materials were used mainly for everyday tools (awls, needles, points, scrapers, spatulae, chisels, axes, adzes, hammers, small percussion tools), for other utilitarian artefacts (such as handles of hafts), for weapons (harpoons, fish hooks) and for ornaments (beads, pendants, buckles, bracelets).

## Raw material management and selection

The differences between raw material choices within Starčevo and Vinča cultures are not drastic, but more of a question of nuances. Ungulate long bones were the preferred raw materials, along with large mammal ribs (mainly cattle). Among the long bones, metapodia, in particular sheep/goat metapodia were the predominant choice, while other long bones are only rarely identified. Pig bones were still mainly avoided. As a new skeletal element, we now encounter worked astragal bones.

As a general trend, we may note an increased standardisation in the raw material choices, *i.e.*, the increase of metapodial bones and ribs at the expense of other bones. However, this is difficult to measure, since it often cannot be identified with certainty which particular bone the long bone segments belong to, but, we may note that techno-types such as heavy points or awls from ulnae or spatula-chisels made from tibiae were not identified at any of the analysed sites. Ribs also seem to be used more often, and typological repertoire is more diverse (see below), but, due to the different nature of the available record, it is not possible to quantify the increase of the rib usage (Fig. 5).

The exploitation of antlers is more prominent within the Vinča culture. While within the Starčevo culture there were assemblages where antler artefacts were few or completely absent, antlers are more frequently encountered in Vinča settlements (all analysed assemblages included antler objects); furthermore, there are several sites where not only antler artefacts prevail, but also a considerable


*Figure 5. Awls made from ribs, Belovode.*

amount of manufacture debris were discovered – such as sites of Jakovo-Kormadin (Vitezović 2010; Krištofić 2016) and Divostin (Vitezović 2013c) (Fig. 6).

Another difference is visible regarding mollusc shells. As in the Starčevo culture, only marine shells were used, mainly fresh ones, with possible exception of use of fossil *Dentalium* shells (cf. Dimitrijević 2014). Contrary to only a few objects from shells in the Starčevo culture and from a few sites only, shells are now encountered more often and are more diverse both regarding the typological repertoire and their species. However, it is difficult to interpret this situation. As already mentioned, differences in excavations strategies and the generally much larger quantity of discovered portable finds from Vinča settlements do not reflect the real situation. Furthermore, the richest assemblage in terms of both quantity and quality comes from the site of Vinča-Belo Brdo, where over 300 fragmented and complete artefacts were discovered, from *Spondylus, Glycymeris, Dentalium* and *Cardium* shells. The typological repertoire is also diverse, and includes beads, bracelets, applications, pendants (Srejović and Jovanović 1959; Dimitrijević and Tripković 2002; 2006). Not only does Vinča-Belo Brdo have the largest portion of the site excavated, it is extraordinary in all other aspects – the prehistoric settlement at Vinča had an extremely long duration of occupation and its character was probably also extraordinary, *i.e.*, it was a trade and exchange centre

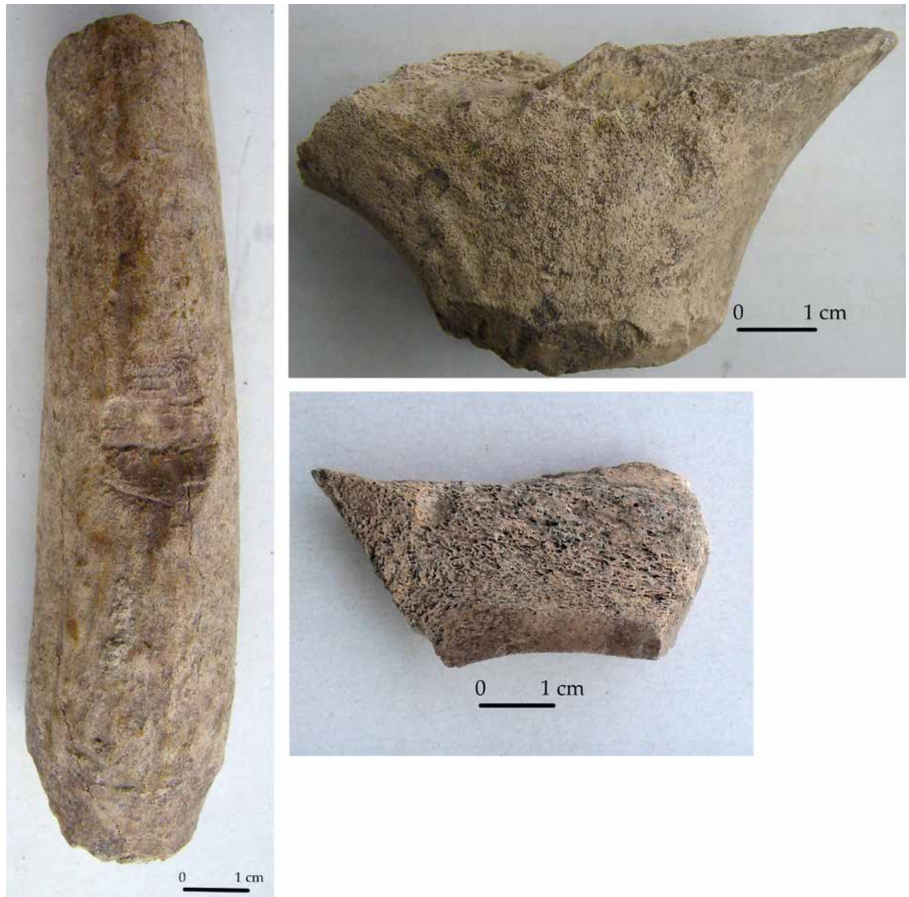


*Figure 6. Semi-finished object and manufacture debris from antler, Jakovo-Kormadin.*

(cf. Vitezović and Antonović 2019). Furthermore, the discovery of a unique Vinča culture cemetery at the site of Botoš-Živanića Dolja yielded an amount of personal ornaments that is not encountered within settlements, and thus contributed to the quantity and diversity of finds of exotic mollusc shells[1] (Marinković 2010). Therefore, although the increase in quantity and diversity of mollusc shell objects in the Vinča culture is connected with more intensified occupation, it is also the result of differences in the nature of the available archaeological record.

## Manufacturing techniques

Again, main techniques for obtaining blanks and shaping osseous artefacts do not differ considerably from those used in the Starčevo culture, although specific manufacturing procedures of the early Neolithic gradually disappear in the Vinča culture.

Metapodial bones, the main raw material, are usually longitudinally divided by grooving and then further shaped by abrasion. It is not clear if the method of shaping by abrasion only was still in use in the early phases of the Vinča culture, however, it was certainly completely abandoned by the later stages.

One new technique for production of pointed artefacts from long bone segments is recognized in the late Neolithic in the region, labelled quartering – the long bone was first divided longitudinally into two equal halves and then

1 Vinča culture graves are known so far only from the sites of Gomolava (several intra-murial burials) and from Botoš-Živanića Dolja (extra murial burials), while only single or several burials located within settlements – at Velesnica, Golokut, *etc.* – are known from the Starčevo culture – see Borić 1996 for details and references.

divided again into four blanks (Choyke and Tóth 2013). However, it is difficult to assess to what extent this specific technique was used within the Vinča culture. We can note, however, that, beside pointed artefacts made from one longitudinal half of a long bone, with a semi-circular cross-section, pointed tools made from diverse long bone segments were also relatively frequent. These include irregularly shaped splinters, probably obtained by direct percussion and finalized by abrasion, as well as tools with a very small portion of the epiphysis preserved at the basal part and a more or less triangular cross-section, obtained either by quartering technique or simply irregular longitudinal division.

Manufacture debris discovered within one pit at the site of Vitkovo is particularly interesting. Several bone segments have a partially executed groove for longitudinal division – the breakage does not follow the groove entirely, but runs next to it. Such "mistakes" could have been quickly fixed; straight, smooth edges were easily obtained by use of abrasive tools. This find from Vitkovo, along with the increased use of diverse, less regular long bone segments, disappearance of some (more time-consuming) débitage procedures (such as careful transversal division by grooving and by use of abrasive fibre) and increased use of abrasion, actually show that *débitage* phases in bone tool production were now quicker, simpler, less carefully executed and more effort was invested in later phases, namely into the final shaping by abrasion. Abrasion in general is very efficient for smoothing rough, irregular surfaces or edges of bones and especially for repairing any mistake or irregularity in the shape (cf. Semenov 1974). Again, quantifying and measuring these changes is very difficult, but all these technological aspects actually suggest an increased production, perhaps because of increased demand for osseous tools and related time-saving manufacturing techniques.

Antler working techniques were also slightly changed. Antlers were generally divided into segments by a combination of diverse techniques, and the following techniques were identified on the Vinča culture material: *débitage by segmentation, débitage by extraction* and *débitage by fracturation* (Vitezović 2017; cf. also Averbouh 2000; Averbouh and Pétillon 2011; Billamboz 1977; Rigaud 2004). The technique called *débitage by segmentation* (*débitage par tronçonnage*) or *cut-and-break technique* (cf. Averbouh 2000, 186; Averbouh and Pétillon 2011, 41) was used for transversal division and included a combination of grooving, cutting and chopping. While in the Starčevo culture the groove was usually made with a chipped stone tool and wet abrasive fibre and was almost perpendicular to the antler piece, in the Vinča culture the groove was most often made by cutting antler with a flint blade or the cortex was thinned by a gradual removal of thin stripes – by whittling and cutting small pieces. This technique may be identified by the negative traces of removed pieces, usually concentrated at the basal part of the tool, which are in some cases quite long, over one cm. After the cancellous tissue was reached, the remaining portion of the antler was chopped off, cut off with one or several blows, or snapped by flexion, and occasionally rough edges from remaining portion that was broken off may still be preserved (Fig. 6).

The technique called *débitage by extraction (débitage par extraction*) or *groove-and-splinter technique* (cf. Averbouh 2000, 186; Averbouh and Pétillon 2011, 41) was used for longitudinal division and for extracting blanks from the outer part of the antler. Usually two parallel grooves were incised longitudinally and then a blank was extracted with a wedge. Although this technique was in use in the Starčevo culture as well, it seems that it was more common in the Vinča culture, *i.e.*, artefact types made from cortex segments are more frequent and more diverse, and include harpoons, chisels, spoons, *etc.*

Another technique may be recognised within the Vinča antler industry. It is the so-called *débitage by fracturation (débitage par fracturation)*, which consists of the fracturing of a block by knapping in order to produce flakes, encountered occasionally in several prehistoric cultures, mainly Palaeolithic (Averbouh 2000, 186;

Averbouh and Pétillon 2011, 41). The find of approximately fifteen small fragments of antler cortex with traces of cutting and whittling, coming from a single context, discovered at the site of Jakovo-Kormadin (Vitezović 2010, 52), suggests occasional use of this or a similar technique within the Vinča culture (Fig. 6).

Perforations on bones and teeth were made exclusively by drilling with a chipped stone perforator. They are slightly more frequent: they occur on ornaments, such as perforated teeth, other pendants and some sort of applications, but also on tools – on awls, needles, even spatulae.

## Typological repertoire

Near-Eastern influences (as defined by Sidéra 1998) are no longer visible in the Vinča culture assemblages. Techno-types such as tibiae spatula-chisels, elaborated fish hooks or antlers sickles are not encountered at any of the Vinča settlements. The techno-type that resembles the spatula-spoons still exists within Vinča assemblages, but is completely altered in terms of technology and use. The main shape and the main idea are preserved: a single piece of raw material was modified into an object with an elongated handle and flat or slightly concave bowl (spoon-part). However, the strict selection of skeletal elements disappears, the entire production process is simplified, and the use wear traces show these objects were mainly used in burnishing and polishing of different organic raw materials. It is interesting that even antlers were used for spoons. Although producing such an object from a single piece of antler required certain skill, they are no longer carefully burnished and polished.

We can note that some artefact types are now much more frequent and the number of standardised subtypes and variations increases. It is not possible to present statistical data for this either, because of the different nature of the archaeological record, but it can be noted more as a general trend in the Vinča osseous industry. Medium-pointed tools or awls usually comprise more than 40% of the assemblages (cf., for example, Selevac – Russell 1990, or Drenovac – Vitezović 2007). Furthermore, they now are encountered in several standardized subtypes and variants: awls made from split ungulate metapodials with half of distal epiphysis at the base, awls from split metapodials with segments of proximal epiphysis at the base, one-sided awls made from split ribs (Fig. 5), double-pointed awls made from split ribs. As mentioned above, the use of ribs increases in the Vinča culture, and we may note two new techno-types made exclusively from ribs: spatula-awls and double-sided awls. Both types are made by using the same technique as for simple awls – ribs are divided into segments, split into two plates and further shaped mainly by abrasion. Double-sided awls have both ends pointed (and used), while spatula-awls have one end pointed and other one used as a burnisher or scraper.

Used astragals emerge as one new artefact type now. Complete astragal bones were sometimes modified, by adding one or several perforations, or used in unaltered shape. Perforations may be situated in the centre or at proximal portion, and the use-wear traces may cover condyles and/or entire lateral surfaces. Bones from ungulates (sheep/goats, cattle, red deer) were usually used, but very rarely from pigs (fig. 7). Astragals with traces of use can be encountered in numerous Neolithic and Chalcolithic sites in south-eastern Europe (cf. Grabundžija *et al.* 2016; Kogălniceanu *et al.* 2014; Meier 2013) and their function is still a matter for discussion. Bronze Age astragals from Hungary were probably used as burnishers on clay, as suggested by experimental work (Meier 2013). For the Vinča culture astragals, use-wear traces resemble consequences of contact with soft, organic materials, such as leather, hide, plant fibres (cf. Peltier 1986; Maigrot 2003; Legrand 2007) and this is why it was suggested that they are connected to textile production (cf. Grabundžija *et al.* 2016; Vitezović 2007). Perhaps they were used as burnishers, and those with perforations perhaps had an additional purpose as weights for loom or as spindle whorls, or they

*Figure 7. Used astragali, some with perforations, Pavlovac-Kovačke Njive.*

were related in another way to fibre production (especially those with groove running from perforation, clearly produced by use) (cf. Grabundžija *et al.* 2016; Vitezović 2007).

One techno-type that disappears in the Vinča culture should also be mentioned – retouching tools. Artefacts used for pressure flaking, retouching and repairing chipped stone tools were crafted from osseous raw materials throughout the Palaeolithic times, they were still present in different Mesolithic cultures, but their frequency declined in the Neolithic period. They were present in the Starčevo culture, though not in large numbers, but their presence in the Vinča culture is questionable. It is possible that some of the small percussion tools discovered at Selevac (Russell 1990) were used as retouchers as well (for an overview of retouching tools in the Neolithic, see Vitezović 2018b).

Perhaps the most conspicuous difference in typological repertoire is visible in hunting and fishing weapons. Projectile points made from bones, relatively frequent in the Starčevo culture, now disappear. Rare examples of projectiles made from long bones are more *ad hoc*, and in a technological aspect completely different from carefully shaped Starčevo projectiles.

Harpoons and large fish hooks, sometimes barbed, emerge as a new techno-type now. They were all made from red deer antler segments. These objects are not encountered within the entire Vinča culture, but are rather limited to areas near large plain rivers – such as Gomolava, on the bank of the Sava river in Srem (objects on display at the permanent exhibition at the Museum of Vojvodina in Novi Sad), and especially Vinča-Belo Brdo, situated near the mouth of the Bolečica river into the Danube.

Harpoons were made from large segments of beams of red deer antlers. Three variants occur: uniserial harpoons, biserial symmetric and biserial asymmetric. They were made by extracting the blank first by *débitage by extraction (débitage par extraction*), and further shaped mainly by cutting and scraping with chipped stone tools (Fig. 8).

Antler hooks are quite large, the usual length of the shank is 7-9 cm, and the point can be sometimes barbed. They were also made from beam segments, through several stages of cutting and scraping with chipped stone tools. Presence of manufacture debris


*Figure 8. Antler harpoon and antler hook, Vinča-Belo Brdo.*

within the site of Vinča-Belo Brdo clearly shows that they were produced locally. At the site of Vinča-Belo Brdo possible lure hooks were also identified made from different bone segments (Cristiani *et al.* 2016). This would suggest, perhaps, that different fish species were hunted at Vinča-Belo Brdo (and probably other sites in the Pannonian plain) and/or different methods of fishing were applied. Also, it is possible that certain functional specialization between sites existed, and that Vinča produced large amounts of fish for exchange with other settlements (cf. Vitezović and Antonović 2019).

Differences and similarities in the typological repertoire in ornaments are more difficult to establish. Not only are personal ornaments very infrequent (with the exception of the sites of Vinča-Belo Brdo and Botoš-Živanića Dolja, as mentioned earlier – but they consist mainly of common types made from mollusc shells) in both Starčevo and Vinča assemblages, but some items have unique shapes. We can observe that buckles in the shape of an open bracelet and ring-shaped ornaments are disappearing in the Vinča culture. Possible new Vinča type, items which were probably used as some sort of decorative needles can be singled out. One unique object from Stragari can be mentioned, with the head (proximal part) resembling a bucranion. Applications made from bones or boar tusks, with two or more perforations, perhaps also represent typical Vinča ornament.

## Discussion and conclusion

The acquiring and managing of raw materials changed significantly as the economy changed. Bones from sheep, goats and cattle became the predominant raw material choice in the Neolithic period, showing that domestic animals were fully adopted and accepted in all segments of economy and consumption, and became not only acceptable, but preferable raw materials for most daily tools. The predominant acquisition of shed antlers in both the Starčevo and the Vinča culture reveals the close relations to and knowledge about the surrounding environment.

The Starčevo culture osseous industry shows an interesting mix of preservation of some of the techno-typological traits connected with the Mesolithic tradition and the introduction of the new techno-types, mainly of Near-Eastern origin, but somewhat altered during the process of adoption into the new cultural milieu (cf. Sidéra 1998, Vitezović 2016b). These changes are taken further in the Vinča culture, where we can also note the increased standardization and some innovations that can be considered as a local characteristic. Mesolithic traditions that can be up to a certain extent recognized in the Starčevo osseous industries disappear in the Vinča culture. Also, Near-Eastern influences, already modified in the Starčevo culture, are no longer visible in the Vinča culture. In her analysis of new elements of Near-Eastern origin in the eastern Balkan bone industries, I. Sidéra (1998) noted that the style of production is rapidly changing from one site to another. In the case of the Starčevo culture bone industry, we may note that only a portion of the "package" of Anatolian influences was adopted; furthermore, some of these traits were adopted after having been already partially altered (such as the forms and functions of spatula-spoons). These modifications continue in the Vinča culture. Unlike, for example, the late Neolithic in Bulgaria, where techno-types such as spatula-spoons from large ungulate metapodials, spatula-chisels from caprinae tibiae or antlers sickles continue to be in use (cf. Lang 2005), the Vinča culture displays traits that can be described as more locally specific, and perhaps even more authentic, original and/or autochthonous.

Manufacturing techniques also show innovations connected with alterations in other technologies. The most important change is the adoption and widespread use of ground stone tools for several finalizing steps, burnishing and polishing. An increased quantity of fine- and medium-sized pointed tools (needles, awls), and the introduction of some new subtypes in variants in the Starčevo and even more in the Vinča culture, perhaps point to an increased production in *perishable technologies* – in processing plant fibres, leather and hides. On the other hand, a gradual disappearance of retouching tools reflects changes in chipped stone industry.

The most important difference between the Mesolithic (and earlier, Palaeolithic traditions) and the Neolithic osseous industries in both the early and the late Neolithic is in the cultural attitude towards osseous raw materials. They are no longer used for figural representations or decorations, but the new material, clay, is now preferred for diverse figural presentations and for objects of possible cultic function. In the Mesolithic, decorations may be occasionally found on non-worked skeletal elements or finished and used tools (cf. Radovanović 1996). No bone tools with decorations have been discovered in either the Starčevo or the Vinča culture, and no anthropomorphic or zoomorphic representations were made from osseous raw materials (the only exception being the projectile-shaped object from Donja Branjevina with a zoomorphic head, while the head of the decorative pin from Stragari may have not been deliberately shaped into that zoomoprhic-looking form). However, osseous raw materials were not only widely used for decorations in both cultures (Bačkalov 1979; Vitezović 2012a), but were in fact the preferred raw material for personal ornaments (particularly noticeable at the cemetery at Botoš – cf. Marinković 2010), as in numerous other prehistoric cultures across Europe and the Near East (cf. Taborin 2004).

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## References

Antonović, D. 2003. *Neolitska industrija glačanog kamena u Srbiji.* Beograd: Arheološki institut.

Averbouh, A. 2000. *Technologie de la matière osseuse travaillée et implications palethnologiques.* Thèse de doctorat. Paris: Université de Paris I.

Averbouh, A., Pétillon, J.-M. 2011. Identification of "debitage by fracturation" in reindeer antler: case study of the Badegoulian levels at the Cuzoul de Vers (Lot, France), in: Baron, J., Kufel-Diakowska B. (eds.). *Written in Bones. Studies on technological and social contexts of past faunal skeletal remains.* Wrocław: Uniwersytet Wrocławki, Instytut Archeologii, 41-51.

Bačkalov, A. 1979. *Predmeti od kosti i roga u predneolitu i neolitu Srbije*. Beograd: Savez Arheoloških društava Jugoslavije.

Beldiman, C. 2007. *Industria materiilor dure animale în preistoria României. Resurse naturale, comunităţi umane şi tehnologie din paleoliticul superior până în neoliticul timpuriu*, Studii de Preistorie, Supplementum 2. Bucureşti: Asociaţia Română de Arheologie, Editura Pro Universitaria.

Beldiman, C., Sztancz, D.-M. 2011. Technology of skeletal materials of the Starčevo-Criş Culture in Romania, in: Luca, S. A., Suciu, C. (eds.). *The First Neolithic Sites in Central/South-East European Transect, Vol II: Early Neolithic (Starčevo-Criş) Sites on the Territory of Romania*, BAR Internatioanl series S2188. Oxford: Archaeopress, 57-70.

Bökönyi, S. 1988. Neolithic fauna of Divostin, in: McPherron, A., Srejović, D. (eds.). *Divostin and the Neolithic of central Serbia.* Pittsburgh: University of Pittsburgh, 419-445.

Borić, D. 1996. Social dimensions of mortuary practices in the Neolithic: A case study. *Starinar* 47, 67-83.

Borić, D. 2009. Absolute dating of Metallurgical innovations in the Vinča culture of the Balkans, in: Kienlin, T.L., Roberts, B.W. (eds.). *Metals and Societies*, Studies in honour of Barbara S, Ottaway, Universitätsforschungen zur prähistorischen Archäologie 169. Bonn: Dr. Rudolf Habelt GmbH, 191-245.

Bulatović, J. 2011. Ostaci životinja iz kasnovinčanske jame na nalazištu Vitkovačko Polje (in Cyrillic, English summary: Animal remains from Late Vinča pit on the finding of Vitkovo Field). *Kruševački zbornik* 15, 237-271.

Bulatović, J. 2018. *Arheozoološki aspekti društvenih i kulturnih promena na centralnom Balkanu u petom milenijumu pre nove ere.* Thesis (PhD). Belgrade: Faculty of Philosophy, University of Belgrade.

Camps-Fabrer, H. 1966. *Matière et art mobilier dans la préhistoire nord-africaine et saharienne*, Mémoires du Centre de recherches anthropologiques préhistoriques et ethnographiques. Paris : Arts et métiers graphiques.

Camps-Fabrer, H. 1979. Principes d'une classification de l'industrie osseuse néolithique et de l'âge des métaux dans le Midi méditerranéen, in: Camps-Fabrer, H. (ed.). *Industrie de l'os et bois de cervidé durant le néolithique et âge des métaux*, Première réunion du groupe de travail 3 sur l'industrie de l'os préhistorique. Paris : CNRS, 17-26.

Camps-Fabrer, H. (ed.). 1990. *Fiches typologiques de l'industrie osseuse préhistorique. Cahier III: Poinçons, pointes, poignards, aiguilles*. Aix-en-Provence: Université de Provence.

Camps-Fabrer, H. (ed.). 1991. *Fiches typologiques de l'industrie osseuse préhistorique. Cahier IV. Objets de parure.* Aix-en-Provence: Université de Provence.

Camps-Fabrer, H. (ed.). 1998. *Fiches typologiques de l'industrie osseuse préhistorique. Cahier VIII. Biseaux et tranchants.* Aix-en-Provence: Université de Provence.

Choyke, A. 2010. Not the Plastic of the Past: The significance of worked osseous materials in archaeology, in: Gömöri, J., Kőrösi, A. (eds.). *Csont és bőr. Az állati eredetű nyersanyagok feldolgozásának története, régészete és néprajza/Bone and Leather, History, archaeology and ethnography of crafts utilizing raw materials from animals*. Budapest: Magyar Tudományos Akadémia VEAB Soproni Tudós Társasága, 19-30.

Choyke, A. 2013. Hidden agendas: ancient raw material choice for worked osseous objects in central Europe and beyond, in: Choyke, A., O'Connor, S. (eds.). *From These Bare Bones: Raw Materials and the Study of Worked Osseous Objects*. Oxford: Oxbow, 1-11.

Clason, A. 1982. Padina and Starčevo: Game, Fish and Cattle. *Palaeohistoria* XXII, 141-173.

Clutton-Brock, J. 1984. *Excavations at Grimes Graves, Norfolk, 1972-1976. Fascicule 1: Neolithic antler picks from Grimes Graves, Norfolk, and Durrington Walls, Wiltshire: a biometrical analysis*. London: British Museum Publications Limited.

Cristiani, E. Dimitrijević, V., Vitezović, S. 2016. Fishing with lure hooks at the Late Neolithic site of Vinča – Belo Brdo, Serbia. *Journal of Archaeological Science* 65, 134-147. DOI: http://dx.doi.org/10.1016/j.jas.2015.11.005

Dimitrijević, V., Tripković, B. 2002. New Spondylus findings at Vinča-Belo Brdo 1998-2001 campaigns and the regional approach to problem. *Starinar* n. s. LII, 48-62.

Dimitrijević, V., Tripković, B. 2006. Spondylus and Glycymeris bracelets: trade reflections at Neolithic Vinča-Belo Brdo. *Documenta praehistorica* XXXIII, 237-252.

Dimitrijević, V. 2014. The provenance and use of fossil scaphopod shells at the Late Neolithic/Eneolithic site Vinča-Belo Brdo, Serbia, in: Szabó, K., Dupont, C., Dimitrijević, V., Gómez Gastélum, L., Serrand, N. (eds.). *Archaeomalacology: Shells in the Archaeological Record,* Proceedings of the 11th ICAZ International Conference. Paris – Archaeomalacology Working group, 23-28 August 2010 Paris, France, BAR International Series S2666. Oxford: Archeopress, 33-41.

Filipović, D., Obradović, Đ. 2013. Archaeobotany at Neolithic sites in Serbia: a critical overview of the methods and results, in: Miladinović-Radmilović, N., Vitezović, S. (eds.). *Bioarheologija na Balkanu. Bilans i perspektive. Radovi bioarheološke sekcije Srpskog arheološkog društva*. Beograd-Sremska Mitrovica: Srpsko arheološko društvo and Blago Sirmiuma, 25-55.

Garašanin. M. 1979. Centralnobalkanska zona, in: Benac, A (ed.). *Praistorija jugoslovenskih zemalja II. Neolitsko doba*. Sarajevo: ANU BiH, Centar za balkanološka istraživanja, 79-212.

Georgiev, G. 1967. Beiträge zur Erfoschung des Neolithikums und der Bronzezeit in Südbulgarien. *Archaeologia Austriaca* 42, 90-144.

Greene, K. 2006. Archaeology and technology, in: Bintliff J. (ed.). *A Companion to Archaeology*. Oxford: Blackwell Publishing, 155-173.

Greenfield, H. 1986. *The Palaeoeconomy of the Central Balkans (Serbia). A Zooarchaeological Perspective on the Late Neolithic and the Bronze Age (ca. 4500 – 1000 BC),* BAR International series S304. Oxford: Archaeopress.

Greenfield, H. 2008. The vertebrate fauna from Hajdučka Vodenica in the Danubian Iron Gates: subsistence and taphonomy from the Early Neolithic and Mesolithic, in: Bonsall, C., Boroneanţ, V., Radovanović, I. (eds.). *The Iron Gates in Prehistory: New perspectives,* BAR International Series S1893. Oxford: Archaeopress, 205-226.

Hayden, B. 1998. Practical and prestige technologies: The evolution of material systems. *Journal of archaeological method and theory* 5 (1), 1-55.

Inizan, M.-L., Reduron, M., Roche, H., Tixier, J. 1995. *Technologie de la pierre taillée.* Paris: CNRS.

Isaakidou, V. 2003. Worked and utilized bone and antler: practical and cultural rationales for the selection of raw materials, in: Kotjabopoulou, E., Hamilakis, Y., Halstead, P. (eds.). *Zooarchaeology in Greece.* London: British School at Athens, 233-238.

Kogălniceanu, R., Ana, I., Margarit, M., Simalcsik, A., Dumitrascu, V.M. 2014. A hoard of astragals discovered in the Copper Age settlement at Iepureşti, Giurgiu County, Romania. *Documenta Praehistorica* XLI, 283-304.

Krištofić, V., 2016. Alatke od roga sa nalazišta Jakovo-Kormadin iz zbirke Arheološkog muzeja u Zagrebu (Antler tools from the site of Jakovo-Kormadin from the collection of the Archaeological Museum in Zagreb). *Vjesnik Arheološkog muzeja u* Zagrebu 49 (1), 29-58.

LeDosseur, G. 2010. The Neolithisation in southern Levant: impact of animal herding on the exploitation of bone materials, from reticence to adoption of domestic herds, in: Legrand-Pineau, A., Sidéra, I., Buc, N., David, E., Scheinsohn, V. (eds.). *Ancient and Modern Bone Artefacts from America to Russia. Cultural, technological and functional signature*, BAR International Series S2136. Oxford: Archaeopress, 17-30.

Legrand, A. 2007. *Fabrication et utilisation de l'outillage en matières osseuses du Néolithique de Chypre: Khirokitia et Cap Andreas-Kastros*, BAR International Series S1678. Oxford: Archaeopress.

Lemonnier, P. 1992. *Elements for and anthropology of technology*. Ann Arbor: Museum of Anthropology/University of Michigan.

Leroi-Gourhan, A. 1964. *Le geste et la parole.* Paris: Éditions Albin Michel.

Leroi-Gourhan, A. 1965. Évolution et techniques *1: L'homme et la matière.* Paris: Éditions Albin Michel.

Leroi-Gourhan, A. 1971. Évolution et techniques *2: Milieu et techniques.* Paris: Éditions Albin Michel.

Maigrot, Y. 2003. Étude technologique et fonctionnelle de l'outillage en matières dures animals La station 4 de Chalain (Néolithique final, Jura, France). Thèse de Doctorat. Paris: Université de Paris I.

Makkay, J. 1991. Knochen, Geweih und Eberzahngegenstände. *Communicationes Archaeologiae Hungaricae* 38, 23-58.

Mărgărit, M., Boroneanţ, A. 2017. The Mesolithic osseous industry from Răzvrata (the Iron Gates Region), in: Mărgărit, M., Boroneanţ, A. (eds.). *From hunter-gatherers to farmers. Human adaptations at the end of the Pleistocene and the first part of the Holocene*, Papers in Honour of Clive Bonsall. Târgovişte: Cetatea de Scaun, 81-92.

Marinković, S. 2010. Arheološki materijal sa lokaliteta Živanićeva Dolja iz zbirke Narodnog muzeja u Zrenjaninu – vinčanska kultura, *Rad Muzeja Vojvodine* 52, 21-36.

Marinova, E., Allué, E. 2013. Wild plant resources and land use in the Mesolithic and Early Neolithic south-east Europe: archaeobotanical evidence from the Danube catchment of Bulgaria and Serbia. *Offa* 69/70, Festschrift Helmut Kroll, 467-478.

Miller, H.M.-L. 2007. *Archaeological approaches to technology.* Oxford: Academic Press/Elsevier.

Murray, C. 1979. Les techniques de débitage de métapodes de petits ruminants à Auvernier-Port, in: Camps-Fabrer, H. (ed.). *Industrie de l'os et bois de cervidé durant le néolithique et âge des métaux*, Première réunion du groupe de travail no. 3 sur l'industrie de l'os préhistorique.Paris: CNRS, 27-35.

Nandris, J. 1972. Bos primigenius and the bone spoon. *Bulletin of the Institute of Archaeology, London* 10, 63-82.

Nikolić, D. (ed.) 2008. *Vinča, praistorijska metropola. Istraživanja 1908-2008* (in Cyrillic). Filozofski fakultet. Beograd: Narodni muzej/Muzej grada/Galerija SANU.

Orton, D. 2008. *Beyond Hunting and Herding: Humans, animals, and the political economy of the Vinča period.* Thesis (PhD). Cambridge: Faculty of Archaeology and Anthropology, University of Cambridge.

Özdoğan, M. 2011. Archaeological evidence on the Westward expansion of farming communities from Eastern Anatolia to the Aegean and the Balkans. *Current Anthropology* 52, Supplement 4, 415-430.

Peltier, A. 1986. Étude expérimentale des surfaces osseuses façonnées et utilisées. *Bulletin de la Société Préhistorique Française* 83 (1), 5-7.

Perlès, C. 2004. *The Early Neolithic in Greece: The First Farming Communities in Europe.* Cambridge: Cambridge University Press.

Ramseyer, D. (ed.). 2004. *Matières et techniques. Fiches de la Commission de nomenclature sur l'industrie de l'os préhistorique*, Cahier XI. Paris: CNRS.

Radovanović, I. 1996. *The Iron Gates Mesolithic*. Ann Arbor: International Monographs in Prehistory.

Russell, N. 1990. The Bone Tools, in: Tringham, R., Krstić, D. (eds.). *Selevac. A Neolithic village in Yugoslavia*. Los Angeles: UCLA, 521-548.

Russell, N. 2006. Çatalhöyük worked bone, in: Hodder I. (ed.), Çatalhöyük perspectives: reports from the 1995-99 seasons. London: British institute at Ankara, 339-367.

Russell, N. 2012. Worked bone from the BACH area, in: Tringham, R.E., Stevanović, M. (eds.). *Last House on the Hill: BACH Area Reports from Çatalhöyük, Turkey.* Los Angeles: Cotsen Institute of Archaeology Press, 347-359.

Schibler, J. 2007. Knochen, Zahn, Geweih und Horn: Werkstoffe der prähistorischen und historischen Epochen. *Nova Acta Leopoldina Neue Folge* 94, 45-63.

Schibler, J. 2013. Bone and antler artefacts in wetland sites, in: Menotti, F., O'Sullivan, A. (eds.). *The Oxford handbook of Wetland archaeology*. Oxford: Oxford University Press, 339-355.

Sellet, F. 1993 Chaîne opératoire: the concept and its applications. *Lithic technology* 18 (1-2), 106-112.

Semenov, S. A. 1976: *Prehistoric technology. An experimental study of the oldest tools and artefacts from traces of manufacture and wear*. Wiltshire: Barnes and Noble.

Sidéra, I. 1998. Nouveaux éléments d'origine Proche-Orientale dans le Néolithique ancien balkanique: analyse de l'industrie osseuse, in: Otte, M. (ed.). *Préhistoire d'Anatolie. Genèse de deux mondes.* Liège: Université de Liège, Service de Préhistoire, 215-239.

Sidéra, I. 2005. Technical data, typological data: a comparison, in: Luik, H., Choyke, A.M., Batey ja Lembi Lõugas, C.E. (eds.). *From Hooves to Horns, from Mollusc to Mammoth – Manufacture and Use of Bone Artefacts from Prehistoric Times to the Present,* Proceedings of the 4th Meeting of the ICAZ Worked Bone Research Group, 26 – 31 August 2003 Tallin, Muinasaja teadus 15. Tallinn: Cultural Endowment of Estonia, 81-90.

Sidéra. I. 2011. Fabriquer des cuillers en os: L'exemple de Kovacevo. *Studia praehistorica* 14, 55-62.

Srejović, D. (ed.). 1989. *The Neolithic of Serbia. Archaeological research 1948-1988.* Belgrade: The University of Belgrade, Faculty of Philosophy, Centre for Archaeological Research.

Srejović, D., Jovanović, B., 1959. Оруђе и оружје од кости и накит из Винче (Ustensiles et armes en os et parures de Vinča). *Starinar* IX-X, 181-190.

Tasić, N., Marić, M.M., Penezić, K., Filipović, D., Borojević, K., Russell, N., Reimer, P.J., Barclay, A., Bayliss, A., Boric, D., Gaydarska, B., Whittle, A. 2015. The end of the affair: formal chronological modelling for the top of the Neolithic tell of Vinča-Belo Brdo. *Antiquity* 89, 1064-1082. DOI: http://dx.doi.org/10.15184/aqy.2015.101

Tóth, Zs. 2012. Bone, antler and tusk tools of the Early Neolithic Körös culture, in: Anders, A., Siklósi, Z. (eds.). *Central/South-East European Transect, volume III: The Körös Culture in Eastern Hungary*, BAR International Series S2334. Oxford: Archaeopress, 171-178.

Vitezović, S. 2007. *Koštana industrija u neolitu srednjeg Pomoravlja*. Thesis (Mphil). Belgrade: Faculty of Philosophy, University of Belgrade.

Vitezović, S. 2009. Коштана индустрија са локалитета Страгари-Шљивик (Bone industry from the site Stragari-Šljivik). *Kruševački zbornik* 14, 135-160.

Vitezović, S. 2010. Неолитска коштана индустрија са локалитета Кормадин у Јакову – ископавања 2008. године (The Neolithic Bone industry fof Kormadin in Jakovo – the excavations of 2008). *Godišnjak Muzeja grada Beograda* LVII, 43-66.

Vitezović, S. 2011a. Студије технологије у праисторијској археологији (Studies of technology in prehistoric archaeology). *Zbornik Matice srpske za društvene nauke* 137 (4), 465-480.

Vitezović, S. 2011b. The Mesolithic bone industry from Kula, eastern Serbia. *Before Farming* 3 (2), 1-21. DOI: http://dx.doi.org/10.3828/bfarm.2011.3.2

Vitezović, S. 2011c. *Koštana industrija u starijem i srednjem neolitu centralnog Balkana.* Thesis (PhD). Belgrade: Faculty of Philosophy, University of Belgrade.

Vitezović, S. 2011d. Early and Middle Neolithic bone industry in northern Serbia. *Acta Archaeologica Carpathica* XLVI, 19-60.

Vitezović, S. 2011e. Коштана индустрија са локалитета Витково-Трифуновићи (ископавања 2001. године) (Bone industry from the site Vitkovo-Trifunovići (excavations season 2001)). *Kruševački zbornik* 15, 351-374.

Vitezović, S. 2011f. Коштани предмети са локалитета Страгари-Шљивик (из Музејске збирке Народног универзитета у Трстенику) (Bone objects from the site Stragari-Šljivik (from the Museum collection of the Adult education centre in Trstenik)). *Kruševački zbornik* 15, 407-421.

Vitezović, S. 2012a. The White Beauty – Starčevo culture jewellery. *Documenta Praehistorica* 39, 91-203. DOI: http://dx.doi.org/10.4312/dp.39.15

Vitezović, S. 2012b. Коштани пројектили са локалитета Старчево-Град (Osseous projectile points from the site Starčevo-Grad). *Glasnik Srpskog arheološkog društva* 28, 233-248.

Vitezović, S. 2013a. From artefacts to behaviour: technological analyses in prehistory. *Anthropologie, International Journal of Human Diversity and Evolution* 51 (2), 175-194.

Vitezović, S. 2013b. Bone industry from Starčevo-Grad. Technology and typology, in: Lang, F. (ed.). *The Sound of Bones*, Schriften zur Archäologie und Archäometrie an der Paris Lodron-Universität Salzburg 5. Salzburg: Archæoplus, 263-276.

Vitezović, S. 2013c. The prehistoric bone tool assemblage from Grivac (central Serbia). *Glasnik Srpskog arheološkog društva* 29, 209-232.

Vitezović, S. 2013d. Винчанска коштана индустрија са Дивостина (The Vinča Culture bone industry from Divostin). *Zbornik Narodnog muzeja* XXI-1, 109-127.

Vitezović, S. 2013e. Bone manufacturing in the Neolithic: the problems of reconstructing the chaîne opératoire and identifying workshops. *Archeometriai Műhely / Archaeometry Workshop* 3, 201-208.

Vitezović, S. 2014. Antlers as raw material in the Starčevo culture, in: Vitezović S. and Antonović D. (eds.). *Archaeotechnology: studying technology from prehistory to the Middle Ages*. Beograd: Srpsko arheološko društvo, 151-176.

Vitezović, S: 2016a. Metodologija proučavanja praistorijskih koštanih industrija. Beograd: Srpsko arheološko društvo.

Vitezović, S. 2016b. Neolithization of technology: innovation and tradition in the Starčevo culture osseous industry. *Documenta Praehistorica* 43. DOI: http://dx.doi.org/10.4312/dp.43.5

Vitezović, S. 2016c. The sea within: the use of mollusc shells as ornaments in the Central Balkans Neolithic, in: Preoteasa, C., Nicola, C.-D. (ed.). *Cucuteni Culture within the European Neo-Eneolithic Context*, Proceedings of the International Colloquium «Cucuteni – 130, 15-17 October 2014 Piatra-Neamţ, Romania, In Memoriam dr. Dan Monah, In Memoriam dr. Gheorghe Dumitroaia. Piatra-Neamţ: Editura "Constantin Matasă", 237-256.

Vitezović, S. 2016d. Bos and the bone spoon revisited: Spatula-spoons in the Starčevo culture, in: Bacvarov, K., Gleser, R. (eds.). *South-eastSouth-east Europe and Anatolia in prehistory*, Essays in honor of Vassil Nikolov on his 65th anniversary, Universitätsforschungen zur prähistorischen Archäologie Band 293, Aus der

Abteilung für Ur- und Frühgeschichtliche Archäologie der Universität Münster. Bonn: Verlag Dr. Rudolf Habelt GmbH, 189-196.

Vitezović, S. 2017a. The Early Neolithic osseous industry in the Iron Gates Region, in: Mărgărit, M., Boroneanț, A. (eds.). *From hunter-gatherers to farmers. Human adaptations at the end of the Pleistocene and the first part of the Holocene*, Papers in Honour of Clive Bonsall. Târgovişte: Cetatea de Scaun, 149-165.

Vitezović, S. 2017b. Antler exploitation and management in the Vinča culture: An overview of evidence from Serbia. *Quaternary International,* 450 (2), 209-223. DOI: https://doi.org/10.1016/j.quaint.2016.12.048

Vitezović, S. 2018a. Fishing and hunting gear from osseous raw materials in the Early Neolithic from Serbia. *Quaternary International* 472 (A), 38-48. DOI: https://doi.org/10.1016/j.quaint.2018.01.021

Vitezović, S. 2018b. Retouching tools from the post-Palaeolithic period in Southeast Europe, in: Hutson, J.M., García-Moreno, A., Noack, E.S., Turner, E., Villaluenga A., Gaudzinski-Windheuser, S. (eds.). *The Origins of Bone Tool Technologies*. Mainz: Verlag des Römisch-Germanischen Zentralmuseums Mainz, 297-315. https://retouchingthepalaeolithic.wordpress.com/online-proceedings/

Vitezović, S. (in press a). The bone industry at Belovode, in: Radivojević, M., Roberts, B.W., Kuzmanović-Cvetković, J., Marić, M., Šljivar, D., Rehren, T. (eds.). *The Rise of Metallurgy in Eurasia: The Archaeology of Early Metallurgy and Society in the Central Balkans.* London: UCL Press.

Vitezović, S. (in press b). The bone industry at Pločnik, in: Radivojević, M., Roberts, B.W., Kuzmanović-Cvetković, J., Marić, M., Šljivar, D., Rehren, T. (eds.). *The Rise of Metallurgy in Eurasia: The Archaeology of Early Metallurgy and Society in the Central Balkans.* London: UCL Press.

Vitezović, S., Bulatović, J., 2013. Managing raw materials in Vinča culture: A case study of osseous raw materials from Vitkovo. *Documenta praehistorica* 40, 279-289.

Vuković, J. 2011. Late Neolithic pottery standardization: Application of statistical analyses. *Starinar* 61, 81-100.

Vitezović, S., Antonović, D. 2019. Functional differentiation and possible regional specialisation of the Vinča culture settlements: Viewpoint from osseous and lithic industries. Quaternary International 2019, in press: https://doi.org/10.1016/j.quaint.2018.12.029

Vuković, J. Vitezović, S., Milanović, D. 2016. Pavlovac-Kovačke Njive – Neolithic layer, in: Perić, S., Bulatović, A. (eds.). *Archaeological investigations along the route of highway E-75 (2011-2014)*. Belgrade: Institute of Archaeology, 167-204.

Whittle, A. Bartosiewicz, L., Boric, D., Pettitt, P. 2002. In the beginning: New radiocarbon dates for the Early Neolithic in northern Serbia and South-East Hungary, *Antaeus* 25, 63-117.

Zidarov, P. 2014. Knochen- und Geweihgeräte: Traditionen und Praktiken im Alltag der Einwohner von Ovčarovo-Gorata, in: Krauss, R. (ed.). *Ovcarovo-Gorata. Eine frühneolithische Siedlung in Nordostbulgarien.* Bonn: Dr. Rudolf Habelt GmbH, 250-270.

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# Early wheelmade pottery in the Carpathian Basin

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## Abstract

This paper discusses the appearance of early wheelmade pottery in the Carpathian Basin, considering thin-section and geochemical analyses of ceramic assemblages of two recently discovered Iron Age settlement remains in Hungary (Nagytarcsa and Nyírparasznya). From the ceramic material of the settlements, a selection of 99 sherds, previously examined by the traditional typological methods of archaeology, was analysed by thin-section petrography. Eight sherds from Nagytarcsa were also analysed by LA-ICP-MS analyses to identify possible connections and variations between the raw materials and tempers in the different ceramic types. The results suggest that fast-wheeled vessels were locally made, and their raw materials show similarities to the hand-formed wares. The technological characteristics of the analysed ceramics suggest the presence of advanced ceramic technology at both sites. Wheelmade fine wares are characterised by more labour input in terms of raw material preparation, surface treatment and firing than hand-formed household products. Furthermore, the technological characterisation of fast-wheeled pottery revealed the presence of previously unobserved combined techniques in the examined region and period, which argues for a more complex process for the adaptation of the potter's wheel.

*Keywords: Vekerzug culture, wheelmade pottery, wheel fashioning, provenance, petrography*

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## Introduction

Early wheelmade pottery occurred in different proportions in the North Pontic steppe and forested steppe regions inspired by Mediterranean influences (Fig. 1). The east European forested steppe is a temperate-climate ecotone and habitat type composed of grasslands interspersed with areas of woodlands or forests. Stretching from the

Ural Mountains to the Carpathian Mountains, the forested steppe belt forms a transition between Central European mixed forests to the north and the Pontic-Caspian steppe to the south. This vast area became part of the Scythian world, as many areas were inhabited by nomadic forest-steppe populations in the early 1st millennium BCE. However, the European forested-steppe belt continued to be populated by sedentary agrarian communities, which were influenced by Scythian culture (Melyukova 1995).

Earliest examples of wheelmade pottery have been documented in the north-western part of the North-Pontic region, within the ceramic assemblage of the West-Podolian Scythian group (located in the Upper Dniester region, Ukraine): 12 wheelmade vessels were unearthed from tumuli burials and 5 (or 6?) are known from settlement contexts. On the southern periphery of this region closer to the River Prut than the Dniester (defined by some researchers as the Trinca cultural group, Moldova), one wheelmade vessel was found in a tumulus and two others were reported from two settlements. Another early wheelmade vessel was discovered in an Iron Age burial mound, situated close to the Carpathian Mountains within the territory of the so-called Podolian-Moldavian group. Moreover, five early wheelmade vessels have been found in contexts in the region of the middle course of the Seret and Prut rivers. This means that in the north-east and east of the Carpathians, in total 14 largely fragmented wheelmade vessels were from burials and 12 (or 13?) were from settlements. The number of wheelmade vessels was similarly low in the region lying south of the Carpathian Mountains (in the territory of Romania); all these wares can be dated to the 6th and 5th centuries BCE (Kashuba *et al.* 2010, Fig. 1, Tab. 1). The distributions of wheelmade jars, jugs and bowls seemingly display a dense pattern north of the Carpathian Mountains, in the upper part of the Wisłoka and San rivers (tributaries of the River Vistula, Poland), however in general only one or two of such wares are reported from 20 sites (4 cemeteries and 16 settlements) in the region. The earliest examples dated to the 6th century BCE and their number gradually increased from the 5th- 4th centuries BCE (Czopek 2012, 300-302, Fig. 4). Crossing the high mountains, we reach the eastern periphery of the Carpathian Basin (the Subcarpathian region) where 26 fragmented and two whole wheelmade early Iron Age vessels were uncovered. These belong to the Kushtanovice group and date from the 6th – 5th centuries to the 4th century BCE. It is important to mention that these finds were mainly found at the early Iron Age settlement near Mali Hejevcii (Uzhorod district, Ukraine), while wheelmade vessels do not appear within the grave goods in this region until the late Iron Age (Kobal 2014, 65, 75). Until now only a single early Iron Age wheelmade jug was reported from Transylvania (Romania), where the ceramic material of the so-called Ciumbrud group contains solely handformed biconical pots (generally decorated with four knobs), bowls with inverted rims and biconical mugs (Moscalu 1983). In contrast, wheelmade vessels are ubiquitous on the Great Hungarian Plain (east Hungary) and on the northern part of the Little Hungarian Plain (west Hungary and southwest Slovakia) during the early Iron Age. Although their number varies greatly from site to site, wheelmade jugs/jars, biconical pots and bowls with inverted rim were the most common finds at Vekerzug culture settlements and cemeteries. Usually similar wheelmade vessels from the neighbouring Transdanubian (Hungary) and Transcarpathian (Ukraine) regions are interpreted as the material evidence of Vekerzug influences (Chochorowski 1985, 48-49; 1996, 116; Kemenczei 2009, 102-105; Czifra *et al.* 2011, 237).

Based on associated finds, such as Scythian type horse harnesses, weapons, jewellery, Greek amphorae and painted wares, wheelmade pottery appeared already in the second half of the 7th century BCE in the North Pontic region (Smirnova 1999, 54; Levitski and Kashuba 2009, 96-98; Kashuba *et al.* 2012, 103). It occurred somewhat later in the Carpathian Basin within the ceramic assemblage of the Vekerzug culture. Several papers were dedicated to the question of the appearance of wheelmade Vekerzug pottery (Dušek, M. 1966; 1974; Lengyel

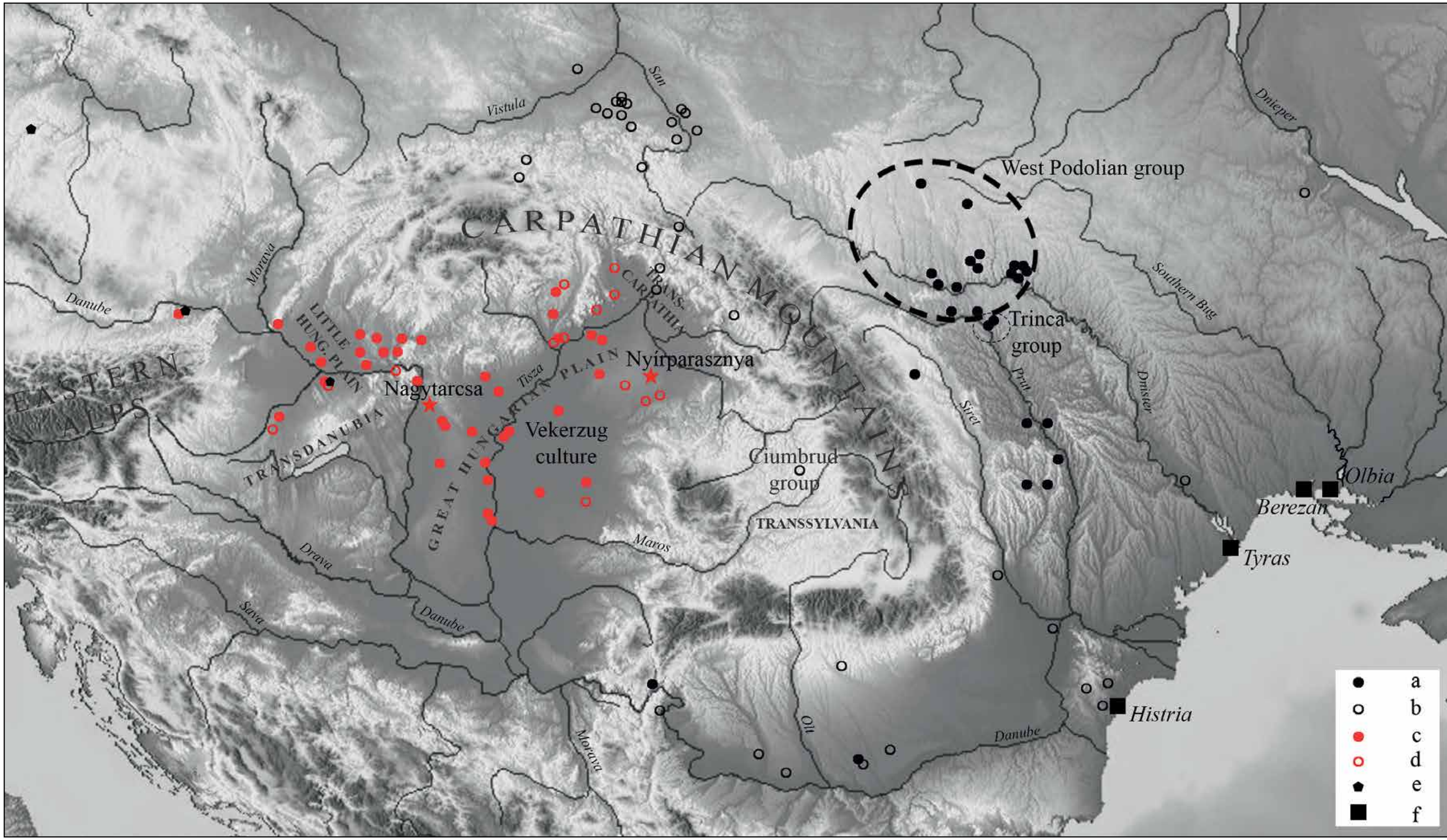


*Figure 1. Distribution of early wheelmade pottery in the Carpathian Basin and adjacent regions (after Czopek 2012, Kashuba et al. 2012 and Tappert 2015 with modifications. The most important Vekerzug sites are mapped out of the known 1073 sites): a) wheelmade pottery (7th-6th centuries BCE); b) wheelmade pottery (6th-5th centuries BCE); c) wheelmade Vekerzug pottery (7th-6th centuries BCE); d) wheelmade Vekerzug pottery (5th century BCE); e) Early La Tène wheelmade pottery; f) Greek colonies (red stars indicate sites discussed in this paper in details).*

1964; Romsauer 1991; Chochorowski 1996). However, the debate remains based on typological grounds with very limited interdisciplinary analysis (Dušek, S. 1979; Czifra *et al.* 2011) and seeks a wider multidisciplinary approach.

## Archaeological background

During the transitional period of the late Bronze and early Iron Ages (Ha B-C phases) significant changes occurred in the Carpathian Basin, which unsettled the development of local cultures and had an impact on their cultural orientation and subsistence strategies (Patek 1993, 140-143; Kemenczei 2005; Chapman *et al.* 2009, 180-181; Metzner-Nebelsick 2002; 2010, 142-143). As elsewhere in the European steppe, according to the accepted model, pastoralism became the main subsistence mode with individuals and societies adapted to a more mobile way of life (Melyukova 1995). Archaeological record suggests radical changes in the eastern part of the Carpathian Basin, where, for example, fortified hilltop settlements – typical of the late 2nd millennium BCE – seemingly almost all disappeared together along with previously flourishing local bronze industries, and the number of sites reduced drastically. At the same time, new types of artefacts (Ponto-Caucasian type weapons, horse harnesses and jewels) appeared in the Carpathian Basin (Chochorowski 1993; Patek 1993; Metzner-Nebelsick 2002; Kemenczei 2005); a new burial rite (inhumation, which is very often in contract position) was also introduced primarily into the southern foreground of the North Hungarian Mountains and at the confluence of Maros and Tisza rivers in Hungary (Patek 1993; Romsauer 1999). The Carpathian Basin was divided into two major cultural-geographical units, with the River Danube forming the borderline. In the broader East Alpine region (present-day Transdanubia and Slavonia), these changes had less effect (Patek 1993; Kemenczei 2005; Metzner-Nebelsick 2002). While the eastern territories (Great Hungarian Plain, the area of the North Hungarian Mountains, Transcarpathia and Transylvania) were gradually involved in complex mutual interactions with the steppe world, which finally resulted in the emergence of Scythian influenced groups in the 7th century BCE (Chochorowski 1985, 149-152; 1998, 473-481; Kemenczei 2009, 111-114). One of these Iron Age groups is the Vekerzug culture (also known as Alföld group), which played an important role in the diffusion of eastern elements primarily towards the Hallstatt culture in the broader East Alpine region. Traces of the Vekerzug culture are documented in the middle and northern parts of the Great Hungarian Plain, reaching the Little Hungarian Plain and the North Hungarian Mountains, although the independent development of the Vekerzug culture was interrupted by the Celtic expansion in the 4th century BCE (Jerem 2003, 192-193; Kemenczei 2009, 113-114; Szabó 2006, 102), "Scythian" type artefacts from La Tène period cemeteries and settlements suggest that the descendants of the Scythians in the Great Hungarian Plain survived and became an important component of eastern Celtic communities (Szabó 2006, 102; 2007, 329-332).

Wheelmade pottery is one of the most intriguing features of the Vekerzug culture. It is important to mention that early wheelmade vessels were widespread in the ceramic assemblage of the Vekerzug culture, while in other regions of the Carpathian Basin and adjacent areas wheelmade vessels were rare exceptions at this time (Moscalu 1983, 159; Kemenczei 2009, 104; Czopek 2012, 304; Kobal 2014, 74). The appearance of early wheelmade pottery in the Carpathian Basin was typologically defined on the basis of grave finds, such as weapons, bronze mirrors, bronze, electrum spiral rings and a certain type of horse gears, dating to the first half of the 6th century BCE (Romsauer 1991, 365; Chochorowski 1996, 131, 134; 1998, 483) and later around 600 BCE (Patay and B. Kiss 2002, 130-131).

Initially, the origin of wheelmade Vekerzug pottery was believed to be connected to the growing influence of the La Tène culture and the presence of Celts in the

Carpathian Basin (Bottyán 1955, 18). This opinion changed due to the observations in the eponymous cemetery at Szentes – Vekerzug (Párducz 1955, 15), and in light of the chronology of grave 462 of Tápiószele (Lengyel 1964, 31), attention turned to the North Pontic Greek colonies as the origin of wheelmade Vekerzug pottery.

Two hypotheses previously postulated on the origin of Vekerzug culture's wheelmade pottery: exogenous (imported mainly from north Pontic Greek colonies) and indigenous (emphasising local production ultimately inspired by Greek colonies such as Histria, Olbia and Tyras). Local production was suggested based on the relatively large number of Vekerzug type wheelmade vessels (generally 25-35 % in cemeteries, which could occasionally reach 50 % as in Szentes-Vekerzug, Dušek, M. 1966, 37; 1974, 387; Párducz 1974, 326-327; Moscalu 1983, 358). In spite of the generally accepted opinion, that wheelmade pottery has a Greek origin, reinforced by the appearance of certain vessels *e.g.* an amphora-like vessel from Szentes-Vekerzug and a kylix from Tiszaszőlős (Párducz 1955, Fig. 28:4; Cseh 2006, Fig. 8:4), there is no clear evidence for direct contact between the Greek world and the Carpathian Basin (Szilágyi 1965; Szilágyi and Szabó 1976). Therefore, the distribution of this pottery manufacturing technique is assumed to be mediated by the Thracians (Dušek, M. 1966, 58-59; 1974, 406; Chochorowski 1985, 134) or most probably by communities from the forested steppe zone (Romsauer 1991, 359, 365-366; Chochorowski 1996, 124, 129, 135). The adaptation of wheel techniques in the Vekerzug culture was associated with a certain level of specialization using complex crafting mechanisms, furthermore with the possible development of pottery workshops (Lengyel 1964, 27; Párducz 1973, 50-51; Dušek, S. 1979, 126, 136). However, this hypothesis has never been explicitly analysed.

The ceramic assemblage of two recently excavated Scythian period settlements in Hungary provides a good opportunity to analyse the provenance and technology of wheelmade vessels in detail and to assess whether the technological characteristics postulate the former existence of specialised workshop(s), as fast-wheeled wares required distinctive technological knowledge.

## The analysed archaeological sites

The two archaeological sites lie in opposite regions of the Vekerzug culture's distribution area. Nagytarcsa is situated in the north-central part of Hungary, some 20 kilometres from Budapest, on a slightly elevated area along the Szilas Stream (Fig. 1). During a rescue excavation (prior to a motorway construction) 19 Iron Age settlement features were discovered at Nagytarcsa in 2007 (Czifra *et al.* 2017).

According to archaeological observations, the settlement of Nagytarcsa has a scattered structure characteristic of the Vekerzug culture, consisting of semi-subterranean structures, oval and circular pits and a fireplace. Unfortunately, only 304 ceramic fragments were found in the settlement features at Nagytarcsa with more than half of them (154 sherds) being undiagnostic hand-formed body fragments. And therefore have little archaeological information. The rest of the ceramics belong to the main vessel types of the Vekerzug culture, such as to biconical vessels, cups with high swinging handles, bowls with inverted rims and squat(barrel)-shaped pots. Apart from the squat-shaped pots that were all hand-formed, other vessel types show hand-formed and wheeled (fast-wheeled or combined technique) versions. Wheelmade fragments represent 8.55 percent (26 pcs) of the total 304 fragments, moreover 73 percent of them are associated with biconical mugs and jars (Fig. 2).

In addition to common Vekerzug types, several Hallstatt type fragments were identified, which are generally characterised by slightly different vessel forms and decorations, more elaborated surface treatment and occasionally graphite burnished surfaces (Kreiter *et al.* 2013, 480-481, Fig. 3/C:1-5; Czifra *et al.* 2017, 267-268, Fig. 10:5, Fig. 15:11-12, Fig. 16:12 and 15). On the basis of diagnostic pottery types (especially the

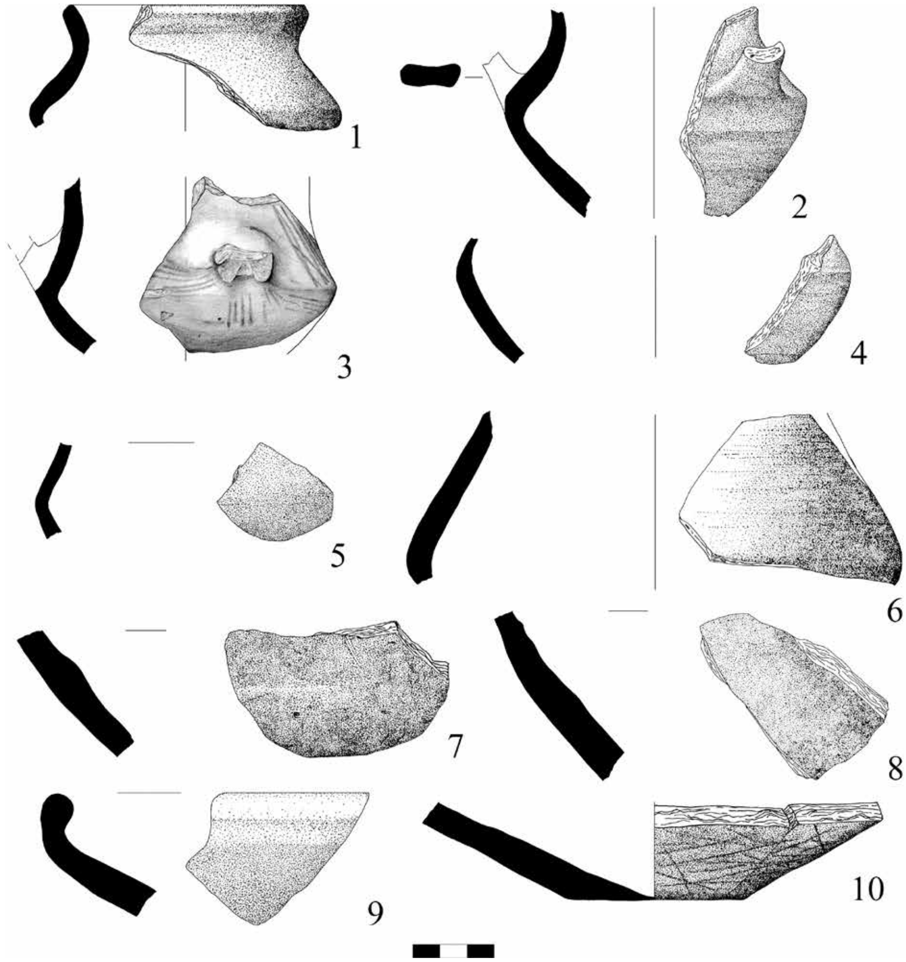


*Figure 2. A selection of characteristic wheeled vessels from Nagytarcsa (1. Sample 1.26213.583.8; 2. Sample 1.26213.581.7; 3. Sample 1.26213.774.9; 4. Sample 1.26213.766.2; 5. Sample 1.26213.583.21; 6. Sample 1.26213.26.3; 7. Sample 1.26213.441.22; 8. Sample 1.26213.718.4; 9. Sample 1.26213.718.1; 10. Sample 1.26213.26.77-78.) Samples 3-4, 9-10 are fast-wheeled, samples 1-2, 6, 8 are either fast-wheeled or made with the combined technique and samples 5, 7 were made with the combined technique.*

Hallstatt ones) and radiocarbon dates, the Iron Age settlement at Nagytarcsa can be dated to the Ha D2-D3 periods (second half of the 6$^{th}$ and first half of the 5$^{th}$ century BCE) (Czifra *et al.* 2011, 236; Kreiter *et al.* 2013, 480; Czifra *et al.* 2017, 270-271, Fig. 19).

Our second archaeological site is located on the outskirts of Nyírparasznya, in the specific, sandy north-eastern sub-region of the Great Hungarian Plain called Nyírség (Fig. 1). Between 2009 and 2011, the site was discovered and excavated in several phases prior to the construction of the M3 Motorway (Czifra 2016).

The final size of the excavated area was 18,444 $m^2$, which yielded 144 features dating to the Scythian period. This settlement had a scattered structure, consisting of semi-subterranean houses, storage and rubbish pits and wells. The presence of large and medium-sized circular structures with multiple postholes around the perimeter is a rare phenomenon in the Vekerzug culture (Czifra 2016, 97-99). The basic pottery sequence is very similar to the ceramic assemblage of Nagytarcsa and contains mostly hand-formed vessel types, such as squat (or barrel)-shaped and biconical pots and bowls with inverted rims. Wheelmade vessels represent 8.1 percent (310 pcs) of the 3815 ceramic fragments (Fig. 3).

Fragments of mugs and jars belong to the most numerous group within wheelmade vessels, while only 14 sherds can be defined as bowls. Besides the common forms, several archaic vessel types were identified, such as bowls with everted rims, bowls decorated with two or four symmetrical knobs on their rims and cups with rooster comb-shaped handles. This sheds further light on the relationship between late Bronze Age and Iron Age communities in the examined geographical area (Czifra *et al.* 2015, 77; Czifra 2016, 99-101). The site can roughly be dated to the same interval as Nagytarcsa, thus to the Ha D2-3 periods (Czifra *et al.* 2015, 72-73; Czifra 2016, 102)


*Figure 3. Diagnostic fast-wheeled vessels from Nyírparasznya (1. Sample 1.34849.19.9; 2. Sample 1.34849.24.13; 3. Sample 1.34849.76.3; 4. Sample 1.34849.113.7; 5. Sample 1.34849.23.19; 6. Sample 1.34849.106.3; 7. Sample 1.34849.147.18; 8. Sample 1.34849.60.12; 9. Sample 1.34849.113.8). Samples 1-3 are fast-wheeled, samples 4-6 and 8-9 are made with the combined technique.*

## Petrographic and LA-ICP-MS analyses

Forty-four samples were selected from Nagytarcsa for petrographic analysis, which represent the most common vessel types namely jars (4 pcs), bowls (15 pcs), cups (2 pcs), mugs (5 pcs), biconical pots (12 pcs) and squat-shaped pots (6). Of these, eight samples such as jars (2 pcs), biconical pots (2 pcs), mugs (3 pcs) and a bowl with inverted rim (1 pc) are considered to be made by the fast wheel, while two mugs were made with a combined technique using wheel fashioning in the final stage of production (hand-formed and refined on a rotary device). The other samples were hand-formed.

Macroscopic and microscopic features on the sherds revealed production techniques. Unfortunately no complete vessels were available to assess all surface features for fast-wheeled vessels as described by Courty and Roux (1995, 17-18), nevertheless several characteristic surface features could be observed aiding the identification of vessel building techniques. Vessels made on the fast wheel show striations on both the exterior and interior and slightly undulating ridges on the interior (Fig. 4). The wall thickness of these sherds is also regular. The analysed bases show concentric striations on their exterior (underside). The fabrics of fast-wheeled vessels also show some orientation of inclusions in thin sections because of the applied pressure on the vessel wall (Fig. 10).

Vessels made with the combined technique show similar features to the fast wheeled ones, (Figs. 5: 1-2, 4; Figs. 6: 2-3) but these sherds also exhibit the characteristics of slab building (analysed on the basis of Roux and Courty 1998): vessels broke along almost straight horizontal lines where the slabs were joined together. The side and/or cross section of the fragments also show horizontal cracks indicating joints of slabs (Fig. 5: 4; Fig. 6: 4). In other cases slabs were bonded together diagonally (overlapped each other), this practice made the vessels stronger since it allowed a better cohesion between the building units.

The majority of tableware and almost all the storage vessels are hand-formed in the Vekerzug culture (Chochorowski 1985). Detailed technological characterization of the hand-formed Vekerzug vessels is still pending. These wares were made from local raw materials with the clay usually tempered with sand, gravel and grog. Occasionally, the size of the tempering material reached even 1 cm. In addition to coil building techniques, slab building was also observed in Vekerzug household wares (Czifra *et al.* 2017, 277-278). While the exterior surface of the bowls and finer biconical pots are smoothed and burnished (Fig. 7: 1-2), there is no trace of such treatment on squat- and flowerpot-shaped vessels (Fig. 7: 3-4). Moreover, it seems that occasionally potters intentionally roughened vessel surfaces (Fig. 7: 4). According to the XRD analysis, rude hand-formed Vekerzug pots were fired at a relatively low temperature (<650º), while finer hand-formed vessels (*e.g.* bowls) were fired at higher temperatures (800-900º) (Czifra *et al.* 2011, 246; 2017, 281).

Fifty-five samples were selected from Nyírparasznya representing the most common vessel types (bowls (10 pcs), biconical mugs (9 pcs), biconical pots (2 pcs), bowls with “spiked” rims (3 pcs), pots (4 pcs), lid (1 pc), suspendable vessel (1 pc), barrel-shaped pots (15 pcs), jar (1 pc), mug (1 pc), strainer (1 pc), cups with rooster comb-shaped handles (2 pcs), flower pot shaped vessels (2 pcs) and undiagnostic fast-wheeled vessels (3 pcs)). Of these, 10 samples from biconical mugs (7 pcs), a jar (1 pc) and undiagnostic vessels (2 pcs) were wheelmade with the combined technique according to the criteria described above. The remaining samples were hand-formed.

Thin section analysis was applied to examine the similarities and differences between raw materials, fabric preparations, and tempering practices of fast-wheeled and hand-formed vessels. By means of petrographic analysis, five fabric groups could be distinguished for Nagytarcsa according to their most characteristic non-plastic inclusions; this is, together with estimated firing temperatures, discussed in details elsewhere (Kreiter *et al.* 2013, 481-482; Czifra *et al.* 2017, 272-277). Vessels made by the fast wheel technique all belong to one fabric group (Fabric 1; Kreiter *et al.* 2013, 481). However, this fabric was not exclusive for fast-wheeled wares but it can also be observed among hand-formed vessels (Figs. 8: 1-2) such as bowls (Inventory Nos. 1.26213.26.8, 1.26213.26.23, 1.26213.26.64-65, 1.26213.67-68, 1.26213.718.1, 1.26213.774.1), cups (1.26213.583.7, 1.26213.583.9), a mug (1.26213.581.7) and a wheel-fashioned mug (1.26213.583.21).

The main characteristic of Fabric 1 is that the vessels were not tempered, the very fine-grained (< 0.1 mm) raw materials probably occurred naturally. Petrographic similarities between fast-wheeled and hand formed vessels, and vessels made by combined techniques suggest that fast-wheeled vessels were locally made (see for details Czifra *et al.* 2011, 243-246; Kreiter *et al.* 2013, 481-482; Czifra *et al.* 2017, 272-277).

In the case of the Nagytarcsa assemblage, the Laser Ablation Inductively Coupled Plasma Mass Spectrometric (LA-ICP-MS) analysis supplemented petrographic analysis in order to compare the main and trace element composition of vessels (Figs. 9: 1-5).

Based on the compositions and fabric groupings of sherds according to the petrographic analysis, eight samples (Inventory Nos. 1.26213.26.70, 1.26213.575.10, 1.26213.583.9, 1.26213.718.4, 1.26213.765.1, 1.26213.765.5, 1.26213.774.1, 1.26213.774.5)

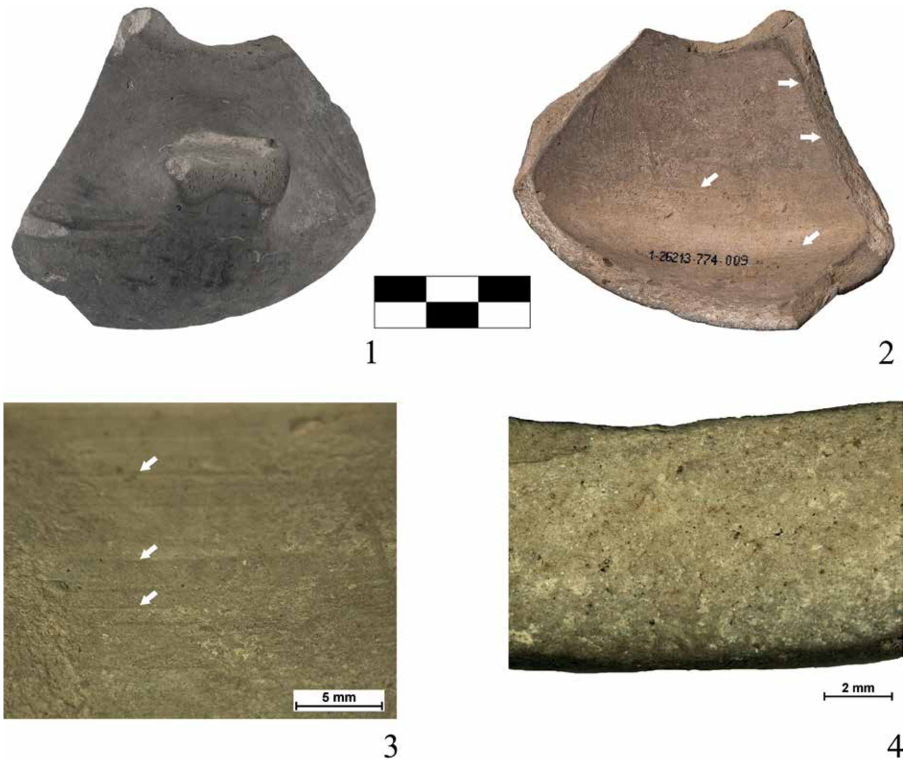


*Figure 4. Fragment of a fast-wheeled mug from Nagytarcsa: diagnostic signs of the use of rotary kinetic energy (sample 1.26213.718.1.).*

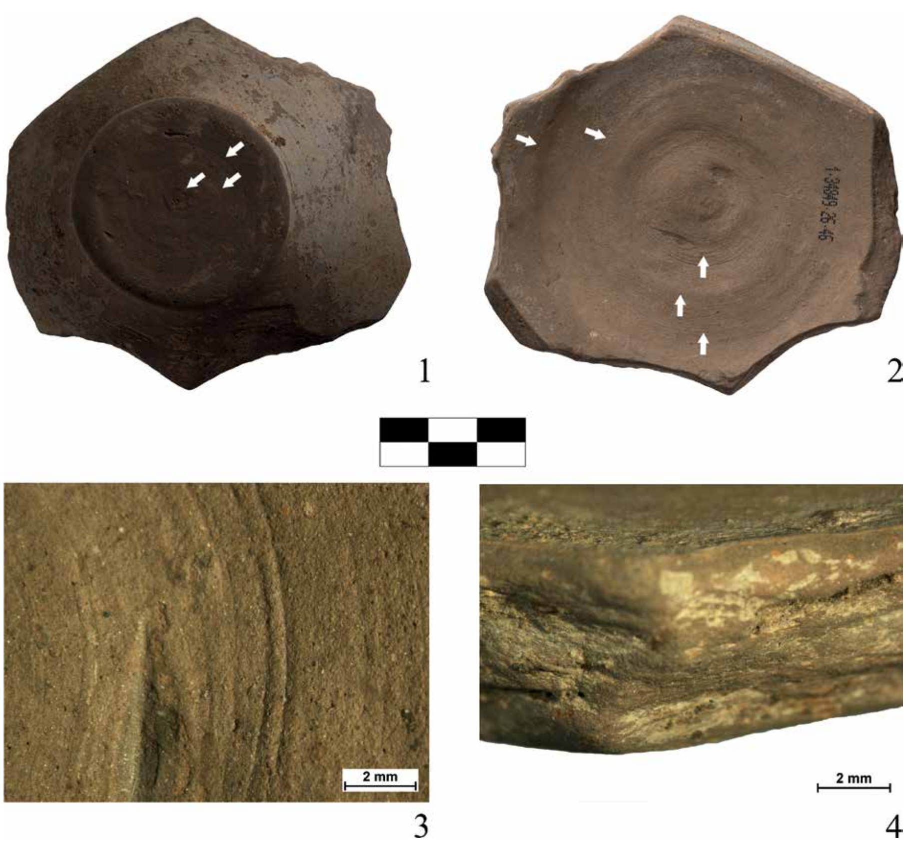


*Figure 5. Fragment of a wheel-fashioned mug from Nyírparasznya (sample 1.34849.26.46.):*
*1. Concentric striations with cracks on the base;*
*2. Horizontal and parallel grooves/striations and rilling on the inner surface (with discontinuities);*
*3. Striations;*
*4. Overlapping layers on the cross-section.*


*Figure 6. Rim-fragment of a wheel-fashioned mug from Nyírparasznya (sample 1.34849.59.1.):*
*1. Stretched outer surface (with an almost horizontal break);*
*2. Grooves, striations and rilling on the inner surface;*
*3. Signs of application of rotary kinetic energy during the vessel forming phase;*
*4. Joint of slabs.*

were selected for a preliminary LA-ICP-MS analysis (Kreiter *et al.* 2013, 482-485; Czifra *et al.* 2017, 280-281). The main elements of the samples are very similar (Fig. 9. 1). LA-ICP-MS distinguished three compositional groups based on the element ratios as shown in Fig. 9.2 (Fe/Sr ratio plot) and Fig. 9.3 (Y/Sr ratio plot). The first group is represented by a bowl with embossed decoration (1.26213.575.10) and by a biconical pot (1.26213.765.5). The second compositional group is represented by a biconical jar (1.26213.26.70), a cup (1.26213.583.9), a bowl (1.26213.765.1) and a squat-shaped pot (1.26213.774.5). The third group contains a pot (1.26213.718.4) and a bowl (1.26213.774.1). The trace element composition of the samples also shows considerable similarities (Figs. 9: 4-5). LA-ICP-MS analysis suggests that the analysed fast-wheeled pot (1.26213.718.4) is compositionally similar to a hand-formed bowl (1.26213.774.1); they also belong to the same fabric group (Fabric 1). The fact that fast-wheeled vessels are petrographically similar to hand-formed vessels (Fabric 1), and according to LA-ICP-MS a fast-wheeled vessel has a similar composition to a hand-formed bowl, suggests that fast-wheeled vessels were locally made from local raw materials. The results indicate that Vekerzug community adopted ceramic production on the potter's wheel because of cultural contacts. Fast-wheeled vessels appear not to have been imported but were made locally by resident potters indicating that different modes of production coexisted at the site. Also observed was the combination of slab building then fashioning on a rotary device (1.26213.26.3, 1.26213.26.77-78, 1.26213.575.10, 1.26213.583.7, 1.26213.583.8, 1.26213.583.21, 1.26213.766.2) at the site, indicating differences between the organisations of productions. Vessels made with the combined technique appear untempered (Fabric 1: 1.26213.26.3, 1.26213.26.77-78, 1.26213.583.21, 1.26213.766.2) or sand tempered (Fabric 2: 1.26213.583.8), while the majority of hand-formed vessels were made from coarser raw materials further indicating differences in ceramic production (Kreiter *et al.* 2013).

With regard to the results of petrographic analysis of the Nyírparasznya sherds, four main fabric groups could be distinguished (Czifra *et al.* 2015). Wheelmade vessels at this site show increased variability in their raw materials. As seen in Nagytarcsa, the majority of fast-wheeled vessels have very fine-grained raw materials although the amount of non-plastic inclusions varies between 10 and 30% (Nyírparasznya

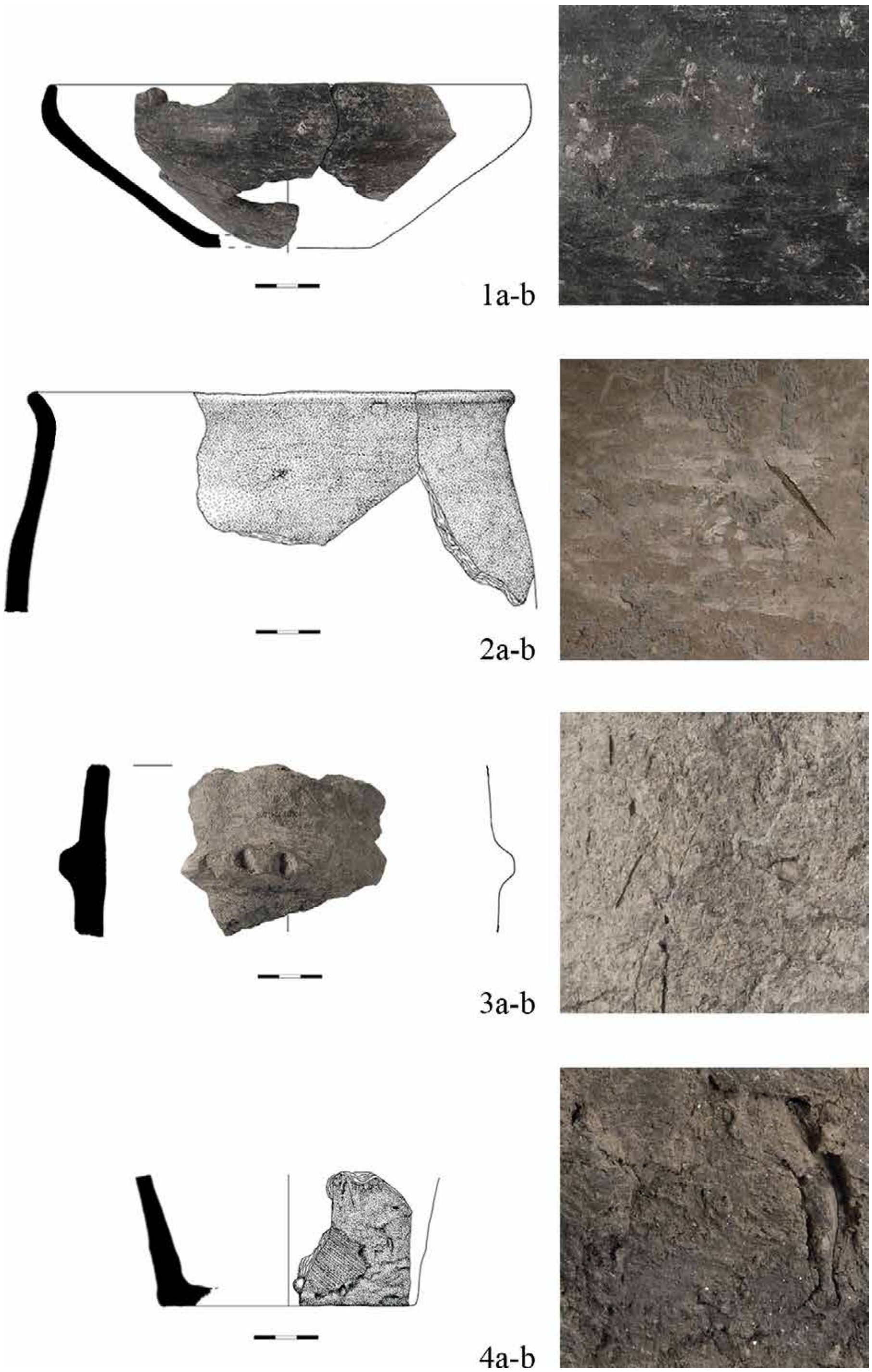


*Figure 7. Hand-formed Vekerzug vessels from Nagytarcsa:*
*1. Bowl with inverted rim (sample 1.26213.583.1-4);*
*2. Biconical pot (sample 1.26213.583.5),*
*3. Squat-shaped pot (sample 1.26213.774.5),*
*4. Squat-shaped(?) pot (sample 1.26213.581.14.).*

Fabrics 1 and 2). These are biconical mugs (Inventory Nos. 1.34849.19.9, 1.34849.23.19, 1.34849.24.13, 1.34849.60.11, 1.34849.76.3, 1.34849.106.3, and 1.34849.113.7), a jar (1.34849.113.8) and an undiagnostic vessel type (1.34849.147.18). One undiagnostic vessel type (1.34849.60.12) shows a slightly coarser raw material (Fabric 3) with fine inclusions suggesting that sand was used as a temper. It seems that at least two different types of raw materials were used for fast-wheeled products. The raw materials of fast-wheeled vessels also appear among hand-formed products (Figs. 8. 3-8). At Nyírparasznya, the biconical mugs were made mainly with the fast-wheel, although hand-formed versions also appear. Hand-formed vessels appear within

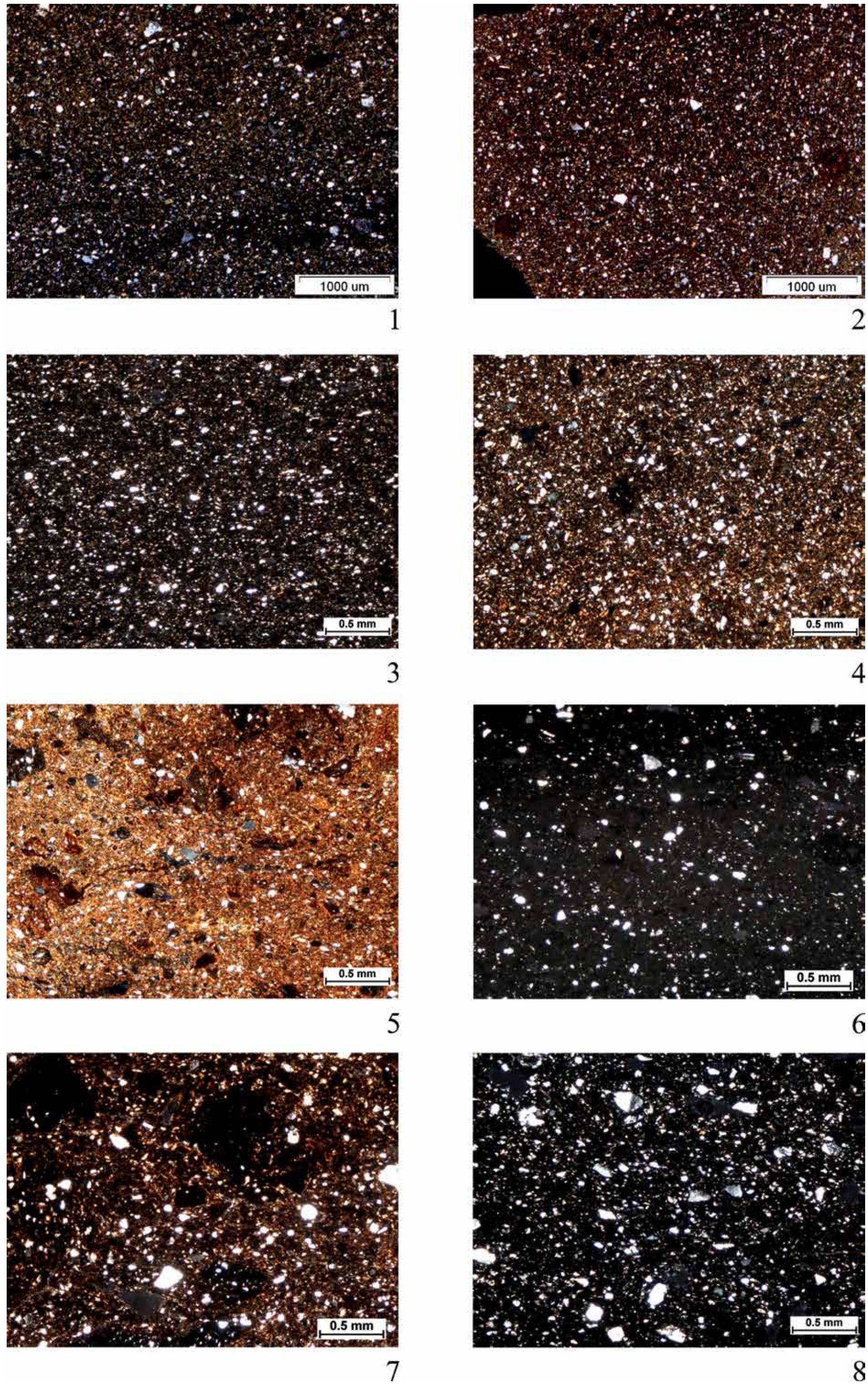


*Figure 8. Micrographs of thin sections:*
*1. Nagytarcsa sample 1.26213.766.2, fast-wheeled; 2. Nagytarcsa sample 1.26213.583.9, hand-formed;*
*3. Nyírparasznya sample 1.34849.85.2, hand-formed; 4. Nyírparasznya sample 1.34849.23.19, fast-wheeled;*
*5. Nyírparasznya sample 1.34849.23.61, hand-formed; 6. Nyírparasznya sample 1.34849.113.8, fast-wheeled;*
*7. Nyírparasznya sample 1.34849.72.1, hand-formed; 8. Nyírparasznya sample 1.34849.60.12, fast-wheeled*
*(all microphotographs are XPL).*

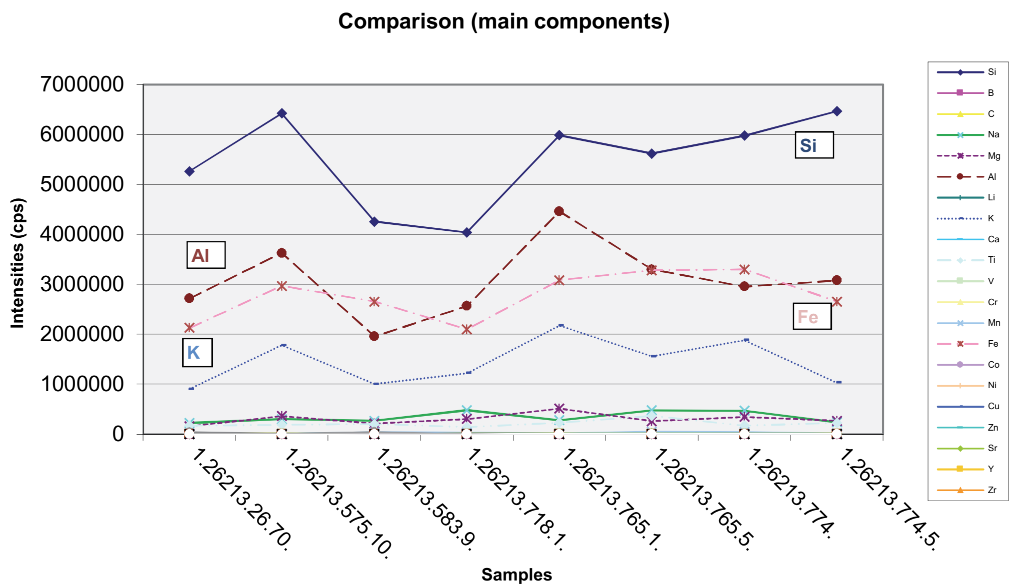


*Figure 9.1. Elemental ratios in the case of some major elements by LA-ICP-MS.*

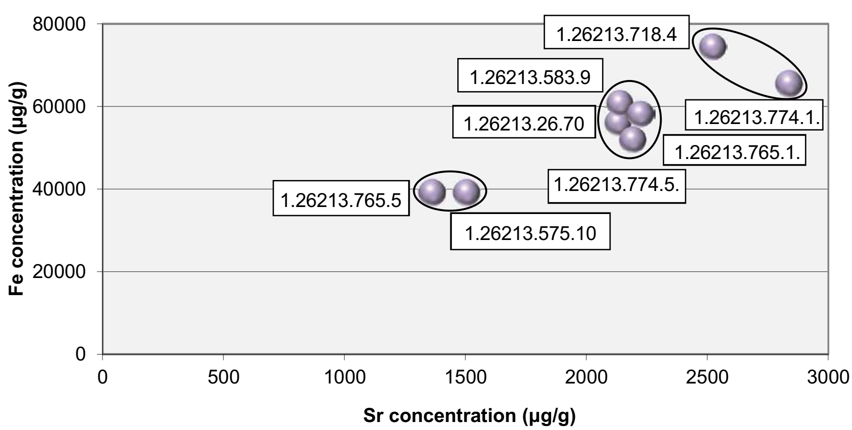


*Figure 9.2. Fe-Sr elemental correlation from solution based ICP-MS concentration measurements.*

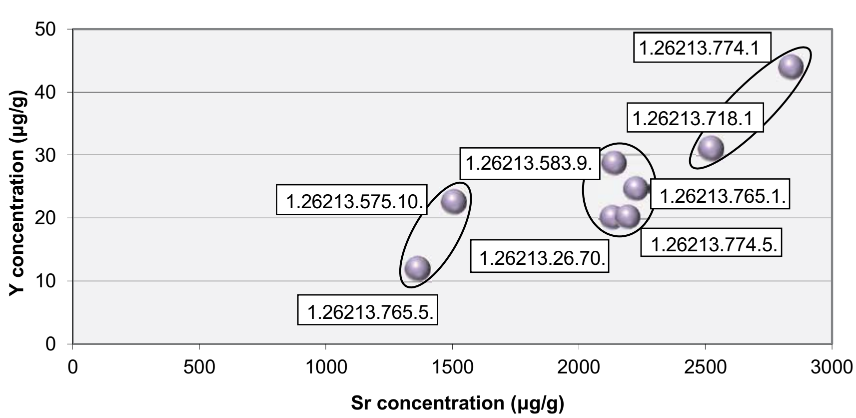


*Figure 9.3. Y-Sr elemental correlation from solution based ICP-MS concentration measurements.*

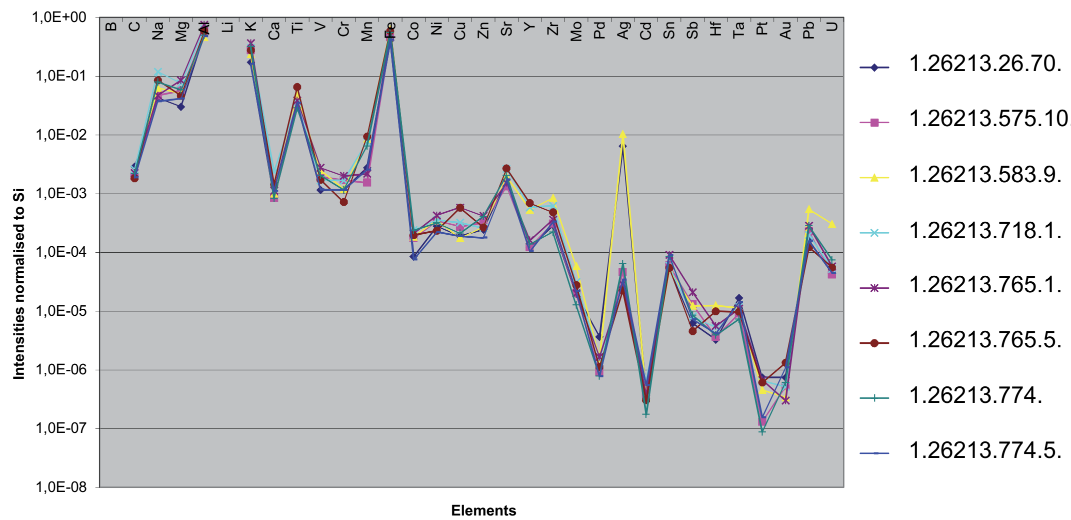


*Figure 9.4. Elemental profiles normalized to Si originated from LA-ICP-MS analysis and intensities.*

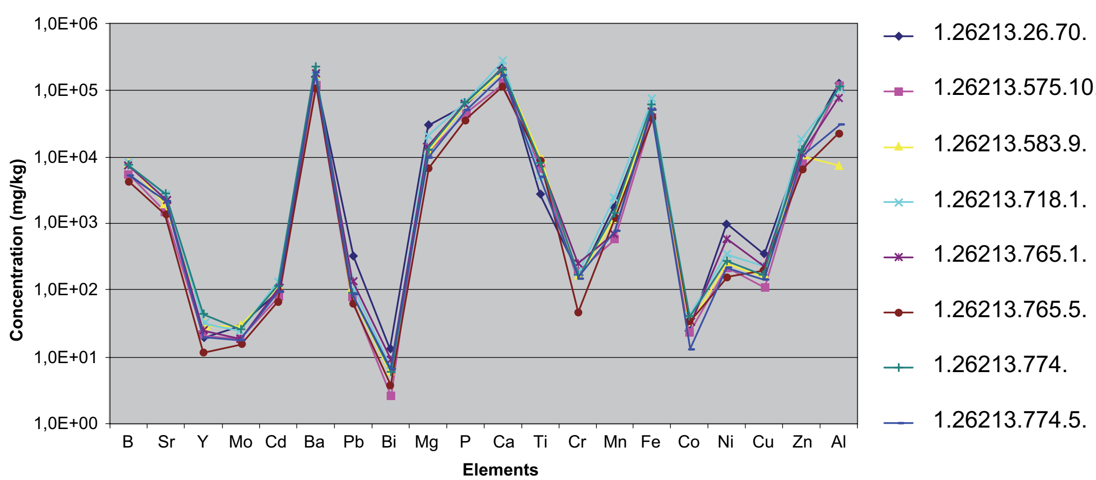


*Figure 9.5. Elemental profiles normalized to Si originated from solution based ICP-MS analysis and concentrations.*

each fabric group (Fabric 1: 10 pcs, Fabric 2: 9 pcs, Fabric 3: 13 pcs) and their raw materials are very similar to the fast-wheeled ones. In this respect, it is highly likely that fast-wheeled products were made locally as seen in the Nagytarcsa assemblage.

The fast-wheeled vessels at the two examined sites show differences in the variability of their raw materials, but these vessels mainly appear in the finest fabric groups – suggesting a deliberate choice of these raw materials for fast-wheeled production. The typological variability within individual vessel types at the examined sites (size of vessels, variability in their proportion, handle and decoration) and the variability in their raw materials may suggest that several potters or perhaps potters' groups/workshops made the ceramics at both sites, particularly in the case of Nyírparasznya. In traditional archaeological assessments, fast-wheeled and hand-formed ceramics on the same site are often considered to be the result of the appearance of specialised workshops, which produced fast-wheeled vessels (Lengyel 1964, 27; Dušek, S. 1979, 126, 136). Typological characterisations of the material examined from these two sites indicate increased variability in the vessels in terms of colour, wall thickness, vessel size, proportion, base, handle form and decorations, even within

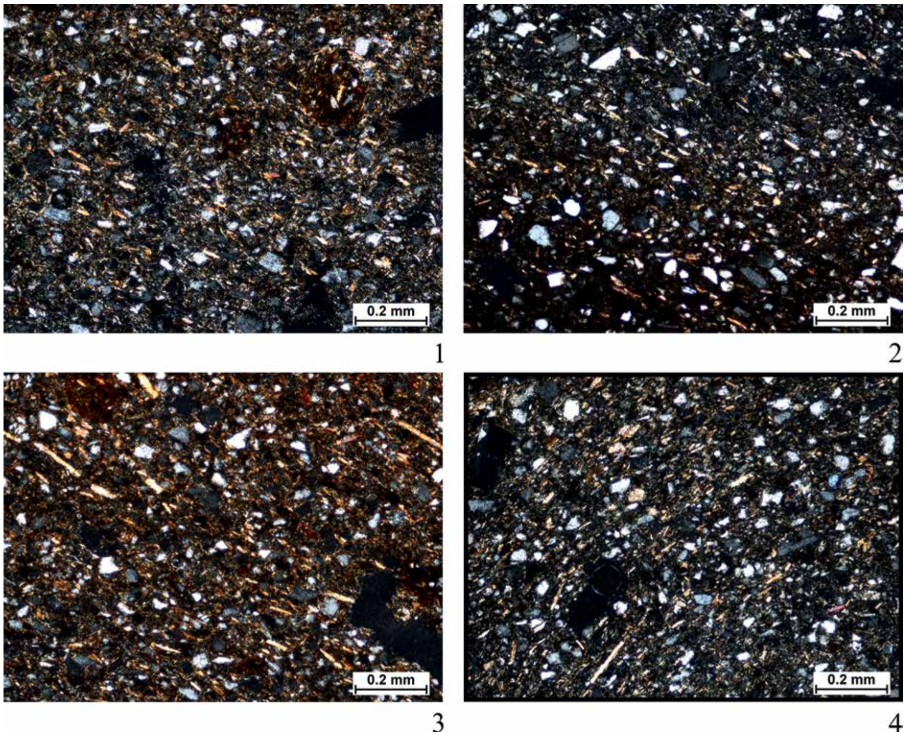


*Figure 10. Orientation of inclusions in the fabrics of wheel-fashioned vessels from Nagytarcsa: 1. Sample 1.26213.26.3. 2. Sample 1.26213.26.77-78. 3. Sample 1.26213.583.21. 4. Sample 1.26213.766.2. (All microphotographs are XPL). Samples 2 and 4 are fast-wheeled, samples 1 and 3 are made with the combined technique.*

one vessel type. These perhaps suggest that several potters or workshops produced vessels. Despite the fact that the examined vessels show increased variability in terms of their raw materials and tempers, it must be noted that elaborately made fine wares (jar, bowl, cup, mug), including all fast-wheeled vessels, are associated with the finest raw materials. This may suggest specialised production of these fine wares. Nevertheless, fast-wheeled and hand-formed vessels found in the same fabric groups suggest a more complex relationship between their productions and/or between their makers than has previously assumed. The appearance of a combined technique (hand formed and refined on a rotary device) further supports this argument.

## Towards a new interpretation

Beyond the fringe of the Mediterranean world wheelmade pottery first appeared in the North Pontic forested-steppe zone in the second half of the 7$^{th}$ century BCE, while its occurrence in the Carpathian Basin is dated to around 600 BCE. Several theories postulated concerning its origin, in which Greek influences played an important role; but information on the adaptation process is mostly indirect and very limited (see Romsauer 1991 and Kashuba *et al.* 2010; 2012). The above summarised results of thin-section and LA-ICP-MS analyses of the selected ceramic materials of Nagytarcsa and Nyírparasznya indicate the use of local raw materials and local production of fast-wheeled pottery in the Vekerzug culture. This observation reinforces the preliminary assessment of the ceramic material from the Vekerzug culture's cemetery at Chotín (Dušek, S. 1979, 133-134). These results correspond with published preliminary results of petrographic and geochemical analysis of ceramics from Scythian Age settlements in the forested-steppe zone at Zalesye and from an early Greek colony at Berezan (Daragan 2009, 129; Dupont 2009, 42-44). Ceramic analyses from these three sites (Chotín, Zalesye, Berezan) also indicate local wheelmade ceramic productions. Ceramic technological data obtained from Nagytarcsa and Nyírparasznya provide a detailed understanding of the adaptation of the wheel technique, with the observation of a combined technique (Fig. 10).

In the light of this, a more complex adaptation process of the potter's wheel has to be considered in this period. The discovery of combined techniques in the Vekerzug potting tradition is not a unique workshop practice, but fits well in the general macro-evolutionary tendency of transmission of the wheel technique. The appearance of fast-wheeled pottery was also preceded by this "intermediate" phase, when fast-wheeled and hand-formed techniques seemingly coexisted from the early 6th until the mid-5th century BCE) (Czifra *et al.* 2015, 72; 2017, 270-271, Fig. 19). The coexistence of different vessel building practices was also observed slightly later in the late Hallstatt/early La Tène period (Augier *et al.* 2013, 565-568), and similar processes were documented elsewhere from earlier periods in the Mediterranean Chalcolithic and early and middle Bronze Age (Roux 2003, 23-24; Roux and de Miroschedji 2009, 170; Choleva 2012, 374-377).

Concerning the organisation of production, ethnographic data show that one recipe is often used for all vessel types by a given potter (DeBoer and Lathrap 1979, 116-117; Plog 1980, 86-87; Tobert 1984, 226-227; Chávez 1992, 85; Sillar 1997, 8; Frank 1998, 83) which, in the majority of cases, correspond well with fast-wheeled vessels at the examined sites (jars, bowls, mugs, biconical pots). Nevertheless, the raw materials used in the making of fast-wheeled vessels were also used in hand-formed and combined techniques products. At Nagytarcsa, all the examined fast-wheeled vessels were made from similar raw materials, however the raw materials of fast-wheeled vessels at Nyírparasznya show more variability. The latter variability may reflect the existence of several potters with different levels of specialisation/organisation of production and with more complex socio-economic relationships than in Nagytarcsa.

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## References

Augier, L., Balzer, I., Bardel, D., Deffressigne, S., Bertrand, É., Fleischer, F., Hopert-Hagmann, S., Landolt, M., Mennessiert-Jouannet, C., Mége, C., Roth-Zehner, M., Saurel, M., Tappert, C., Thierrin-Michael, G., Tikonoff, N., Ruffieux, M., Van Es, M. 2013. La céramique façonnée au tour: témoin privilégié de la diffusion des techniques au Hallstatt D2-D3 et à La Tène A-B1, in: Colin, A. and Verdin, F. (eds.). *L'âge du Fer en Aquitaine et sur ses marges. Mobilité des hommes, diffusion des idées, circulation des biens dans l'espace européen à l'âge du Fer*, Actes du 35 eColloque international de l'AFEAF, 02 – 05 Juin 2011 Bordeaux, Aquitania Supplément 30. Bordeaux: Fédération Aquitania Maison de l'Archéologie, 563-594.

Bottyán, Á. 1955. *Szkíták a magyar Alföldön* [Scythians on the Great Hungarian Plain], Régészeti Füzetek 1. Budapest: Magyar Nemzeti Múzeum Történeti Múzeum.

Chapman, J., Magyari, E., Gaydarska, B. 2009. Contrasting Subsistence Strategies in the Early Iron Age?, New Results from the Alföld Plain, Hungary and the Thracian Plain, Bulgaria. *Oxford Journal of Archaeology* 28 (2), 155-187.

Chávez, M.K.L. 1992. The organization of production and distribution of traditional pottery in south Highland Peru, in: Bey III, G.J., Pool, C.A. (eds.). *Ceramic production and distribution: an integrated approach.* Oxford: Westview Press, 49-92.

Chochorowski, J. 1985. *Die Vekerzug-Kultur. Charakteristik der Funde*, Prace Archeologiczné 36. Warsawa-Kraków: Państwowe wydawnictwo naukowe.

Chochorowski, J. 1993. *Ekspansja kimmeryjska na tereny Europy Środkowej (Die kimmerische Expansion in das mitteleuropäische Gebiet)*, Rozprawy Habilitacyjne Uniwersytet Jagielloński 260. Kraków: Uniwersytet Jagielloński.

Chochorowski, J. 1996. Problem recepcji elementów kultury antycznej (greckiej) w kotline Karpackiej w VI w. p.n.e. Na marginesie dyskusji o genezie tzw. szarej ceramiki toczonej (Problem der Rezeption der Elemente der antiken (griechischen) Kultur im Karpatenbecken im 6. Jh. v.u.Z. Ein Diskussionbeitrag zur Genese der sog. grauen Drescheibenkeramik), in: Chochorowski, J. (ed.). *Problemi epoki brązu i wczesnej epoki żelaza w Europie Środkowej/Probleme der Bronze- und der frühen Eisenzeit in Mitteleuropa*, Księga jubileuszowa poświęcona Markowi Gedlowi w sześćdziesiątę rocnicę urodzin i czterdziestolecie pracy w Uniwersytecie Jagiellońskim. Kraków: Oficyna Cracovia, 115-147.

Chochorowski, J. 1998. Die Vekerzug Kultur, in: Hänsel, B., Machnik, J. (eds.). *Das Karpatenbecken und die osteuropäische Steppe*. *Nomadenbewegungen und Kulturaustausch in den vorchristlichen Metallzeiten (4000-500 v.Chr.)*, Prähistorische Archäologie Südosteuropa 12. Rahden: Leiden, 473-491.

Choleva, M. 2012. The First Wheelmade Pottery at Lerna. Wheel-Thrown or Wheel-Fashioned? *Hesperia* 81, 343-381.

Courty, M. A., Roux, V. 1995. Identification of wheel throwing on the basis of ceramic surface features and microfabrics. *Journal of Archaeological Science* 22 (1), 17-50.

Cseh, J. 2006. Archaeologia Scythica. Adalékok a Közép-Tisza mente vaskori történetéhez (Archaeologica Scythica. Additamenta to history of the Middle Tisza region in the Iron Age). *Tisicum – A Jász-Nagykun-Szolnok megyei Múzeumok Évkönyve* 15, 13-42.

Czifra, Sz. 2016. Szkíta kori település a Nyírségben: Nyírparasznya III. forduló (előzetes jelentés) (A Scythian period settlement in the Nyírség region: Nyírparasznya, III. forduló (Preliminary report)), in: Kvassay, J. (ed.). *Régészeti kutatások Magyarországon 2011-2014*. Budapest: Forster Központ and Magyar Nemzeti Múzeum, 97-119.

Czifra, Sz., Kreiter, A., Pánczél, P. 2015. Typology versus petrography: analysis of unique Scythian Age cups from Nyírparasznya (NE Hungary), in: Szatmári, I. (ed.). *An der Grenze der Bronze- und Eisenzeit*, Festschrift für Tibor Kemenczei zum 75. Geburtstag. Budapest: Magyar Nemzeti Múzeum, 67-80.

Czifra, Sz., Kreiter, A., Széles, É., Tóth, M., Viktorik, O. 2011. Kora vaskori korongolt kerámia a Kárpát-medencében (Early Iron Age wheel-turned pottery in the Carpathian Basin). *Archaeometriai Műhely* 8 (3), 235-249.

Czifra, Sz., Kreiter, A., Széles, É., Tóth, M., Viktorik, O., Tugya, B. 2017. Scythian Age settlement near Nagytarcsa. *Acta Archaeologica Academiae Scientiarum Hungaricae* 68 (2), 241-298.

Czopek, S. 2012. Nowe znaleziska „scyto-trackiej" ceramiki toczonej z wczesnej epoki żelaza na terenie południowo-wschodniej Polski (New finds of "Scytho-Thracian" wheel-made pottery from the Early Iron Age in south-eastern Poland), in: Blajer, W. (ed). *Peregrinationes archaeologicae in Asia et Europa Joanni Chochorowski dedicatae*. Kraków: Instytut Archeologii Uniwersytetu Jagiellońskiego – Wydawnictwo Profil-Archeo, 297-305.

Daragan, M. 2009. Grey pottery from monuments of the early Scythian period in the Middle Dnestr region (Western Podolian group of monuments), in: Avram, A., Buzoianu, L., Chera, C., Custurea, G., Dupont, P., Lungu, V., Nastasi, I. (eds.). *Pontic Grey Wares*, International Conference Bucurest – Constanza, 30 September – 03 October 2008 Bucurest, Pontica 42, Supplementum I. Constanţa: Muzeul de Istorie Naţională şi Arheologie, 119-148.

DeBoer, W. and Lathrap, D. 1979. The making and breaking of Shipibo-Conibo ceramics, in: Kramer, C. (ed.). *Ethnoarchaeology: implications of ethnography for archaeology.* New York: Academic Press, 102-138.

Dupont, P. 2009. Determination d'origine des ceramiques grises du Pont Euxin: donnees archeometriques recentes, in: Avram, A., Buzoianu, L., Chera, C., Custurea, G., Dupont, P., Lungu, V., Nastasi, I. (eds.). *Pontic Grey Wares*, International Conference Bucurest – Constanza, 30 September – 03 October 2008 Bucurest, Pontica 42 Supplementum I. Constanţa: Muzeul de Istorie Naţională şi Arheologie, 41-50.

Dušek, M. 1966. K otázke tráckej keramiky (Zur Frage der thrakischen Keramik). *Archeologické rozhledy* 18 (1), 54-64.

Dušek, M. 1974. Die Thraker im Karpatenbecken. *Slovenská Archeológia* 22 (2), 361-434.

Dušek, S. 1979. Mineralogisch-archäologische Untersuchungen zur hallstattzeitlichen Drehscheibenkeramik der Südwestslowakei. *Slovenská Archeológia* 27 (1), 125-138.

Frank, B.E. 1998. *Mande potters and leather workers. Art and heritage in West Africa*. Washington DC: Smithsonian Institution Press.

Jerem, E. 2003. The Late Iron Age: the Celts of the La Tène period, in: Visy, Zs. (ed.). *Hungarian archaeology at the turn of the millennium.* Budapest: Ministry of National Cultural Heritage – Teleki László Foundation, 192-200.

Kashuba, M., Daragan, M., Levitski, O. 2010. Tehnologicheskie novshestva rannego zheleznogo veka: perspektivii izucheniya rannej goncharnoi seroglinyanoi keramiki Vostochnogo Prikarpatya (Early Iron Age technological innovations: prospects for the study of early grey wheelmade pottery from East Carpathian foot-hill area). *Revista archeologică* 5 (2), 28-61.

Kashuba, M., Levitski, O., Daragan, M. 2012. Research on early grey wheel-thrown pottery (mid 7th to 6th century B.C.) in the barbarian milieu of the Eastern Carpathian region, in: Kern, A., Koch, J.K., Balzer, I., Fries-Knoblach, J., Kowarik, K., Later, C., Ramsl, P. C., Trebsche, P., Wiethold, J. (eds.). *Technologieentwicklung und -transfer in der Hallstatt- und Latènezeit*, Beiträge zur Internationalen Tagung der AG Eisenzeit und des Naturhistorischen Museums, Prähistorische Abteilung – Hallstatt 2009, Beiträge zur Ur- und Frühgeschichte Europas 65. Langenweißbach: Verlag Beier & Beran, 103-107.

Kemenczei,T.2003.TheMiddleIronAge:ScythiansintheTiszaregion(7th-5thcenturiesB.C), in: Visy, Zs. (ed.). *Hungarian archaeology at the turn of the millennium.* Budapest: Ministry of National Cultural Heritage – Teleki László Foundation, 179-183.

Kemenczei, T. 2005. *Funde ostkarpatenländischen Typs im Karpatenbecken*. Prähistorische Bronzefunde XX/10. Stuttgart: Franz Steiner Verlag.

Kemenczei, T. 2009. *Studien zu den Denkmälern skythisch geprägter Alföld Gruppe*. Inventaria Praehistorica Hungariae XII. Budapest: Magyar Nemzeti Múzeum.

Kobal, J.J. 2014. Scheibengedrehte graue Keramik der Kuštanovice Kultur aus Transkarpatien (Ukraine). *Materiały i Sprawozdania Rzeszowskiego Ośrodka Archeologicznego* 35, 65-76.

Kreiter, A., Czifra, S., Széles, É., Tóth, M., Viktorik, O. 2013. Petrographic, LA-ICP-MS and XRD analyses of Hallstatt Ceramics from a Scythian Age Settlement in North Hungary, in: Bergebrant, S., Sabatini, S. (eds.). *Counterpoint: Essays in Archaeology and Heritage Studies in Honour of Professor Kristian Kristiansen*, BAR International Series S2508. Oxford: Archaeopress, 477-490.

Lengyel, I. 1964. A fazekaskorong megjelenésének kérdése a Nagyalföldön (Zur Frage des frühesten gebrauches der Töpferscheibe in der Grossen Ungarischen Tiefebene). *Folia Archaeologica* 16, 25-32.

Levitski, O. and Kashuba, M. 2009. Early grey wheelmade ware from East-Carpathian region (on the basis of finds from Trinca-Izvorul lui Luca settlement), in: Avram, A., Buzoianu, L., Chera, C., Custurea, G., Dupont, P., Lungu, V., Nastasi, I. (eds.). *Pontic Grey Wares,* International Conference Bucurest – ConstanzaPontica 42 Supplementum I. Constanţa: Muzeul de Istorie Naţională şi Arheologie, 93-118.

Melyukova, A.I. 1995. Scythians of South-easteastern Europe. in: Davis-Kimball, J., Bashilov, V.A., Yablonsky, L.T. (eds.). *Nomads of the Eurasian Steppes in the Early Iron Age*. Berkeley: Zinat Press, 27-58.

Metzner-Nebelsick, C. 2002. *Der "Thrako -Kimmerische Formenkreis" aus der Sicht der Urnenfelder – und Hallstattzeit im südostlichen Pannonien*, Vorgeschichtliche Forschungen 23. Rahden/Westf.: Verlag Marie Leidorf GmbH.

Metzner-Nebelsick, C. 2010. Aspects of mobility and migration in the eastern Carpathian Basin and adjacent areas in the early Iron Age (10th-7th centuries BC), in: Dzięgilewski, K., Przybyła, M.S., Gawlik, A. (eds.). *Migration in Bronze and Early Iron Age Europe*, Prace Archeologiczne 63. Kraków: Księgarnia Akademicka, 121-151.

Moscalu, E. 1983. *Ceramica Thraco-Getica* [The Thraco-Dacian ceramic], Bibliotheca Muzeologica 1. Bucureşti: Muzeul Național de Istorie.

Párducz, M. 1955. La cimetière Hallstattien de Szentes-Vekerzug III (les fouilles de 1952 et 1953). *Acta Archaeologica Academiae Scientiarium Hungaricae* 6 (1), 1-22.

Párducz, M. 1973. Probleme der Skythenzeit im Karpatenbecken. *Acta Archaeologica Academiae Scientiarium Hungaricae* 25 (1), 27-73.

Patay, P. and B. Kiss, Zs. 2002. Az Alsótelekes-dolinkai szkítakori temető közöletlen sírjai (az 1962. és 1964. évi feltárás eredményei) (Die Unpublizierten Gräber des skythenzeitlichen Gräberfeldes von Alsótelekes-Dolinka (Die Ergebnisse der Freilegungen der Jahre 1962 und 1964)). *Folia Archaeologica* 49-50, 79-141.

Patek, E. 1993. *Westungarn in der Hallstattzeit*. Acta humaniora 7. Weinheim: WileyVCH.

Plog, S. 1980. *Stylistic variation in prehistoric ceramics*. Cambridge: Cambridge University Press.

Romsauer, P. 1991. The earliest wheel-turned pottery in the Carpathian Basin. *Antiquity* 65, 358-367.

Romsauer, P. 1999. Zur Frage der westgrenze der Mezőcsát-Gruppe, in: Jerem, E. and Poroszlai, I. (eds.). *Archaeology of the Bronze and Iron Age. Experimental Archaeology, Environmental Archaeology, Archaeological Parks*, Proceedings of the Intrnational Archaeological Conference, Százhalombatta, 3-7 Octobre 1996. Budapest: Archaeolingua, 167-176.

Roux, V. 2003. A dynamic systems framework for studying technological change: application to the emergence of the potter's wheel in the Southern Levant. *Journal of Archaeological Method and Theory* 10 (1), 1-30.

Roux, V., Courty, M.A. 1998. Identification of Wheel-fashioning Methods: Technological Analysis of 4th-3rd Millennium BC Oriental Ceramics. *Journal of Archaeological Science* 25 (8), 747-63.

Roux, V., de Miroschedji, P. 2009**.** Revisiting the History of the Potters' Wheel in the Southern Levant. *Levant* 41 (2), 155-173.

Sillar, B. 1997. Reputable pots and disreputable potters: individual and community choices in present-day pottery productions and exchanges in the Andes, in: Cumberpatch, C.G., Blinkhorn, P.W. (eds.). *Not so much a pot, more a way of life*. Oxford: Oxbow, 1-20.

Smirnova, G. I. 1999. Eshche raz o seroj kruzhalnoj keramike iz ranneskifskih pamyatnikov Srednego Podnestrovya [Another opinion concerning grey wheel pottery from the early Scythian sites and barrows of the Middle Dniester Region]. *Arkheologitcheskij Sbornik Gosudarstvennij Ermitazh* 34, 44-57.

Szabó, M. 2006. Les Celtes de l'Est, in: Szabó, M. (ed.*). Les Civilisés et les Barbares du Ve au IIe siècle avant J.-C*, Actes de la table ronde de Budapest 17-17 juin 2005. Collection Bibracte 12/3. Glux-en-Glenne: Centre Archéologique Européen, 97-117.

Szabó, M. 2007. Les relations celto-scythes sources archéologiques, in: Szabó, M. (ed.). *L'habitat de l'époque de La Tène à Sajópetri Hosszú-dűlő*. Budapest: L'Harmattan – Institut archéologique de l'université Eötvös Loránd, 329-332.

Szilágyi, J. Gy. 1965. Trouvailles Grecques sur le territoire de la Hongrie, in: Demargne, P. (ed.). Le *Rayonnement des civilisations grecque et romaine sur les cultures priphériques*, Huitiéme Congrès International d'Archéologie classique Paris 1963. Paris: de Boccard, 386-390.

Szilágyi, J.Gy. and Szabó, M. 1976. Art antique au Musée Déri de Debrecen et dans d'autres collections hongroises. *Bulletin de Musée Hongrois des Beux-Art* 46-47, 3-85.

Tappert, C. 2015. Origins, Development and Distribution Models of Wheel-Thrown Pottery in Early La Tène Central Europe, in: Danielisová, A., Fernández-Götz, M. (eds.). *Persistent Economic Ways of Living. Production, Distribution, and Consumption in Late Prehistory and Early History*, Archaeolingua Seria Maior 35. Budapest: Archaeolingua, 167-183.

Tobert, N. 1984. Potters of El-Fasher: one technique practised by two ethnic group, in: Picton, J. (ed.). *Earthenware in Asia and Africa*. London: Percival David Foundation, 219-237.

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# The onset of wheel-throwing in Middle Asia. A Neolithic innovation?

*Massimo Vidale*

## Abstract

It is widely acknowledged, that rotating devices started to be in use in the pottery making craft industries of the ancient Near East from at least the middle-late Chalcolithic times; and that in the 3rd millennium BCE coil-forming techniques were aided by the use of basalt wheels, recently identified in securely dated levantine contexts. However, it is controversial when exactly the use of these devices debouched into true wheel-throwing, *i.e.* in primary forming techniques in which pots are shaped in a single operation from a unique lump of clay. Here, I comment on archaeological information obtained from palaeo-technological studies of two transitional Chalcolithic sites in central-northern Iran, Chesmeh-Ali and Tepe Pardis, *c.* 5200-4700 cal. BCE (Fig. 1). Departing from unilineal models of technological evolution, in which a technique is gradually flanked and replaced by a more efficient one, it is argued that many different techniques, including wheel-throwing, were latent in the craft know-how of the early agriculturalists and coexisted since Neolithic times. Such latent technical repertories variously influenced and affected each other for a long time, becoming dominant and evident in the archaeological record when a given social context required certain types of products by certain craft groups. Perhaps, the images of discontinuity in technical change that permeate the present reconstructions are, at least in part, artefacts of information gaps. Finally, the paper re-considers in a different light traditional hypotheses of cognitive links between the potter's wheel and other sources of rotatory motion, suggesting other possible lines of investigation.

*Keywords: Origin of wheel-throwing, sequential slab construction, coil building, Chesmeh-Ali, Tepe Pardis, transitional Chalcolithic of central-northern Iran*

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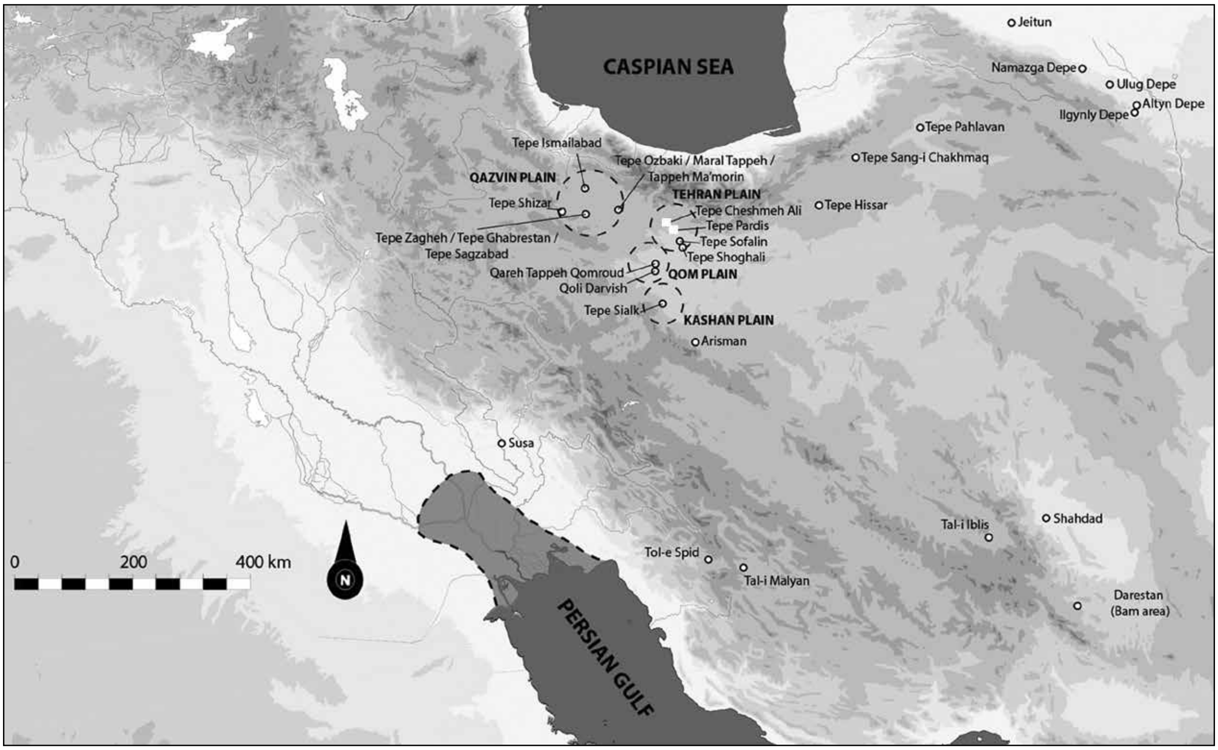


*Figure 1. Map showing the transitional Chalcolithic sites of central-northern Iranian Plateau and other important sites of the region. Chesmeh-Ali and Tepe Pardis (Iran) are emphasized with white squares (courtesy of F. Desset).*

## Introduction

Potter's wheels were used as primary forming devices in Mesopotamia at least since the final Ubaid/ Uruk times, *c.* 4000 BCE (Potts 2012; Laneri 2011; Simpson 1997); in the last centuries of the 4th millennium BCE, moulding and wheel-throwing were parallel technical processes that allowed part of the ceramic mass production of the late Uruk period (Moorey 1999 [1994], 146; Pollock 1999, 5; Nadali and Polcaro 2015, 78-81).[1] However, V. Roux states that

> *'…in the Southern Levant, although the wheel coiling technique (shaping coiled rough outs on the wheel) appears by the second half of the fifth millennium, it does not become predominant before the second half of the second millennium BCE… between the fifth and the second millennia BCE, this technique disappeared (and reappeared) twice, once after the collapse of the chalcolithic societies, in the middle of the fourth millennium BCE, and once after the collapse of the first urban societies, at the end of the second millennium BCE'* (2009, 195, see also 198 and following pages)

The author proposes that this is probably because the specialised potters who used the wheel had a specific status and worked mainly for the main cities and the elites in power.

Actually, it has become increasingly clear that the use of rotating devices in the early ceramic craft industries of prehistoric southern Eurasia has a much longer prehistory. For example, the fine Samarran painted bowls (late 7th-early 6th millennium BCE) found in upper Mesopotamia were formed in moulds, then by applying one or two coils to make the upper part of the vessel and the rim, and finally by fashioning and thinning these upper coils on a rotating device (Adriaens *et al.* 2001). As detailed and experimentally recreated by the authors

1 Unexplained remains M. Liverani's statement that in the same period "…the potter's wheel is available also in households context" (1998, p.69, translated by the author).

*'…The strong regularity in the orientation and thickness with which these horizontal structural lines were executed makes it most likely that a slow rotating device was used… Such a device, which had to be kept in motion continuously, may have been fairly simple. A dish-shaped vessel placed on an even surface would do. Similar to the moulds used for shaping the base, such a rotating device would be difficult for the archaeologist to recognise.'* (Adriaens *et al.* 2001, 158).

No wonder that primitivistic views of the development of ceramic crafts in the ancient Near East and nearby regions are fading away. Moulding (allowing forms of serial production) was used in Mesopotamia and in the Iranian Plateau at least since the 6th millennium BCE. Highly skilled forms of wheel-fashioning[2] of coil-built vases allowed the creation of the elegant, tall beakers of Susiana in the 5th millennium BCE (Laneri 1997; 2009). Coil-built, wheel-fashioned vessels, the most common product in the transitional Chalcolithic at the site of Tepe Pardis (Tehran Plains, Iran), are safely dated by $^{14}$C between 5200 and 4700 cal. BCE (general discussion in Fazeli *et al.* 2014; and Fazeli Nashli *et al.* 2010, paper which provides a great part of the material evidence on which this note is built, see below). The same technique, combined with moulding, is identified in the earliest pottery so far known in the Halil Rud valley, in south-eastern Iran (*c.* 4200-3700 cal. BCE, see Vidale and Desset 2013).

Roux and de Miroschedji (2009) have discussed in detail two rotating devices in basalt, defined *tournettes*, found in what is defined as an elite building at Tel Yarmuth (late early Bronze Age, *c.* 2600-2350 BCE). Such *tournettes* are interpreted as the potter's wheel common in the 3rd millennium BCE in the Southern Levant, and presented together a long list of similar tools in use from Chalcolithic to late Bronze Age times. The same stone wheels, found in the site of Khirbet al-Batrawy, in the same region (*c.* 2500-2300 BCE) are also discussed in Fiaccavento 2013.

Thus, we may take for granted that efficient rotatory devices and moulds were abundantly used since late Neolithic-early Chalcolithic times, albeit perhaps discontinuously, across a wide geographical area spreading from the Levant to the core of the Iranian Plateau. But, as clarified by decades of work of Roux and her colleagues, establishing when, where and why pivoted potter's wheels, capable of generating centrifugal force for a fastened, intensive production of pots is another and more controversial issue.

The earliest potter's wheel materially found in Mesopotamia seems to belong to the Jemdet Nasr period, *c.* 3100 BCE (Moorey 1999 [1994], 146). Our studies of the pottery sequence of Shahr-i Sokhta based on experimental replicas of the pottery's forming stages and X-ray radiography (Buson and Vidale 1983; Vidale and Tosi 1996; Laneri and Vidale 1998; Laneri 2009; Laneri and Dipilato 2000) shows the early use of a direct wheel-throwing process (without coils) since Period I, *c.* 3200-3100 BCE, for mass-producing a single type of small cylindrical beaker, one of the most common containers in the early urban settlement. We speak of mass production because fragments of these fine beakers were dumped by the hundreds in each excavated context, and there is no evidence that their use was restricted to a privileged minority of the urban population.

In contrast, the rest of the ceramic types were made with a different coiling and wheel-fashioning sequence, or by moulding combined with wheel-fashioning, and thus remained for centuries, until direct wheel-throwing in the second half of the 3rd millennium BCE, slowly spread to other small and medium-sized forms.[3] Fig. 2 shows the X-ray image, from two different angles, of a pear-shaped beaker of the Shahr-i Sokhta, Period I found in the Eastern Residential Area: the continuous spiral revolving from bottom

2 In this paper, 'wheel-throwing' refers to the forming of a pot on a rotating device in a single continuous operation (as stated in the abstract), regardless the specific rotational speed, while 'wheel-fashioning' implies the thinning and soldering of coils, to strenghten the walls, with the aid of a device of the same kind.

3 *Contra*, Courty and Roux 1999, after high-magnification inspections of the pots' microfabrics, maintained that all forms were made with coils and fashioned on the wheel. See also Roux 1994.

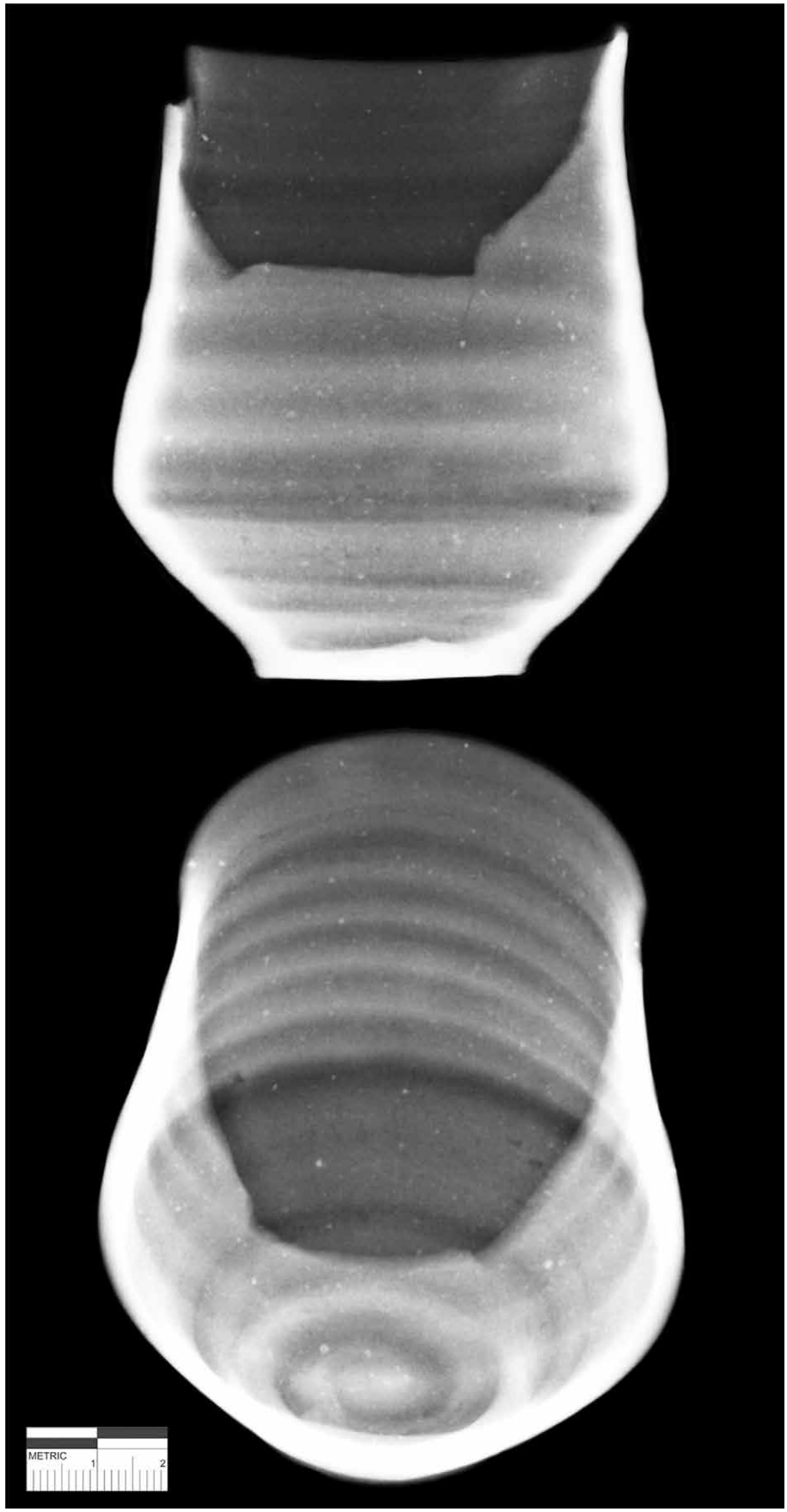


*Figure 2. X-ray images, from different angles, of a pear-shaped beaker of Shahr-i Sokhta, Iran, Period I (c. 3200-2900 BCE). The continuous spiral and the general structure of the small pot exclude the use of coils fashioned with a rotatory device and demonstrate the use of a true potter's wheel in the late 4th millennium BCE (S. Dipilato).*

upwards, and the gradual thinning of the wall leave no doubt about the exclusive use of the potter's wheel in a single continuous operation and on a single clay preform.

In Egypt, early evidence of the use of some kind of rotatory devices to fashion coil-built pots appears in the Naqada III period ca 3200 – 3050 BCE (Wodzińska 2009, 25). Both tomb iconography and material analysis reveal the leading role of temples' workshops and pharaonic bureaucracy in the adoption of the potter's wheel by attached specialists since the 4th[4] dynasty, *i.e. c.* from the 26th century onwards, quite likely during the reign of Snefru (Doherty 2015; more conservative estimates in Wodzińska 2009, 113; see also Vandiver and Lacovara 1985/6 and Sterling 2004). The context seems to have been the intensive and fast production of small pots of regular forms to be used in court and temple rituals. In the northern Levant, later evidence suggests a gradual introduction of rotatory devices from the early 3rd millennium BCE, culminating in a wider adoption, for the production of small vessels, in the second half of the same millennium (Roux and Jeffra 2015).

## Methodological problems

There are three orders of methodological issues that are crucial for the present discussion. The first is a question of definitions, and their links with material archaeological material evidence. Is a sherd or ceramic support capable of rotating without generating centrifugal force, a kind of "slow wheel", and could it be called a *tournette*? If a pivoted wheel is used at low revolution speeds (as it is commonly done with larger pots), will the use of this device be archaeologically recognized on the finally fashioned and fired pottery as the work of a "slow wheel"? Or should we rather assume, in contrast, that once a pivoted wheel is built and operated, it is anyhow capable of rotating at variable speed, and of generating centrifugal force that within specific chaîne opératoire performed differently, according to the partology, size and forms of the vessels?

So far, many of the involved questions have wavered around the revolution speed of the wheels. V. Roux and de Miroschedji (2009, 164-165) quite confidently link "fast wheels" to performances of a minimum speed of 150 rotations per minute (rpm), normally achieved with modern kick wheels propelled by the foot or with a large flywheel pushed with a long stick. In contrast, slow rotary instruments would be smaller in diameter and rotate at the much lower speed of 80-100 rpm[5]. When such slow wheels are pivoted, Roux and colleagues would call them *tournettes*. According to them, such *tournettes* would not allow potters to apply the "wheel-throwing technique *stricto sensu*", but only the wheel-fashioning of gradually assembled coils. As a consequence, true wheel-throwing techniques would be generally adopted in the Near East and Middle Asia only during the 1st millennium BCE.

I disagree, because the acritical use of rotational speed as the main classification criteria may be deceptive inspired as it is by modern principle of efficiency in mechanics. In 2016-2017, at the experimental archaeology laboratory of Padua University, we tested the use of an accurate replica of a 6th-5th century BCE Greek potter's wheel, after several images drafted with variable levels of detail on attic black- and red-figures pottery (Pulitani *et al.* 2017). We soon realized that, besides a life-sized replica of the famous François crater, we could quite efficiently reproduce every attic vase form – no matter their size – with a revolu-

4 In July 2018, the international press reported without further details the discovery of a pottery-making workshop at the 4th dynasty temple of Kom Ombo (Aswan), with molding facilities and a hand-powered potter's wheel in limestone.

5 Such "speedometric" range modifies previous statements by Amiran and Shenhav (1984) who, with Rye (1981, 74) established a speed of about 80-to-100 rpm as a performance threshold of a true potter's wheel. The faith in speed as the crucial factor in wheel-throwing goes back to Foster 1959.

tion speed never exceeding 35-40 rpm. And who would ever call a potter's wheel with a diameter of almost 1 m and a total weight of more than 50 kg a *tournette*?

Clearly, speed is a complex dependent variable of more complex systems, and not a prime mover. Rather than focusing on rotational speed, we should consider as a crucial parameter the capability of making a pot from a single lump, and in a single operation. This leaves the question of the distinction between a "slow wheel" and a "fast wheel" completely open, and perhaps not as immediately relevant as we previously thought.

The second question regards the capability of archaeologists to understand correctly the forming technology of the pottery they unearth and classify. In the last decades, only a small number of studies have analytically dealt with the materiality and the technical identity of prehistoric and protohistoric ceramics. In most cases, identification of manufacturing techniques were left to simple visual assessments and untrained expertise, and therefore many published statements are not reliable. If X-rays radiography and mammography, SEM inspection of fractures at low magnification, and petrographic studies of thin sections allow an in-depth investigation of a vessel's body inner structure (among others, Foster 1983; Glanzman 1983; Vandiver 1987; Vandiver *et al.* 1991; Courty and Roux 1995; Roux and Courty 1998; Dipilato and Laneri 1998; Laneri and Vidale 1988; Cazzella *et al.* 1991; Fazeli *et al.* 2011), and thus to retrace part of the object's technical genesis, these approaches have had a quite limited application, particularly in the light of the continuous, ongoing discovery of new prehistoric assemblages in the study area.

Also, there was little debate on how the viewpoints and results of a micro-structural observation technique were reflected at a macro-structural level. For example, how do the micro-pores considered by Courty and Roux (1995) relate with those normally considered at a much larger structural scale by X-rays radiography? Apparently, the SEM inspection of microfabrics proposed in this last article were rarely pursued by following scholars, and its validity, in absence of further research, remains unchallenged (for recent quantitative advances in this research perspective see Thér and Toms 2016).

The third and last issue is also the more obvious: in spite of super-abundant ethnographic and ethnoarchaeological information, we still know very little of the ancient ceramic *chaîne opératoires*. While describing our pottery, we tend to apply a limited set of explanatory models, systematically ignoring anomalies and divergent evidence. First of all, we insist opposing hand- to wheel-based forming techniques, when it is clear that in the past, as today, every non-industrial manufacturing sequence combined in the same path has quite different, independent steps and the involved cognitive approaches. Because, in many cases a technique conceals the signs of previous steps, available manuals do not help in disentangling this kind of cumulative, but also destructive evidence. In these conditions, it will hardly be surprising that a careful inspection of even a single site could posit new questions, and challenge long-established viewpoints.

## The case of Tepe Pardis (Tehran Plains), Iran

For the purpose of this note, I maintain that

> *'…X-rays radiography, a non-destructive analytical technique, has the ability to visualize a larger section of a pottery vessel as compared to microscopic methods and, as a consequence, can provide clearer information about the orientation of the pores and inclusions inside the clay fabric of a vessel and the overall structure of the inner body – the fundamental elements for determining the use of certain manufacturing techniques by ancient potters'* (Laneri 2011, 66).

Most of the following data derive from our examination of a sample of 1236 potsherds from Trench VII-TP07 of the dig of the transitional Chalcolithic pottery manufacturing site of Tepe Pardis, Tehran Plains, Iran (see Fazeli and Diamali 2002;

Fazeli *et al.* 2005; Fazeli Nashli and Abbasneiad Seresti 2005; Fazeli Nashli *et al.* 2010, 2014; general summary in Vidale *et al.* 2018). The examined sequence is bracketed between the late Neolithic (layers 7023-7022) and the transitional Chalcolithic (layers 7021-7004), *c.* 5200-4700 *c.* BCE. The study took two weeks in the laboratory of the Institute of Archaeology, Tehran University. A set of potsherds were analysed in Rome with X-rays diffraction (XRD) and a ESEM system; and X-rayed for investigating their microstructure with mammographic machinery. The findings widely reported and illustrated in Fazeli Nashli *et al.* 2010, to which the reader is re-addressed, may be thus summarised:

- most of the pots were abundantly chaff-tempered and made with sequential slab construction or SSC process (Vandiver 1987): *i.e.* by pre-forming small clay lumps or pellets, flattening them into slabs of various shapes and joining them to form bases, walls and rims. Many other vessels were made with coils, probably fashioned on the potter's wheel (Fig. 3). The evidence confirmed what we already knew after the X-ray inspection of other contemporary potsherds from Chesmeh-Ali, near Tehran (Fig. 4, from Dipilato and Laneri 1998);
- distinguishing the longer slabs from coils was not always easy. In both transitional Chalcolithic sites (Tepe Pardis and Chesmeh-Ali) the mouth of some slab-built bowls were made with elongated slabs which got close to the forms of coils (Figs. 4-6). Apparently, long strips of clay were used to close/secure the mouth of slab-constructed pots, similar to a cord closing a soft leather bag. In this light, the earliest coils might have been an adaptation of slabs to a specific technical constraint;
- X-ray images of some clay strips applied to re-enforce the mouth showed a neat spiralling distribution of inclusions (burnt vegetal particles) and pores in a consistent diagonal setting, generally acknowledged, after the quoted work of Vandiver, Berg and others, as reliable evidence of wheel-throwing (very evident in Fig. 8). The formation and angle of elongated voids does not depend upon rotational speed (as demonstrated in Berg 2008) but rather, as our experiments suggested (unpublished research), on the strength applied by the potter when a vessel is quickly opened and its walls lifted at low rotational speeds. In fact, the faster the wheel rotates, the higher the number of rotations endured by the formed pot, and we found that the angle of the voids, in general, is inversely related to the number of rotations. These are the bases on which we hypothesized that the upper part of bowls, in the discussed early sites, were fashioned on a potter's wheel;
- A couple of tiny, thin potsherds showed the same microstructure also below the rim, on the wall;
- Coil-building and wheel-fashioning, in the uppermost layers of the stratigraphic sequence, became an important technical choice. The expansion of wheel-fashioning is duly reflected in a gradual shrinking in size of the chopped chaff inclusions, constantly added as temper;
- A single potsherd witnessed the construction of a pot around a basket or fibres bag, the extraction of this latter, and, after drying, the application of a new outer clay coat (Fig. 9). This shows a variation in technique that, between the late 6th to the mid- 4th millennia BCE, was diffused, with spatial and temporal gaps, from China and the northern Indo-Pakistani Subcontinent, including Baluchistan and Makran, westwards to Fars and Susiana (complete references in Fazeli Nashli 2010, 98);
- Finally, at least three potsherds belonging to globular pots had been moulded and beaten with a paddle on upturned (convex) pots, a technique abundantly present in the ethnoarchaeological records, but not reported, so far, in the study area.

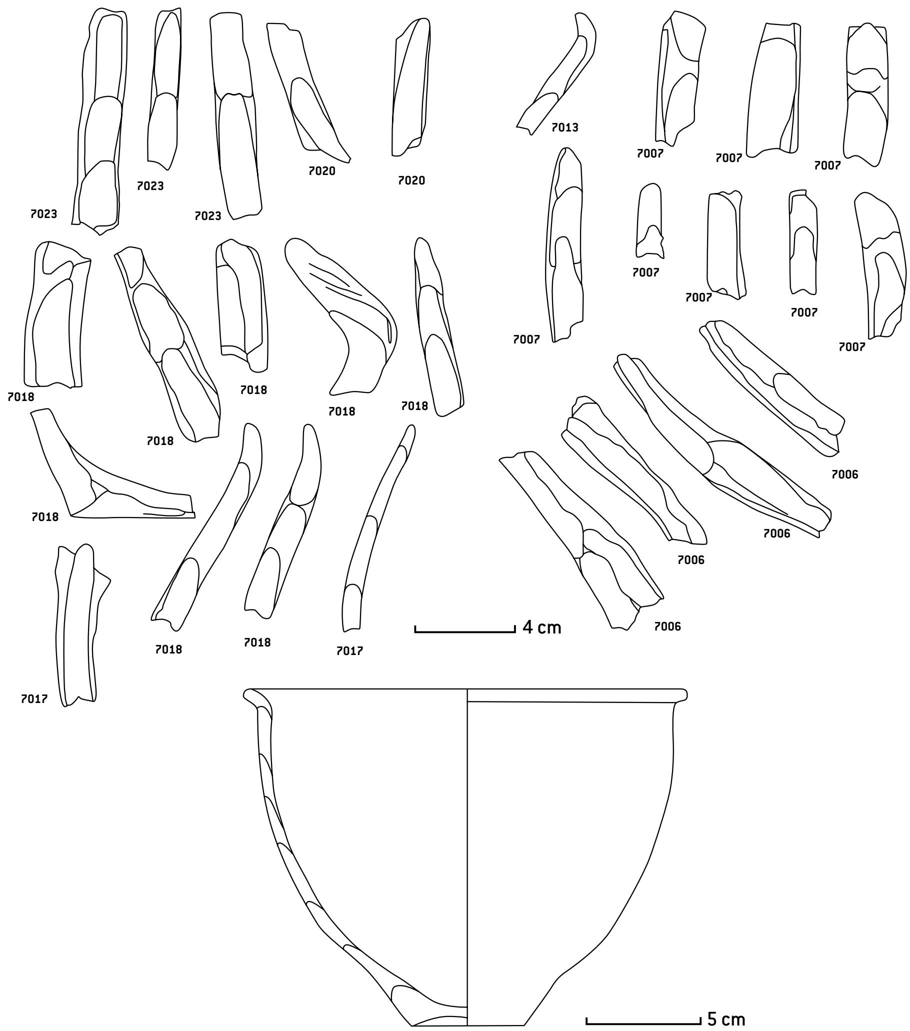


*Figure 3. Sections of potsherds from Tepe Pardis (c. 5200-4700 BCE) recorded by the means of visual inspection of fracture surface with oblique light. Coil-built pots are represented together with slab-constructed containers (lower right) (M. Vidale, from Fazeli et al. 2010).*

## Some palaeo-technological implications

In the picture outlined by these preliminary finds, sequential slab construction coexisted by the earliest forms of coil (or “proto-coil”) building, and with the use of wheels that were efficient enough to modify not only the surface, but also the inner structure, in depth, of the mouth (and in a few cases, of the wall) of the vessels. It seems likely, in the present light, that coils first developed as a means of fixing the mouth (see the modern experiment in Fig. 7), and therefore increasing the strength, of slab-constructed open vessels; and that the containers thus built where further finished along the mouth on a potter’s wheel, applying a force sufficient to modify the inner orientation of the organic inclusions and pores of the uppermost strips. Thus, in this early stage, a technique would have been a material consequence of the others before finding in later times independent functions and socially shared fields of application. At least one sherd in the Tepe Pardis sample was part of a vessel that seems to have been entirely shaped on a potter’s wheel (Fazeli *et al.* 2010: Fig. 20).

Basket-marked wares having an archaic look were probably made, at the same time, with one or more unknown techniques. As baskets, cords, fibre bags disappear, the sherd of Fig. 8 is very suggestive. Most probably, basketry and other kinds of fibres-woven containers, in spite of Leroi-Ghouran careful statements (1993, 154) have been a source of influence and continuous technical

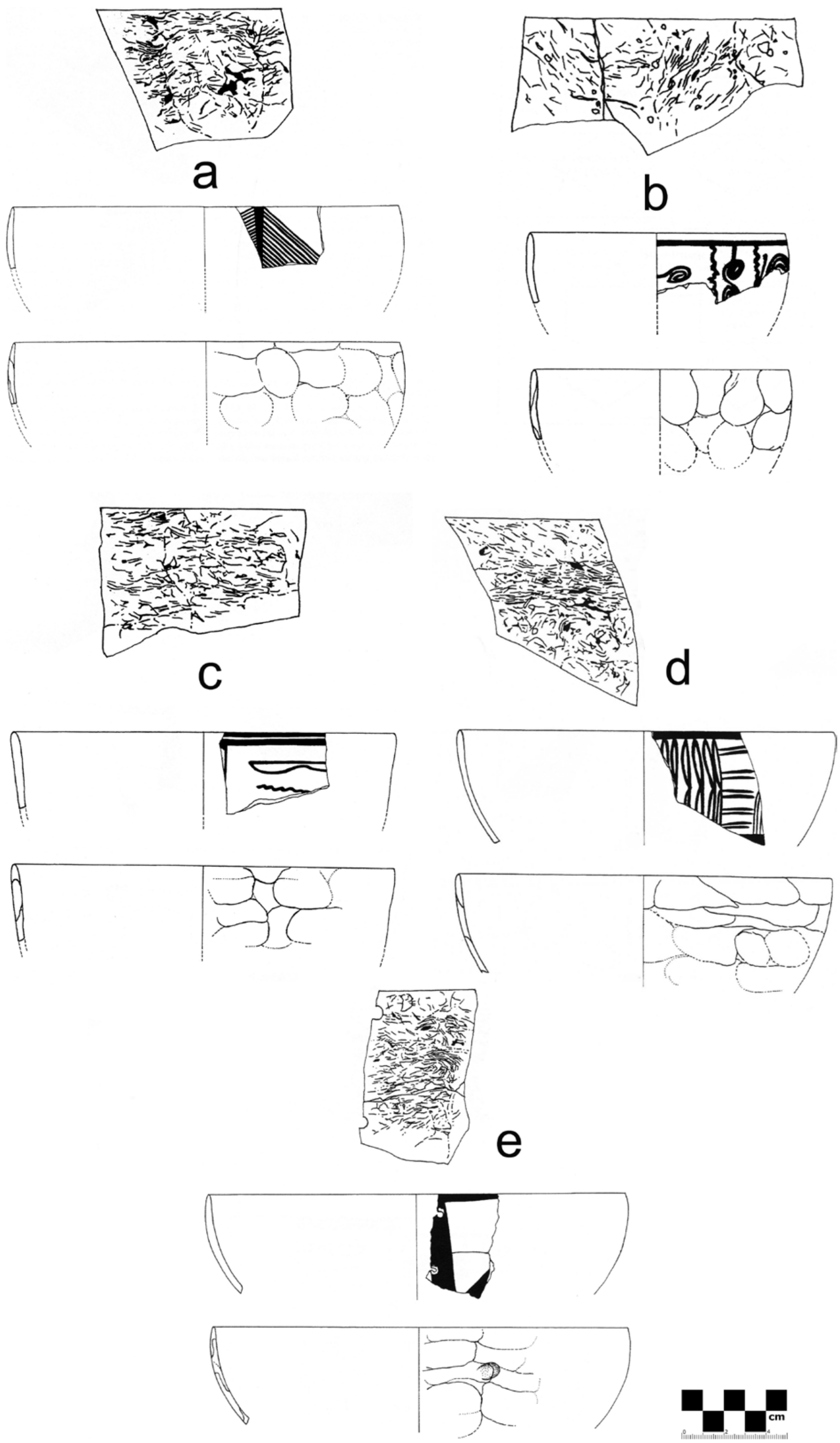


*Figure 4. The structure of hemispherical bowls from Chesmeh-Ali, Iran (c. 5200-4700 BCE) interpreted after the evidence of X-ray imagery. Note the walls constructed with slabs and the upper sections (mouth) fixed with elongated slabs or "proto-coils" to stabilize their construction (M. Vidale, after Dipilato and Laneri 2008).*

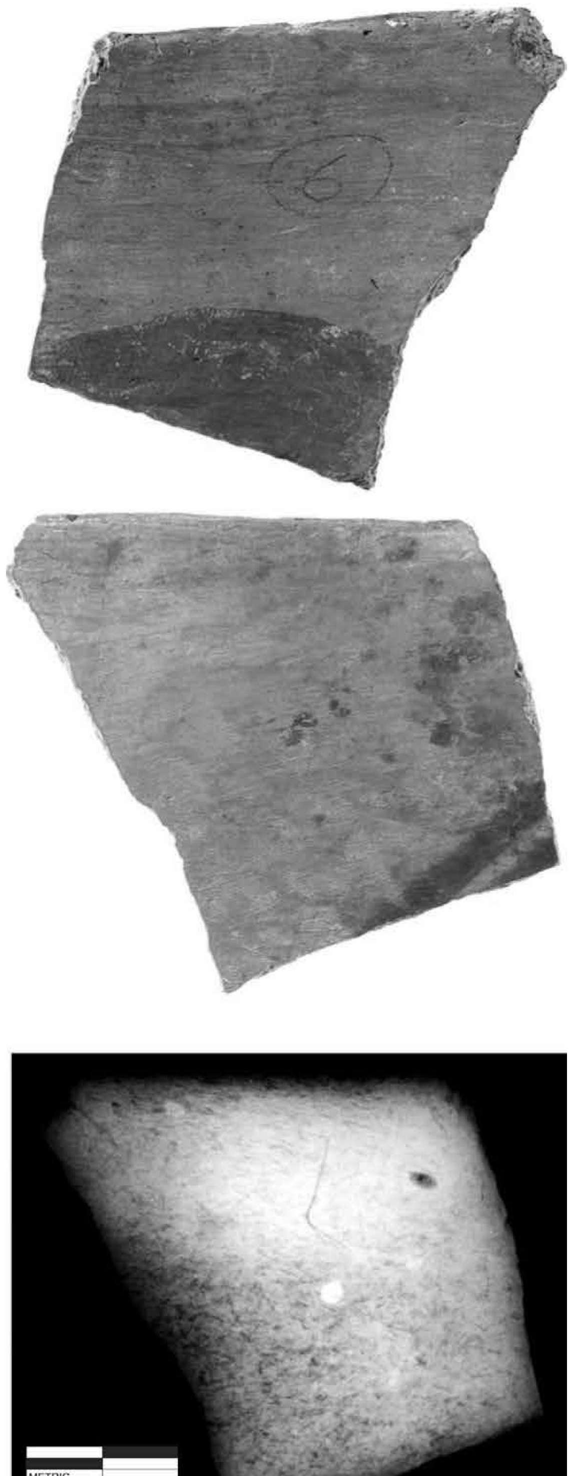


Figure 5. X-ray image of a bowl from Tepe Pardis, Iran (c. 5200-4700 BCE), showing a thicker coil-like slab applied on the rim (S. Dipilato).


Figure 6. X-ray image of a bowl from Tepe Pardis, Iran (c. 5200-4700 BCE), showing a thicker coil-like slab applied on the rim (S. Dipilato).

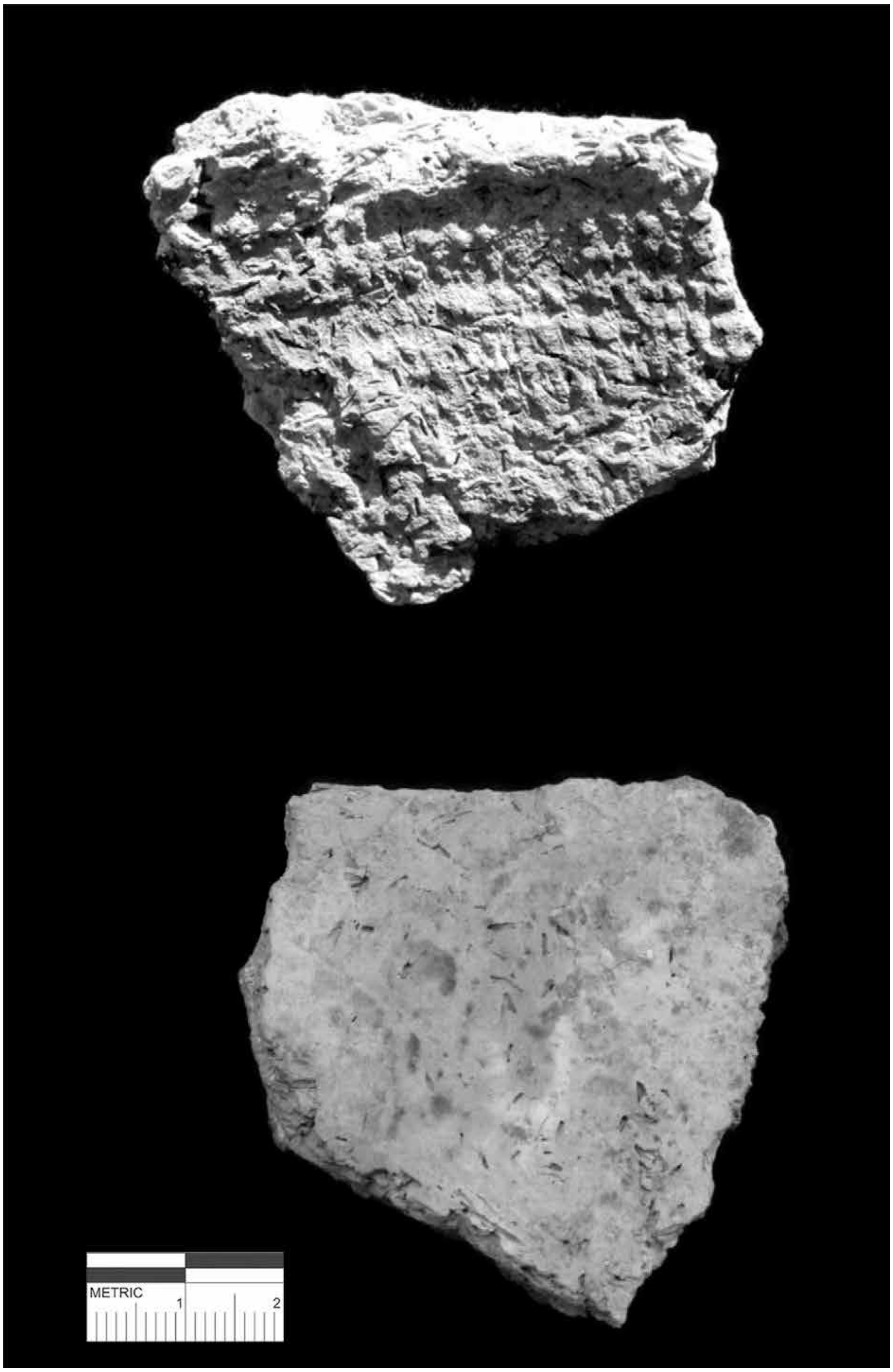


*Figure 7. Tepe Pardis, Iran (c. 5200-4700 BCE): a sherd belonging to a container originally moulded in a basket or fibre bag (M. Vidale).*

cross-breeding with ceramics for millennia (examples at Shahr-i Sokhta, during the 3rd millennium BCE, see Mugavero and Vidale 2003, 2006).

In particular, coil-building in pottery has always been considered to be closely linked, at a cognitive level, with spiral basket weaving (Leroi-Ghouran 1993, 194; further discussion in Mugavero and Vidale 2006). Fig. 10 proposes a provocative, *longue durèe* comparison between the baskets commonly used nowadays in the Swat valley (Khyber Pukhtunkhwa, Pakistan) and one of the most famous bowls of the early Chalcholithic Samarran production of upper Mesopotamia (on exhibit at the Pergamon Museum, Berlin). The comparison strongly suggests that the organization of the designs on the prehistoric vessel, although clearly representational (fishing

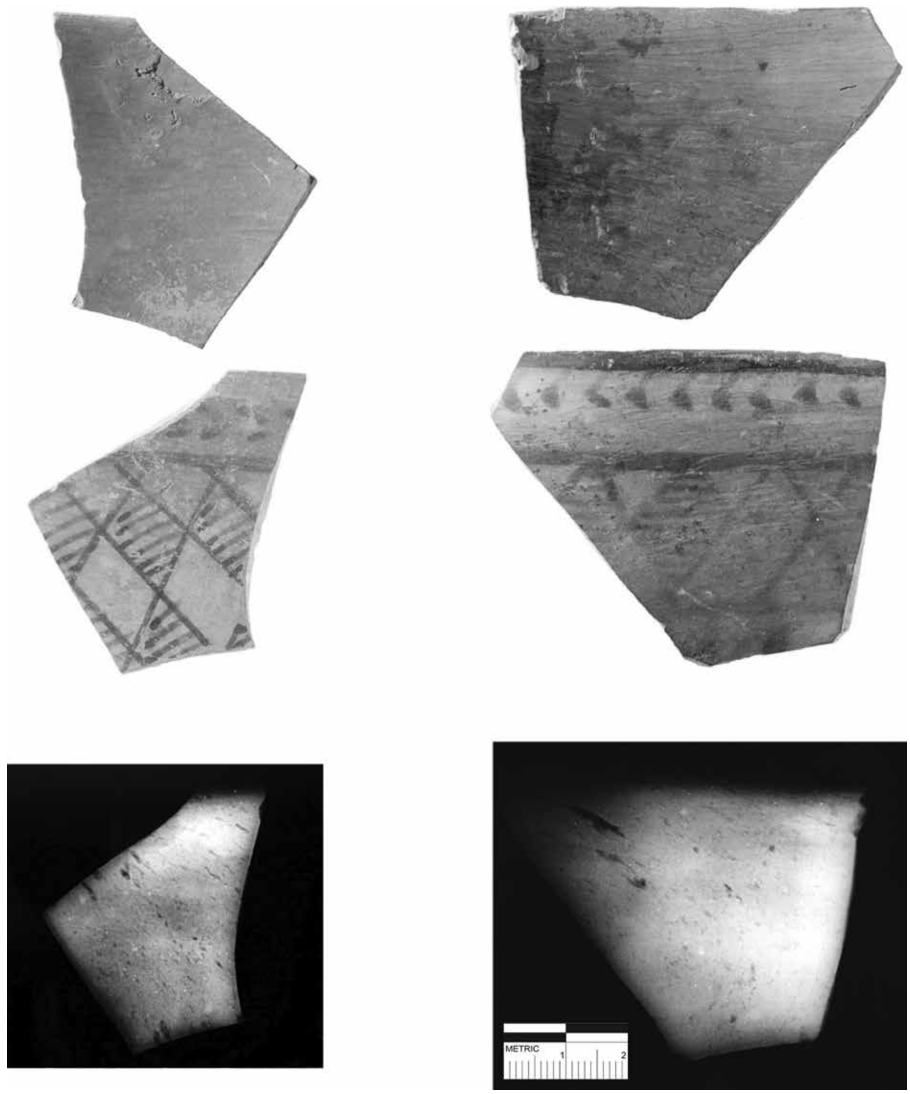


*Figure 8. X-ray image of two painted bowls from Tepe Pardis, Iran (c. 5200-4700 BCE), whose upper part appears strongly affected by a wheel-throwing process (because of the abundant oblique pores running from lower right to upper left: cfr. Berg 2008, 2011. Courtesy of S. Dipilato).*

with cormorants, a recurrent subject in the Chalcolithic of Eurasia) replicated rather faithfully the materiality of a basket (from the swastika-like centre, necessary to start the construction of a basket, to the oblique stitching across the coils, to which the long birds' wings may allude, and to the angular patterns of the frieze inside the rim, that probably replicate the braids needed to close and secure the edge of a basket).

The evidence of some pots made by paddling large slabs of clay against a globular pot (Fazeli *et al.* 2010, Fig. 17) reminds us that in the study area and period craft persons might have used a range of forming techniques much wider of what we commonly expect, and whose indicators we are not fully trained to recognize.

Our case-studies suggest that in the late Neolithic of Middle Asia, as well as the Middle East, potting communities had at their disposal a potential inventory of technical choices much wider than previously imagined. Many different techniques and even cognitive approaches to the transformation of matter had been inherited from millennia of previous skills. Since Lemonnier (2002), we often look at these potential choices as alternatives dictated by traditional values and social processes, or by the forms of transmission of technical know-how through apprenticeship. Our case-studies would suggest, within the above scenario, the effects of a well- defined technical trajectory, in that sequential slab construction may have involved a growing use of coils in the form of strips, applied to the pots' mouth. At

*Figure 9. In an experiment by students, at the experimental archaeology facility of Padua University, the mouth of slab-constructed bowls are fixed and stabilized with coils (M. Vidale).*

the same time, for the purpose of closing and consolidating the fragile slab-built bodies, the coils along the mouth were shaped and reinforced through the use of a rotating device. Whether the highly curated, finely figured pots of the transitional Chalcolithic of the Tehran plains produced by this *chaîne opératoire* were perceived as particular symbols of prestige or status, in the "trans-egalitarian" societies of the time (Vidale *et al.* 2018) will remain hard to understand.

## Conclusions: a matter of milk and butter?

The idea that a potter's wheel was a latent innovation in the technical repertories of the early agricultural communities of Middle Asia changes the picture. Everybody will remember that Vere Gordon Childe (1892-1957) had linked, through his emphasis on "Rotatory Motion" (1954, Chapter 9) the introduction of the potter's wheel to other important innovations such as the first wheeled wagons in central Europe, Central Asia and in the ancient Near East, and in perspective to the spread of copper technologies in the Bronze age. Similar statements were shared by A. Leroi-Ghouran (1993, 157). However, chronologically, even for Childe it was clear that in Egypt the potter's wheel was certainly used several centuries before a chariot was constructed (Doherty 2015; Nicholson and Shaw 2000, 125-126), while in Central Europe, north of the Alps, wagons appeared *c.* 3000 years before a substantial evidence of pottery mass-produced on the potter's wheel. In fact, the earliest wooden wheels for carts so far known in this region were found in Hungary

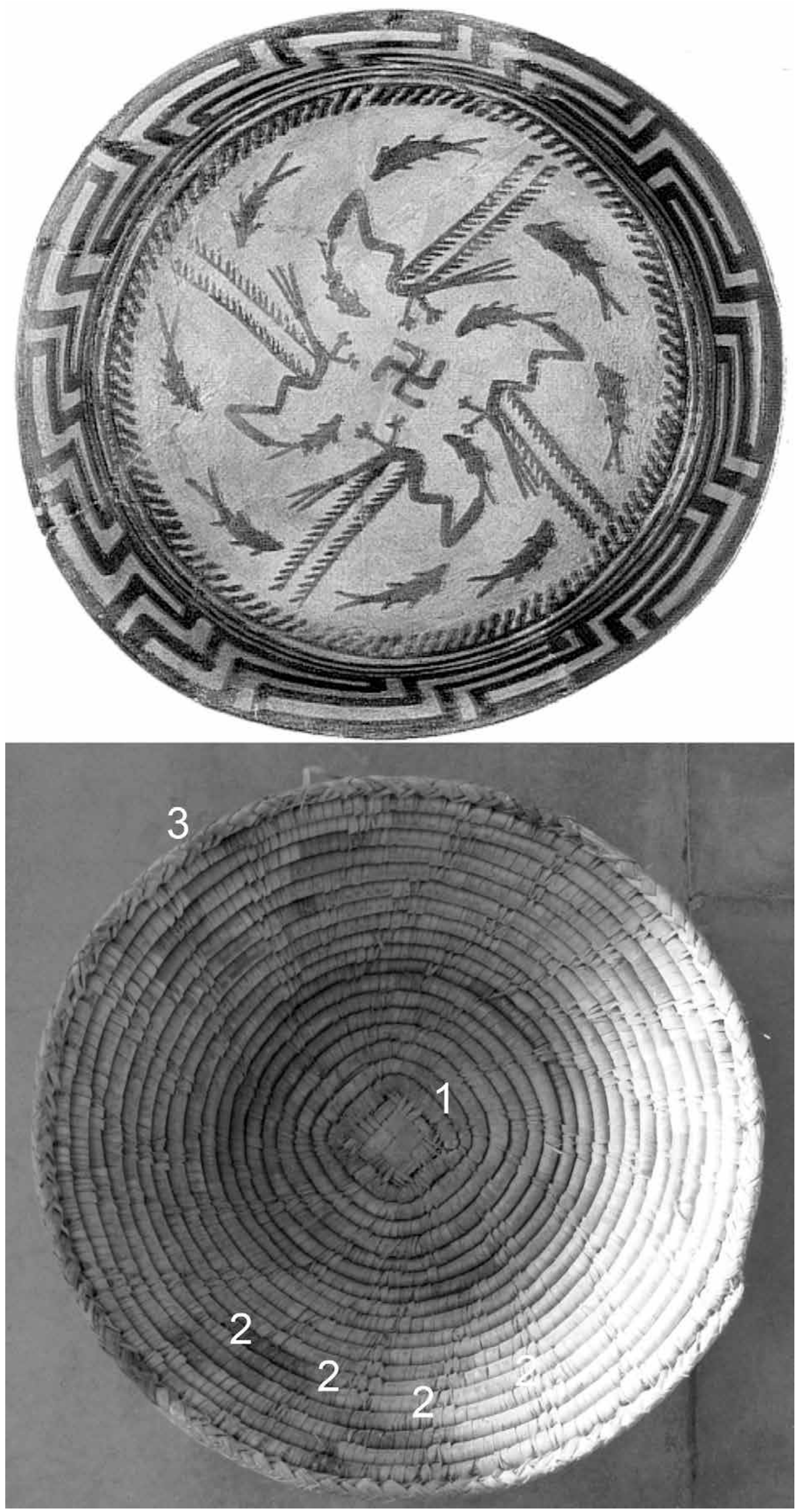


*Figure 10. A comparison between the baskets commonly used nowadays in the Swat valley (Khyber Pukhtunkhwa, Pakistan), below, and a famous bowl of the early Chalcolithic samarran production of upper Mesopotamia on exhibit at the Pergamon Museum, Berlin, above. (1), a square, swastika-like base is necessary to start building the basket; (2), oblique stitching, in a rotational arrangement, are required to fix the coils applied to form the walls; (3), the edge is strengthened with a braid-like twine, reflected, in the ceramic vessel, in a dynamic angular motif (M. Vidale).*

and Slovenia, in cemeteries of the Lengyel and Baden Aeneolithic cultures and are dated *c.* 3750-3500 BCE (Struhár *et al.* 2010). Thus, it is no surprise that Childe's correlations, in the light of current information, are no more tenable. What remains deeply inspiring and admirable in Childe's pages is the seminal reference to overlapping socio-technical cognitive networks and multiple cognitive links in the flows of technical innovation, today the focus of much speculation (among others, Flichy 1996; Roux 2011; Whitworth 2009; Pineda 2014; Woolgar ND).

Roughly speaking, the five millennia between 10000 and 5000 BCE gathered in the same permanent settlements, and inside the same resident communities, a thick maze of specialised technical knowledge that had no precedents. Quite different cognitive approaches and disparate technologies that had developed in restricted niches (such as the economic specializations of hunter-gatherers) must have started to cross-breed at an unusual intensity and speed, with important repercussions in advanced materials processing. A revealing example is the invention of dentistic surgery with stone-tipped drills in early Neolithic Mehrgarh (*c.* 7000-6000 BCE, Coppa *et al.* 2006), a technology exapted[6] from three millennia of previous specialised experience by microbeads makers and cutters of hard silicatic stones (Coşkunsu 2008). In this light, where should we search for the roots of such potter's wheels?

Perhaps in centrifugation, a technique that, once woven structures and strings were available, allowed for a fast and simple way of separating liquids from solid components. Centrifugation may involve fast rotation, while visualizing at the same time an irreversible fast change of state in the processed matters (liquid to solid). Its discovery and use, besides the controversial evidence of stone spheroids interpreted as bolas by middle Palaeolithic hunters (Jelinek 2013) has not be considered, as far as I know, in the literature on prehistory.

I propose, although on purely intuitive grounds, that the earliest evidence of wheel-turned pots in northern Iran might coincide with the still poorly explored early scenarios of Sherratt's (1981) "secondary products revolution" in the ancient Near East and Middle Asia (Greenfield 1984, 2010; see also Vigne and Helmer 2007; Evershed *et al.* 2008; Sudo 2010; Salque *et al.* 2012; Dunne *et al.* 2012). The invention of the potter's wheel might be linked to the introduction of rotatory churning of milk to make butter. In fact, at a cognitive level it is churning that, by the means of a substantial energy input and rotational movement, changes radically the state of a matter from a state (milk) to a completely different one (butter), as on the potter's wheel shapeless clay turns into a completely artificial, symmetric empty form. Such rotatory churns, however, being made of wood, would hardly be preserved in burial. Also, alternative churning techniques are well known, and the use in this craft of specialised ceramics (Morris 2013) is currently matter of investigation.

If wheel-throwing was invented in the framework of a "culturally-responsive human-technology interaction research and design" (Pineda 2014), contemporary Neolithic societies should have widely shared, among their cultural attitudes and values, the creation of totally new materials, consumable goods and aesthetics, at the cost of a general misalignment with previous cognitive frames. I suspect that in the 6th millennium BCE drilling, micro drilling, fire starting with a rotatory stick, the spindle turning with its whorl, the stone door's socket, rotational churning for making butter, and the technical ghost we are looking for – an early potter's wheel – were as many knots of a pervasive socio-technical network, that materialized in new forms. These implications are part of Childe's discussion on "Rotatory Motion", but from a renovated perspective.

In conclusion, the invention and adoption of the potter's wheel in the know-how of the ancient Near East and Middle Asia is still largely unexplored. Rather than belonging to a linear evolutionary trajectory, already described in

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6 In evolutionary biology, exaptation is the use a structure for a new function, other than that for which it was developed through natural selection.

form of "…a bumpy path marked by phenomena of continuity and discontinuity" (Laneri 2011, 64), it may be conceived as one of multiple threads supporting each other continuously spiralling in a thick braid of traditions, communities and tasks that developed in mutual influence along millennia of technical contamination.

We can try to re-trace some aspects and reflections of the mutual interference of diverse technical approaches, but, as made abundantly clear by current studies, some critical factors remain, the social contexts of use, visibility and communicative functions of wheel-thrown ceramics. For the moment, even the models we have of this process between the 4th and the 3rd millennia BCE are contradictory: at Shahr-i Sokhta, the mass production of a probable drinking vessel (turn to Fig. 2) for an enlarged early urban community; in the southern Levant and in Egypt, a production apparently sponsored by elite groups (within palaces and temples) for their self-representation in public rituals. While everybody now assumes that relationships between technology and society are not simple and unidirectional, the task of historical explanation remains complex, and broadening knowledge by the means of analytical investigations, as always, discourages the search for comfortable shortcuts.

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## References

Adriaens, A.M., Broekmans, T., Van As, B., Jacobs, L., Nieuwenhuyse, O. 2001. Making Samarra Fine Ware – Technological Observations on Ceramics from Tell Baghouz (Syria). *Paléorient* 27 (1), 147-165.

Amiran, R., Shenhav, D. 1984. Experiments with an Ancient Potter's wheel, in: Rice, P.M. (ed.). *Pots and Potters: Current Approaches in Ceramic Archaeology*. Los Angeles: University of California/Los Angeles Press, 107-112.

Berg, I. 2008. Looking through pots: recent advances in ceramics X-radiography. *Journal of Archaeological Science* 35 (5), 1177-1188.

Berg, I. 2011. Exploring the Chaîne Opératoire of Ceramics through X-Radiography, in: Scarcella, S. (ed.). *Archaeological Ceramics: A Review of Current Research*, BAR International Series S2193. Oxford: BAR Publishing, 57-63.

Buson, S., Vidale, M. 1983. The forming and finishing process of the pear-shaped beakers of Shar-i Sokhta: analysis of the relationships between technological and Morphological Evolution through Experimental Simulation. *East and West* 33, 31-52.

Carr, C. 1990. Advances in Ceramic Radiography and Analysis: Applications and Potentials. *Journal of Archaeological Science* 17, 13-34.

Carr, C. 1993. Identifying Individual Vessels with X-Radiography. *American Antiquity* 58 (1), 96-117.

Carr, C., Riddick, E.B. 1990. Advances in Ceramic Radiography and Analysis: Laboratory Methods. *Journal of Archaeological Science* 17, 35-66.

Cazzella, A., Desogus, P., Levi, S.T., Vidale, M. 1991. Applicazione di tecniche radiografiche allo studio della ceramica dell'età del bronzo, in: Burragato, F. Grubessi O., Lazzarini L. (eds.). *Atti del 1st European Workshop on Archaeological Ceramics (Roma 1991)*. Firenze: All'Insegna del Giglio, 415-420.

Childe, V.G. 1946. *What Happened in History*. London: Pelican Books.

Childe, V.G. 1954. Rotary Motion, in: Singer, C., Holmyard, E.J., Hall, A.R., Trevor, I.E., (eds.). *A History of Ancient Technology I: From Early Times to the Fall of Ancient Empire*. Oxford: Oxford University Press, 187-215.

Coppa, A., Bondioli, L., Cucina, A., Frayer, D.W., Jarrige, C., Jarrige, J.-F., Quivron, G., Rossi, M., Vidale, M., Macchiarelli, R. 2006. Early Neolithic tradition of dentistry. *Nature* 440, 755-756.

Courty, M.-A., Roux, V. 1995. Identification of Wheel Throwing on the Basis of Ceramic Surface Features and Microfabrics. *Journal of Archaeological Science* 22, 17-50.

Coşkunsu, G. 2008. Hole-making Tools of Mezraa Teleilat with Special Attention to Micro-borers and Cylindrical Polished Drills and Bead Production. *Neo-Lithics* 1, 25-36.

Dipilato, S., Laneri, N. 1998. Sequential Slab Construction and Other Problems Concerning Hand-Building Techniques in Chalcolithic Iran: Experimenting with Mammographic X-Ray Images, in: Milliken, S., Vidale, M. (eds.). *Craft Specialization: Operational Sequences and Beyond*, Papers from the European Association of Archaeologists Third Annual Meeting at Ravenna 1997, Vol. 4, BAR International Series S720. Oxford: BAR Publishing, 59-68.

Doherty, S.K. 2015. *The Origins and Use of the Potter's Wheel in Ancient Egypt*, Egyptology 7. Oxford: Archaeopress.

Dunne, J., Evershed, R.P., Salque, M., Cramp, Bruni, S., Ryan, K. Biagetti, S., di Lernia, S. 2012. First dairying in green Saharan Africa in the fifth millennium BC. *Nature* 486, 390-394.

Evershed, R.P., Payne, S., Sherratt, A.G., Copley, M.S., Coolidge, J., Urem-Kotsu, D., Kotsakis, K., Özdoğan, M., Özdoğan, A.E., Nieuwenhuyse, O., Akkermans, P.M.M.G., Bailey, D., Andeescu, R.-R., Campbell, S., Farid, S., Hodder, I., Yalman, N., Özbaşaran, M., Bıçakcı, E., Garfinkel, Y., Levy, T., Burton, M.M. 2008. Earliest date for milk use in the Near East and southeastern Europe linked to cattle herding. *Nature* 455, 528-531.

Fazeli, H., Djamali, M. 2002. The process of specialized ceramic production at Zagheh based upon the archaeological evidences and petrography studies, in: Azarnoush, M. (ed.). *The First Symposium of Archaeometry in Iran: The Role of the Sciences in Archaeology*. Tehran, 203-224.

Fazeli, H., Coningham, R.A.E., Batt, C. M. 2005. The Qazvin Plain Revisited: a Reappraisal of the Chronology of Northwestern Central Plateau, Iran, in the 6th to the 4th Millennium BC. *Ancient Near Eastern Studies* 42, 3-82.

Fazeli Nashli, H., Abbasnejad Seresti, R. 2005. Social Transformation and Interregional interaction in the Qazvin Plain During the 5th, 4th and 3th millennia B.C. *Archäologische Mitteilungen aus Iran und Turan* 37, 7-26.

Fazeli Nashli, H., Vidale, M., Bianchetti, P., Guida, G. 2010. The Evolution of Ceramic Manufacturing Technology During the Late Neolithic and Transitional Chalcolithic Periods at Tepe Pardis, Iran. *Archäologische Mitteilungen aus Iran und Turan* 42, 87-112.

Fazeli Nashli, H., Wong, E.H.Y., Azizi Kharanaghi, H. 2014. The Evolution of Specialized Ceramic Production during the Late Neolithic and the Transitional Chalcolithic Periods in the Qazvin and Tehran Plains (Iran), in: Lamberg-Karlovsky, C.C., Genito, B. (eds.). *'My Life is like the Summer Rose'. Maurizio Tosi e l'Archeologia come modo di vivere*, Papers in honour of Maurizio Tosi for his 70th birthday. BAR International Series S2690, Oxford: Archaeopress, 233-244.

Fiaccavento, C. 2013. Potters' Wheels from Khirbet Al-Batrawy: a Reconsideration of Social Contexts. *Vicino Oriente* XVII, 75-103.

Flichy, P. 1996. *L'innovazione tecnologica. Le teorie dell'innovazione di fronte alla rivoluzione digitale*. Milano: Feltrinelli.

Foster, G.M. 1959. The potter's wheel, an analysis of an idea and artifact in invention. *Southwestern Journal of Anthropology* 15 (2), 99-119.

Foster, G.V. 1983. Xeroradiography: Non-Invasive Examination of Ceramic Artifacts, in: England, P. A., van Zelst, L. (eds.). *Application of Science in Examination of Works of Art*, Proceedings of the Seminar, September 7-9, 1983. Boston: Museum of Fine Arts, 213-216.

Greenfield, H.J. 1984. A model of changing animal exploitation strategies during the later prehistory of the Central Balkans, in: Clutton-Brock, J.C., Grigson, C. (eds.). *Animals and archaeology, vol. 4, Husbandry in Europe*, BAR International Series S227, Oxford: BAR Publishing, 45-56.

Greenfield, H.J. 2010. The Secondary Products Revolution: The Past, the Present and the Future. *World Archaeology* 42, 29-54.

Jelinek, A.J. 2013. *Neanderthal Lithic Industries at La Quina*. Tucson: The University of Arizona Press.

Laneri, N. 1996. Analisi radiografica e macrostrutturale delle ciotole tronco-coniche dell'inizio del III millennio a.C., Shahr-i Sokhta (Iran). *Orient Express* 1996 (1), 17-19.

Laneri, N. 1997. Le coppe di Susa del Museo Pigorini, Roma. Analisi tecnologica attraverso l'indagine radiografica. *Contributi Materiali di Archeologia Orientale* 7, 177-205.

Laneri, N. 2009. *Biografia di un vaso: Tecniche di produzione del vasellame ceramico nel Vicino Oriente antico tra il V e il II millennio a.C.* Paestum: Pandemos.

Laneri, N. 2011. The Life-History of the Potter's Wheel in the Ancient Near East, in: Scarcella, S. (ed.). *Archaeological Ceramics: A Review of Current Research*, BAR International Series S2193, Oxford: BAR Publishing, 64-72.

Laneri, N., Dipilato, S. 1999. Searching for the Archaeological Evidence of Wheel-Throwing at Ebla, Susa and Shahr-i Sokhta, in: Taddei, M., De Marco, G. (eds.). *South Asian Archaeology 1997*, Vol. 1. Rome: Istituto italiano per l'Africa e l'Oriente, 521-540.

Laneri, N., Dipilato, S. 2000. From Slab Construction to the Potter's Wheel: An Evolution or a Trasformation? A Journey Across the History of Pottery Manufacturing Techniques in the Near East Between the Vth and the IInd Millennium BC, in: Matthiae, P., Enea, A., Peyronel L., Pinnock, F. (eds.). *Proceedings of the Ist International Congress on the Archaeology of the Ancient Near East.* Roma: Università di Roma La Sapienza, 773-780.

Laneri, N., Vidale, M. 1998. An Anatomy for the Truncated-Conical Bowls of Shahr-i Sokhta. *East and West* 48 (3/4), 225-264.

Lemonnier, P. (ed.). 2002. *Technological Choices: Transformation in Material Cultures Since the Neolithic*. London and New York: Routledge.

Leroi-Ghouran, A. 1993. *Evoluzione e Tecniche, vol. I, L'Uomo e la Materia.* Milano: Jaca Book.

Liverani, M. 1999. *Uruk la Prima Città*. Gius. Roma-Baro: Laterza & Figli.

Middleton, A.T. 1995. Integrated Approaches to the Understanding of Early Ceramics: The Role of Radiography, in: Fabbri, B. (ed.). *Fourth Euro-Ceramics. The Cultural Ceramic Heritage*, 3rd European Meeting on Ancient Ceramics, Vol. 14. Faenza: Gruppo editoriale Faenza editrice, 63-74.

Moorey, P.R.S. 1999. [1994]. *Ancient Mesopotamian Materials and Industries: The Archaeological Evidence*. Winona Lake: Eisenbrauns.

Morris, S.P. 2013. From Clay to Milk in Mediterranean Prehistory: Tracking a Special Vessel. *Backdirt* 2013, 70-79.

Mugavero, L., Vidale, M. 2003. The Use of Polychrome Containers in the Helmand Civilization: A Female Function? *East and West* 53 (1-4), 67-94.

Mugavero, L., Vidale, M. 2006. The Helmand Polychrome Wares as Skeuomorphs. Interlacing Pottery Making, Painting and Basketry. *East and West* 56 (4), 433-437.

Nadali, D., Polcaro,A. 2015. *Archeologia della Mesopotamia Antica.* Roma: Carocci Editore.

Nicholson, P.T., Shaw, I. (eds.). 2000. *Ancient Egyptian Materials and Industries.* Cambridge: Cambridge University Press.

Pineda, R.G. 2014. *Technology in Culture. A Theoretical Discourse on Convergence in Human-Technology Interaction*, Jyväskylä studies in computing 191, Academic dissertation. Jyväskylä: Jyväskylä University Printing House.

Pollock, S. 1999. *Ancient Mesopotamia. The Eden that Never Was*. Cambridge: Cambridge University Press.

Potts, D.T. 2012. *A Companion to the Archaeology of the Ancient Near East*. Chichester: John Wiley & Sons.

Pulitani, G., Caldana, I., Busato, R., Schiavon, F., Conti, G., Rampazzo, E., Vidale, M. 2017. Performances of (and on) the Greek Potter's Wheels: an experimental project. *EIDOLA, International Journal of Classical Art History* 14, 35-56.

Roux, V. 1994. La technique du tournage: définition et reconnaissance par les macrotraces, in: Audouze, F., Binder, D. (eds.). *Terre cuite et Société, Document Technique, Economique, Culturel*. Juan-les-Pins: APDCA, 45-58.

Roux, V. 2008. Evolutionary Trajectories of Technological Traits and Cultural Transmission: a Qualitative Approach to the Emergence and Disappearance of the Ceramic Wheel-Fashioning

Techniques in the Southern Levant, in: Stark, M.T., Bowser, B.J., Horne, L. (eds.). *Cultural Transmission and Material Culture. Breaking Down Boundaries*. Tucson: University of Arizona Press, 82-104.

Roux, V. 2011. Anthropological Interpretation of Ceramic Assemblages: Foundations and Implementations of Technological Analysis, in: Scarcella, S. (ed.). *Archaeological Ceramics: A Review of Current Research*, BAR International Series S2193. Oxford: BAR Publishing, 80-88.

Roux, V., Corbetta, D. 1990. *Le Tour du Potier. Spécialization Artisanale et Compétences Techniques*, Monographie du CRA n.4. Paris: Editions CNRS.

Roux, V., Courty, M A. 1998. Identification of Wheel-fashioning Methods: Technological Analysis of 4th-3rd Millennium BC Oriental Ceramics. *Journal of Archaeological Science* 25, 747-765.

Roux, V., Jeffra, C. 2015. The Spreading of the Potter's Wheel in the Ancient Mediterranean. A Social Context-Dependent Phenomenon, in: Gauss, W., Klebinder-Gauss, G., von Rüden, C. (eds.). *The Transmission of Technical Knowledge in the Production of Ancient Mediterranean Pottery*, Proceedings of the International Conference at the Austrian Archaeological Institute at Athens, 23rd – 25th November 2012, Österreichisches Archäologisches Institut Sonderschriften Band 54. Wien: Österreichisches Archäologisches Institut, 165-182.

Roux, V., de Miroschedji, P. 2009. Revisiting the History of the Potter's Wheel in the Southern Levant. *Levant* 41 (2), 155-173.

Rye, O.S. 1977. Pottery manufacturing techniques: X-ray studies. *Archaeometry* 19 (2) 205-211.

Rye, O.S. 1981. *Pottery Technology. Principles and Reconstruction*. Manuals on Archaeology 4.Washington D.C.: Taraxacum.

Salque, M., Bogucki, P.I., Pyzel, J., Sobkowiak-Tabaka, I., Grygiel, R., Szmyt, M., Evershed, R.P. 2012 Earliest Evidence for Cheese-making in the Sixth Millennium in Northern Europe. *Nature* 493, 522-525.

Sherratt, A. 1981. Plough and pastoralism: aspects of the secondary products revolution, in: Hodder, I., Isaac, G., Hammond, N. (eds.), *Pattern of the Past: Studies in honour of David Clarke*. Cambridge: Cambridge University Press, 261-305.

Simpson, S.J. 1997. Early Urban Ceramic industries in Mesopotamia, in: Freestone, I., Gaimster, D. (eds.). *Pottery in the Making. World Ceramic Traditions*. London: British Museum Press, 50-55.

Sterling, S. l. 2004. The Scale of Pottery manufacture during the Old Kingdom. *Aegyptos* 2 (4) 4-9.

Sudo, H. 2010. The Development of Wool Exploitation in Ubaid-Period Settlements of North Mesopotamia, in: Carter, R.A., Philip, G. (eds.). *Beyond the Ubaid. Transformation and Integration in the Late Prehistoric Societies of the Middle Eas*t, Papers from The Ubaid Expansion? Cultural Meaning, Identity and the Lead-up to Urbanism, International Workshop held at Grey College, University of Durham, 20-22 April 2006. Studies In Ancient Oriental Civilization 63. Chicago: The Oriental Institute of The University of Chicago, 169-179.

Struhár, V., Soják, M., Kučerová, M. 2010. An Aeneolithic copper yoked-ox statuette from the Lisková cave (northern Slovakia), in: Pavuk, P., Kalábková, P., Kovár, B., Jelinek, P. (eds.). *Panta Rhei*, Studies in Chronology and Cultural Development of the South-Eastern and Central Europe in Earlier Prehistory, Presented to Juraj Pavúk on the Occasion of his 75th Birthday, Studia Archaeologica et Mediaevalia 9. Bratislava: Comenius University in Bratislava and Archaeological centre, 449-467.

Thér, R., Toms, P. 2016. Quantification of the orientation and alignment of aplastic components of a ceramic body as a method for distinguishing among various means of using a rotational device in pottery forming. *Journal of Archaeological Science: Reports* 9, 33-43. 10.1016/j.jasrep.2016.06.048

Vandiver, P., Lacovara, P. 1985/6. An outline of technological changes in Egyptian pottery manufacture. *Bulletin of the Egyptological Seminar* 7, 53-85.

Vandiver, P. 1987. Sequential Slab Construction, A Conservative Southwest Asiatic Ceramic Tradition, ca. 7000-3000 B.C. *Paléorient* 13 (2), 9-35.

Vandiver, P. 1991. New Applications of X-Radiographic Imaging Technologies for Archaeological Ceramics. *Archaeomaterials* 5, 185-207.

Vidale, M., Desset, F. 2013. Mahtoutabad I (Konar Sandal South, Jiroft): preliminary evidence of occupation of a Halil Rud site in the early fourth millennium BC, in: Petrie, C.A. (ed.). *Ancient Iran and Its Neighbours: Local Developments and Long-range Interactions in the 4th Millennium BC*, British Institute of Persian Studies , Archaeological Monograph Series 3. Oxford: Oxbow Books, 233-252.

Vidale, M., Tosi, M. 1996. The Development of Wheel Throwing at Shahr-i Sokhta: Slow and Fast Revolutions Towards Statehood. *East and West* 46, 151-169.

Vidale, M., Fazeli, H., Desset, F. 2018. The Late Prehistory of the northern Iranian Central Plateau (c. 6000-3000 BC): growth and collapse of decentralised networks, in: Meller, H., Gronenborn, D., Risch, R. (eds.). Überschuss ohne Staat – Politische Formen in der Vorgeschichte, Tagungen des Landesmuseum für Vorgeschichte Halle (Saale), Band 18. Halle (Saale): Landesamt für Denkmalpflege und Archäologie Sachsen-Anhalt, Landesmuseum für Vorgeschichte, 1-44.

Vigne, J.-D., Helmer, D. 2007. Was Milk a "Secondary Product" in the Old World Neolithisation Process? Its Role in the Domestication of Cattle, Sheep and Goats. *Anthropozoologica* 42, 9-40.

Whitworth, B. 2009. The Social Requirements of Technical Systems, in: Whitworth, B., de Moor, A. (eds.). *Handbook of Research on Socio-Technical Design and Social Networking Systems*, Vol. II. InformatIon scIence reference: Hershey/New York, 3-21. DOI: 10.4018/9781605662640.ch001. https://www.researchgate.net/publication/314504381_The_Social_Requirements_of_Technical_Systems, accessed on November 2018.

Wodzińska, A. 2009. *A Manual of Egyptian Pottery, Volume 2: Naqada III-Middle Kingdom*, AERA Field Manual Series 1, Ancient Egypt Research Associates, Inc. Hollis: Puritan Press.

Woolgar, S. (ND) *Rethinking the Dissemination of Science and Technology*, 3th International Conference on Public Communication of Science and Technology (PCST), 10 – 13 April 1994 Mantreal, Canada. http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.616.914, accessed on November 2018.

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# Technological innovation. Defining terms and examining process through the talc-faience complex in the Indus Civilization

*Heather Margaret-Louise Miller*

## Abstract

Technological innovation in the Indus Civilization (3rd millennium BCE) involved both adoption and invention. I view invention and adoption as two components of the process of innovation, with the different pathways for (technical) knowledge transmission and reception by producers as well as different aspects of (cultural) knowledge and value in consumer adoption and demand serving as the linkages between invention and adoption. Archaeological approaches to these processes can focus on innovations in materials, knowledge, and/or skills, all of which are necessarily intertwined in the adjustments made by artisans to deal with issues affecting production or demand. I use examples from the Indus Valley talc-faience (steatite and siliceous paste) complex, as part of the larger western Eurasian faience or frit complex, to illustrate these ideas.

*Keywords: Innovation, Invention, Adoption, Transmission, Knowledge, Skills, Siliceous Paste, Faience, Talc, Steatite*

## Introduction

My paper explores approaches to the process of innovation, using the example of the ancient faience (or frit or siliceous paste) material complex, particularly in the Indus Civilization. My focus is on explicitly outlining my framework for the archaeological examination of innovation, including the definition of terms and the exploration of broad models of inter-regional exchange of knowledge related to innovation. I focus on general approaches to innovation, in terms of innovation in materials, knowledge and skill, rather than concentrating on specific investiga-

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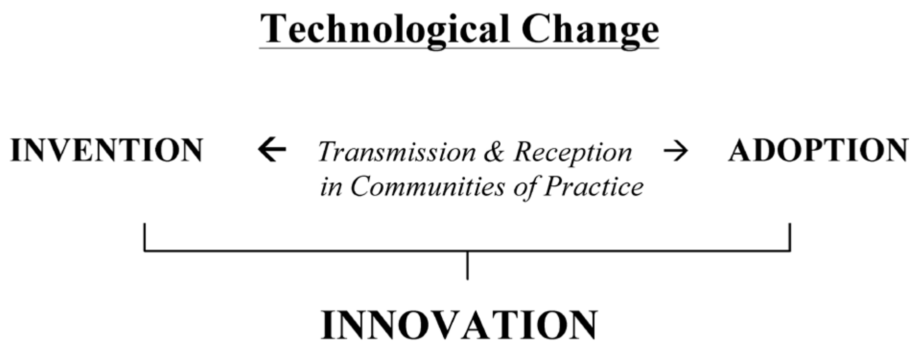


*Figure 1. Definitional Relations and Aspects of Technological Innovation.*

tions into the development of the talc-faience complex in the Indus Civilization; however, references to more specific studies are provided throughout.

Technological innovation in the Indus Civilization, one of the early urban Bronze Age civilizations of the third millennium BCE, certainly involved both adoption and invention, although the degree of each involved in specific cases would have varied. To begin by making my use of terms clear, I view invention and adoption as two components of the process of innovation. This terminology employs the definitions laid out for archaeologists by Torrence and van der Leeuw (1989, 3), which, greatly simplified, define invention as “the original conception of a new idea, behaviour or thing” and adoption as “the behaviour and actions involved in both the acceptance of and the use of what was invented”. Adoption in this definition includes both adoption within a society and adoption from outside of a society, which is often referred to as diffusion. In this terminology, innovation then refers to the entire process: the conception of an idea, its realization (in material or behavioural form), and its adoption by a group with whatever social, economic or political changes are required. Describing the process of innovation in this way allows us to make links between (archaeological) technological approaches to innovation, the focus of this volume, and approaches to innovation focused on knowledge transmission, including educational, psychological, and anthropological works on cross-cultural transmission and reception, as well as learning within a community of practice (*e.g.* Greenfield *et al.* 2000; famously, Lave and Wenger 1991; Wenger 1998).

Studies of invention tend to be focused on issues of design or concept and technique; essentially, a focus on production. In contrast, discussions of adoption, in the Torrence and van der Leeuw (1989) sense of adopted and incorporated inventions, necessarily are more concerned with the perspective of users of inventions, and society more broadly; that is, adoption, and perhaps innovation as a whole, tends to be focused on consumption issues, such as use or function, popularity or reasons for adoption, and social value of objects and the ideas those objects represent. Invention and adoption studies are thus as much intertwined and inter-nested as production and consumption studies, since producers and consumers typically influence each other. (See articles in Schiffer 2001 for more discussion, especially Kingery 2001; an earlier version of these ideas is also presented in Miller 2018). In both production and consumption, the processes of knowledge transmission and reception can serve as the linkages between invention and adoption (Fig. 1). This approach will be illustrated by examples from the perspective of both the production and consumption of faience objects during the third millennium BCE.

## Adoption and adaptation as innovation

The siliceous pastes or faiences of the third millennium encompass a complex of materials no longer in existence, materials used to make valued yet widely distributed items produced and consumed across western Eurasia for well over a millennium in their peak period alone. What these materials have in common is a lustrous, shiny, glazed surface. Like the later glasses and porcelains, many different recipes were used to make a similar-looking silica paste-based material that was fashioned into beads, figurines, small vessels, inlay, and other objects during the third and second millennia BCE across western Eurasia, notably in Egypt and Mesopotamia, but also Europe and the Mediterranean in the west and the Indus Valley in the east. These materials were created in a variety of colours, including white, black, red and especially blues to blue-green. Moorey (1999) provides an overview of these materials for Mesopotamia, and Nicholson (1998, 2000) offers an excellent entry into the extensive literature for Egypt, as the Egyptian faiences are the best-known and best-studied examples.

The materials in this complex are called by many names, including faience, Egyptian faience, composition, glazed composition, frit, paste and siliceous paste. (Vitreous silicates refer to a larger class, including other glazed materials and glass). Different names are habitually used in excavation reports for different regions, typically 'faience' in Egypt and the Indus, and 'frit' in Mesopotamia, complicating comparative studies. In the Indus, we must speak of this group of materials as belonging to the larger talc-faience complex due to the entwined nature of the faience materials with the use of talc or steatite in the Indus Civilization corpus.

The recipes for these artificial materials employed relatively abundant raw materials (silica, plant or mineral fluxes, and mineral colourants, primarily), which were hand-shaped or moulded, and then transformed at high temperatures (*c.* 900-1100 degrees Celsius) to a new material that was valued but also distributed across social and economic levels. Parallels can be drawn to some degree to the development of glass, of glazed pottery and porcelains, and of early plastics (Miller 2018), both from a production and a consumption perspective: in the continuous technological re-development of the materials themselves over time and space, as well as in the way that these materials were used to make goods that would be considered 'luxury goods' but that were distributed across a wide range of consumer groups.

In all three of the earliest civilizations, Egypt, Mesopotamia, and the Indus, the first material developed in this complex was a silica-based glaze over a talc or steatite stone core. (In the archaeological literature, especially in the Indus, talc and steatite are typically used interchangeably to refer to types of soapstone, usually white, that were relatively soft naturally, but would harden with firing). In all three regions, subsequent developments created what would become the most common version of these materials: glazed paste objects based on ground silica, produced by applying a wet or a dry glaze over a paste body, or by creating a paste body incorporating a glaze that effloresced out during firing. (Vandiver 1982 has an excellent basic discussion and illustration of the range of processes; Tite and Shortland 2008 provides important recent regional summaries).

While the use of the older glaze-over-stone method appears to become rare in most regions after the adoption of paste-based formulas, in the Indus steatite stone continues to be used to create stone beads with a siliceous glaze. This may relate to the fact that steatite was used extensively for millennia in the Indus region to make beads and small objects, and was an important material long before the development of faiences. In addition, some of the Indus siliceous paste objects also include steatite fragments within their siliceous base (Barthélémy de Saizieu 2003; Barthélémy de Saizieu and Bouquillon 1997; Bouquillon and Barthélémy de Saizieu 1995; Mackay 1931, 1938; Miller 2007, 2008 for summaries). Such an inclusion of steatite fragments in a siliceous paste body seems to be unique to the Indus, and forms an interesting case study in itself for variation in production, as discussed below. The diversity of material types within the Indus talc-faience (or steatite-faience) complex becomes even greater in the third and second millennia BCE, in terms of both material recipes and production techniques (*e.g.* Kenoyer 1994, 2005; Vidale 1986, 1987, 2000; Miller 2007; Uesugi *et al.* 2017). Nevertheless, these materials still appear very similar in appearance, although there are visible gradations in quality between individual objects, as seen in attributes like density, strength and glossiness or lustre. They thus form an excellent archaeological example for examinations of the process of innovation.

At a broad scale, then, what can we say about the production and consumption processes associated with the faience complex throughout western Eurasia? What was involved in the spread of these materials and their manufacture? For example, were the diversity of recipes and production techniques used to make these materials a by-product of separate, independent development to fit desires in each region for a lustrous material formed like pottery but firing to look like colourful stone? Or were the different recipes and techniques a response to the presence of somewhat different raw materials easily available in each region? Were craftspeople working independently and secretly, with producers in other regions trying to break into their craft secrets, as in the history of glass and porcelains, or was there widespread exchange of information but a diversity of local production material, technique and application solutions to fit local conditions and desires?

It seems likely that the development of the faience complex in western Eurasia involved at the very least inspiration through exchange of finished objects between Mesopotamia, Egypt and/or the Indus as part of a shared inter-cultural network, if not acquired or obtained production knowledge. Isolated, independent invention of an artificial silica-based material at approximately the same period in all these regions is extremely unlikely. People across western Eurasia were clearly interested in these materials, and used them to make beads, figurines and small containers. Thus, from a consumption point of view, this new material was desired and adopted across this large region. This is a good example of how adoption would certainly qualify as innovation, justifying the use of Torrence and van der Leeuw's (1989) terminology. Producers would have to invent or adapt production methods for such objects to their local raw materials, skills, and knowledge, while consumers would have to fit these new materials into their existing value hierarchies, including their use for status display (see Miller 2007, 203-226 for an in-depth example).

We could describe this new complex of materials as being 'adopted independently', though, in several senses. From the consumer perspective, we can see similarities but also regionally-specific uses or forms of consumption. Although in general faience complex materials were used in most places to make ornaments, small vessels, and figurines that were likely amulets, the faiences were also used in somewhat different ways in different regions, to make different types of locally or regionally desired objects. For example, while faience beads were found everywhere, bangles and tokens/sealings were made of faience in the Indus but not elsewhere; in contrast, there was a much greater use of these materials for figures and inlay and containers in Egypt than in the Indus. Consumers in the two societies were adopting the materials in different ways.

Producers would need to be attuned to these local consumer desires and expectations. They likely also played a role in creating local demand through their local adaptations and inventions within the complex. An example of this relates to the Indus faience bangles mentioned above. A very thorough archaeometric study of two dozen Indus Civilization-period faience objects was done by McCarthy and Vandiver (1990) with a focus on the special case of Indus faience bangles (bracelets or sometimes anklets made in the form of a rigid circle). Creation of a bangle shape in this material would form a challenge, as the material would need to resist impacts, abrasions and crack propagation while in a rather thin circular form with a hollow center. A few of these bangles even had deeply cut incisions to create a pattern along the outer surface, adding to the structural challenges of developing a fired siliceous material capable of maintaining such a shape in a wearable ornament (Fig. 2). McCarthy and Vandiver (1990; McCarthy 2008) found that the Indus bangles were made with a special fritted faience paste formed by cycles of heating to near melting,

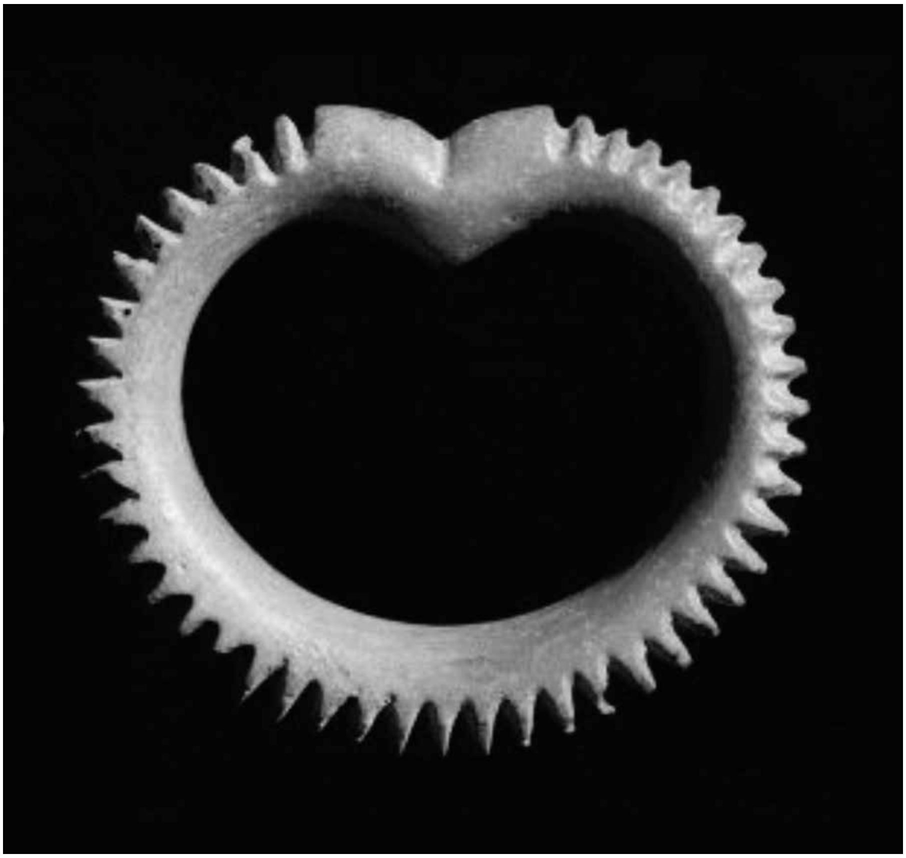

*Figure 2. Example of Indus faience bangle with deeply incised edge decoration. (Courtesy D. Frenez/J.M. Kenoyer).*

grinding to a powder, and re-heating and re-grinding. This special fritted faience provided the necessary strength and resistance to breakage needed for objects like bangles. The tradition of wearing bangles has a great time depth in the Indus Valley region, pre-dating the Indus Civilization and continuing to the modern era. Bangles were made from a variety of materials during the Indus period, including shell, copper, and clay-based terracotta and stoneware. It is not surprising that there would have been interest in producing bangles out of faience. Producers responded to such consumer desires, or anticipated it, by using this more complex faience paste production method, one of several recipes and techniques in use in the Indus at the time. McCarthy and Vandiver (1990) stressed that this Indus fritted faience production method produced a quality of faience not seen in Egypt until the later New Kingdom era, which would seem to indicate an independent invention of this particular recipe and technique by producers in the third millennium Indus Civilization for this special purpose, whether earlier faience recipes and materials were adopted in earlier periods from other regions or not.

From a production perspective, then, these materials were 'adopted independently' in the sense that knowledge of techniques of production and raw materials used by craftspeople likely came through many different pathways, as discussed in Miller (2018). Local independent invention of production techniques may have been inspired by the desire to copy a traded end-product, or by the desire to translate a material already adopted from elsewhere into a locally-desired form or use, as seems likely in the Indus bangle case above. Development and adoption of these materials locally may have come with migrating or itinerant or imported craftspeople; or there may have been deliberate attempts to acquire knowledge from others by local producers – by observation or apprenticeship elsewhere and return, or through stories of production methods elsewhere, or even targeted attempts to steal craft secrets as seen in historic periods for glass and porcelains. Knowledge acquisition associated with the transfer of people/knowledge might look different in terms of similarity of production techniques in the two areas than the transfer of objects alone, but this can be complicated by the need for knowledgeable producers to adapt to local raw materials or to develop new techniques to fill local consumer desires, as discussed above. Similarly, independent invention of production techniques might be deceptively similar if there are relatively few options for creating the object or material; this complication is unlikely to be an issue for the highly flexible faience material complex, but other technologies may need to be aware of the possibilities of parallel development as an alternative to adoption.

## Invention – or retention? – as innovation

Would Indus fritted faience be an adaptation of an adopted material, or an invention in its own right? Both of course, depending on the scale examined, whether from the perspective of the faience complex as a material compared to other materials (such as clay-based stonewares or porcelains, for example), or whether focused on the development of specific regional or use types within the faience complex. This is why the Torrence and van der Leeuw definition of innovation is so useful, as it provides a way for archaeologists to use the term innovation to cover cases where technological change may be viewed differently from different perspectives, or where we simply do not know enough yet about the process to determine what occurred during the change.

Fritted faience is not the only unusual Indus Civilization faience type; as mentioned above, the Indus faiences also included a type that incorporated steatite powder into their siliceous paste bodies, the 'steatite-faiences'. As noted, with the shift to paste bodies, the use of talcose or steatite stone as the base body for siliceous glazed objects seems to largely disappear outside the Indus region. In the Indus, however, we continue to see objects with a solid talc body and a siliceous glaze, along with the variety of siliceous pastes. Some of these pastes also include steatite fragments embedded within the siliceous base, and this last material appears to be found only in the Indus (Barthélémy de Saizieu 2003; Barthélémy de Saizieu and Bouquillon 1997; Bouquillon and Barthélémy de Saizieu 1995; Mackay 1931, 1938; Miller 2007, 2008 for summaries). We do not know if this particular steatite-faience recipe is common or rare in the Indus corpus. The researchers listed above who have done analytical work on this material have stressed that it appears identical to other Indus faience recipes even under low magnification, and objects were identified as made from steatite-faience only after analytical work. While Barthélémy de Saizieu and Bouquillon were primarily focused on beads for their studies across several periods of the Indus tradition in the western borderlands, Mackay specifically notes that steatite-faience material was found in a range of different types of objects from the Indus Civilization period at the city of Mohenjo-daro. The fact that McCarthy and Vandiver (1990) did not find it in their study focused primarily on bangles from the Indus Civilization period urban site of Harappa, however, implies that this material was not suitable for the special requirements posed by bangles.

Why then do some of the Indus siliceous pastes contain talc/steatite fragments, especially as these fragments are invisible in the completed object to the consumer and even to the producer? Is there a technological reason related to production properties, or an ideological reason related to retaining the important essence of steatite in these new materials? I was unable to conceive of a technological reason for such steatite inclusions, especially as within the Indus as well as beyond it, most faience recipes do not contain talc inclusions. The objects containing talc fragments do not appear to be more structurally complex than those without; on the contrary, the most structurally complex objects, elaborate bangles, use a special fritted recipe that contains no steatite (McCarthy and Vandiver 1990). Aside from these bangles, though, Mackay's comments indicate that steatite-faience was apparently used for much the same range of objects as other common siliceous paste recipes, and was not associated with specific types of objects requiring special technical compositions. Recent experimental work by Kenoyer, however, has shown that there could well be technological, production reasons for the addition of talc/steatite to some types of Indus faience. Kenoyer found a significant improvement in the workability of the unfired material when a proportion of steatite powder was added to his usual experimental siliceous pastes, making it much easier to form and shape the desired objects (see Miller and Kenoyer 2018). The addition of steatite powder reduced crumbling of the paste and created a smoother surface, and workability actually improved with increased handling and shaping of the material, likely because the talc particles aligned. There is thus a strong case for a definite tactile value for producers in the addition of a small amount of talc powder to faience to increase workability, with relatively little visual change to the final objects as long as the talc powder was kept to a small proportion.

So why was this technique not used for all objects made from Indus faience? And why does it not seem to have been adopted elsewhere at all? There is no mention of such a material for Egypt, where considerable analysis has been done on faiences throughout many time periods. In terms of restricted use in the Indus, there may have been trade-offs in the use of talc powder to improve workability in Indus faiences. The exact nature of potential problems requires more experimental and archaeometric research, but some possibilities for investigation include changes to the colour or lustre of the final material, negative effects on the strength of the material compared to the fritted faience, or difficulties in use of efflorescence glazing techniques. In other regions, alternative materials and recipes with improved workability may have been more easily available (*e.g.* natron in Egypt, perhaps?), or alternate production techniques such as production in moulds rather than modelling by hand may have been preferred, so that talc powder was not useful. Michelaki *et al.*'s (2015) interesting recent ideas about taskscapes may also be of use here; among other points, they propose that particular raw materials were used to make Neolithic Italian pottery because these materials were adjacent to other resources being collected, even though very suitable raw materials that were not used were not far away. Given the widespread use of talc stone to make many artefacts of the Indus Civilization, the easy availability of steatite powder from fellow craftspeople in the Indus settlements may have made it a useful addition for faience producers when and where it was easily available, but dispensable when it was not. At this point in our research, however, improved workability must be considered as a probable explanation for the addition of talc/steatite particles to some Indus faiences by producers.

I would argue, though, that the improved production aspect of the addition of steatite powder does not preclude other additional explanations for its presence in some Indus faience recipes. There have been frequent discussions about the importance of talc as a material for the Indus people, for whom it seems to have had specific representational significance (*e.g.* Kenoyer 1998; Vidale 2000; see Miller 2007, 209-211, 217-225 for a summary). We know that talc is an important material for the Indus Valley Tradition from the sixth millennium BCE or earlier, and steatite stone bases never completely leave the faience complex in the Indus, unlike other regions. Steatite in its white, fired form seems to have played an important role in the Indus tradition, with particular social and perhaps ritual meanings, given its extensive use over many millennia, particularly for beads, as well as its central use for Indus Civilization seals. A remarkable property of talc stone is that although it is soft and multi-coloured in its natural state, when heated to high temperatures (above 1000°C), all types of talc become hard and many become bright white (Law

2008). This striking material transformation may have given steatite a special significance for the Indus; other new materials valued by Indus people were also transformed by heat (Vidale and Miller 2000; Miller 2007), including the lustrous, brightly coloured faiences made from quartz and mineral dusts discussed here; black chert-like stoneware bangles made from tan-coloured clay (Vidale 1990), and even the reddening of the natural red agates highly valued by the Indus peoples (Kenoyer *et al.* 1994; Roux and Matarasso 1999). A regard for colour transformation alone does not provide a complete explanation of apparent Indus values; note that most of these materials above also became harder, and sometimes lustrous. The relative indifference of Indus people to lapis and even turquoise, as well as their restricted use of shell, can be explained by the Indus esteem for materials transformable in colour and nature (hardness) by heat, and for materials with high reflectivity or shine. The use of steatite in particular seems to relate to an 'Indus' identity, as has been said by many Indus scholars since the very first studies of the civilization in the 1920s and 1930s. Indus steatite-faience could combine esteem for heat-transformed materials, the desire for specific colours and high shine, and the Indus-specific value for steatite as (apparently) a symbol of Indus identity.

The same problem confronts us for this explanation as for the technical workability explanation for the presence of steatite-faience recipes. If steatite is so important, why is the addition of steatite not more widespread in the Indus recipes, at least as far as we know? Is it an issue of the difficulties for some recipes when steatite is added, so that the other desires – for colour, transformation, and shine – take priority? In this case, is a technological effect modifying a social or ritual desire? That is, are two desires being balanced? From a producer point of view, the addition of steatite powder to faience recipes may have greatly aided workability during forming, particularly for certain recipes, although this had to be balanced with effects on other attributes of firing. From a consumer point of view, Indus steatite-faience was a brightly coloured, heat-transformed material with a highly lustrous surface, that also contained, invisible but important, an essence of steatite, that material of Indus-specific value. Could both the producer and consumer perspectives and valuations be true? This is an important option to consider beyond the usual oppositional approach to production and consumption answers for material choices. And it brings us back to my interest in why such a diversity of recipes may have developed in this region, with this one specific example of steatite-faience alone providing so many possibilities and research questions.

In sum, the faience or siliceous paste material complex provides an excellent case study for the topic of technological innovation, because of the variety of production methods employed across time and space, the variety of similar yet culturally distinct uses of these materials, and also the extensive opportunities for both invention and adoption, given the known trading and social ties across western Eurasia and beyond during this time period. These terms and approaches to the study of innovation are useful for many other materials and products, though, and will hopefully be of use to others in their research.

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Many thanks to Michela Spataro for her invitation to this invigorating conference, and her impressive patience with my submission delays. I also thank the many colleagues who have discussed these issues of Indus technological innovation over the years – too many to individually thank, but all remembered with gratitude. I am especially indebted to the colleagues and collaborators whose work is cited in this paper.

## References

Barthélémy de Saizieu, B. 2003. *Les parures de Mehrgarh: perles et pendentifs du néolithique précéramique à la période pré-indus: fouilles, 1974-1985.* Paris: Editions recherche sur les civilisations: Association pour la diffusion de la pensée française/Ministère des affaires étrangèrs.

Barthélémy de Saizieu, B., Bouquillon, A. 1997. Evolution of glazed materials from the Chalcolithic to the Indus period based on the data of Mehrgarh and Nausharo, in: Allchin, R., Allchin, B. (eds.). *South Asian Archaeology 1995*, 2 Vols, Proceedings Of The 13th Conference Of The European Association Of South Asian Archaeologists, 05 – 09 July 1995 Cambridge. Oxford: IBH. Volume 1, 63-76.

Bouquillon, A., Barthélémy de Saizieu, B. 1995. Découverte d'un nouveau matériau dans les parures de la période pré-Indus de Mehrgarh (Balochistan): la "faïence" de stéatite'. *Techne: la science au service de l'histoire de l'art et des civilisations. Autoportrait d'un laboratoire, le Laboratoire de recherche des musées de France* 2, 50-55.

Greenfield, P.M., Maynard, A.M., Childs, C.P. 2000. History, culture, learning, and development. *Cross Cultural Research,* 34 (4), 351-374.

Kenoyer, J.M. 1994. Faience from the Indus valley civilization. *Ornament* 17 (3), 36-39, 95.

Kenoyer, J.M. 1998. *Ancient Cities of the Indus Valley Civilization*. Karachi: Oxford University Press/American Institute of Pakistan Studies.

Kenoyer, J.M. 2005. Steatite and Faience Manufacturing at Harappa: New Evidence from Mound E Excavations 2000-2001. *Museum Journal (National Museum of Pakistan)* III-IV (Jan-Dec 2002), 43-56.

Kenoyer, J.M., Vidale, M., Bhan, K.K. 1994. Carnelian Bead Production in Khambhat, India: An Ethnoarchaeological Study, in: Allchin, B. (ed.). *Living Traditions. Studies in the Ethnoarchaeology of South Asia.* Oxford: IBH Publishing Co. Pvt. Ltd., 281-306.

Kingery, W.D. 2001. The Design Process as a Critical Component of the Anthropology of Technology, in: Schiffer, M.B. (ed.). *Anthropological Perspectives on Technology.* Albuquerque: University of New Mexico Press, 123-138.

Lave, J., Wenger, E. 1991. *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.

Law, R.W. 2008*. Inter-regional interaction and urbanism in the ancient Indus Valley: a geologic provenience study of Harappa's rock and mineral assemblage.* Thesis (PhD), Department of Anthropology, University of Wisconsin-Madison. Ann Arbor, Michigan: Proquest/UMI Microfilms.

Mackay, E.J.H. 1931. Ivory, shell, faience, and other objects of technical interest, in: Marshall, J. (ed.). *Mohenjo-daro and the Indus Civilization*. London: Arthur Probsthain. Volume 2, 562-588.

Mackay, E.J.H.,1938. *Further excavations at Mohenjo-daro. Being an official account of Archaeological Excavations at Mohenjo-daro carried out by the Government of India between the years 1927 and 1931.* Delhi: Government of India Press.

McCarthy, B. 2008. Faience in Ancient South Asia, in: Selin, H. (ed.). *Encyclopedia of the History of Science, Technology and Medicine in Non-Western Cultures,* Second Edition. Berlin/New York: Springer, 915-917.

McCarthy, B., Vandiver, P.B. 1990. Ancient high-strength ceramics : fritted faience bracelet manufacture at Harappa (Pakistan), ca. 2300-1800 B.C., in: Vandiver, P.B., Druzik, J., Wheeler, G.S. (eds.), *Materials issues in art & archaeology II*, Symposium, 17 – 21 April 1990 , San Francisco, California, Materials Research Society Symposium Proceedings 185. Pittsburgh: Materials Research Society, 495-510.

Michelaki, K., Braun, G.V., Hancock, R.G.V. 2015. Local Clay Sources as Histories of Human-Landscape Interactions: a Ceramic Taskscape Perspective. *Journal of Archaeological Method and Theory* 22, 783-827.

Miller, H.M.-L. 2007. *Archaeological Approaches to Technology.* Walnut Creek: Left Coast Press.

Miller, H.M.-L. 2008. The Indus Talc-Faience Complex: Types of Materials, Clues to Production, in: Raven, E. (ed.), *South Asian Archaeology 1999*, Proceedings of the 15th International Conference of the European Association of South Asian Archaeologists, 05 – 09 July 1999 Universiteit Leiden. Gonda Indological Studies 15. Leiden: International Institute of Asian Studies (IIAS), 111-122.

Miller, H.M.-L. 2018. Invented, Adopted, Inspired, Acquired, Obtained? Technological Change and the Talc-Faience (Siliceous Paste) Complexes of the Indus Valley Tradition, in: Bentz, M., Helms, T. (eds.). *Craft production systems in a cross-cultural perspective*, Studien zur Wirtschaftsarchäologie 1. Bonn: Dr. Rudolf Habelt GmbH, 209-214.

Miller, H.M.-L., Kenoyer, J.M. 2018. Invisible Value or Tactile Value? Steatite in the Faiences of the Indus Valley Tradition, in: Frenez, D., Jamison, G.M., Law, R.W., Vidale, M., Meadow, R.H. (eds.). *Walking with the Unicorn: Social Organization and Material Culture in Ancient South Asia,* Jonathan Mark Kenoyer Felicitation Volume. Oxford: Archaeopress, 389-394.

Moorey, P.R.S. 1999 [1994]. *Ancient Mesopotamian Materials and Industries: The Archaeological Evidence.* Winona Lake: Eisenbrauns. Reprint of 1994 volume of same name published. Oxford: Clarendon Press.

Nicholson, P.T., 1998. Materials and Technology, in: Friedman, F.D., Borromeo, G. (eds.). *Gifts of the Nile. Ancient Egyptian Faience.* London: Thames and Hudson, 50-64.

Nicholson, P.T. (with Peltenburg, E.) 2000. Egyptian Faience, in: Nicholson, P.T., Shaw, I. (eds.). *Ancient Egyptian Materials and Technology.* Cambridge: Cambridge University Press, 177-194.

Roux, V., Matarasso, P. 1999. Crafts and the Evolution of Complex Societies: New Methodologies for Modeling the Organization of Production, a Harappan Example, in: Dobres, M.-A., Hoffman, C.R. (eds.). *The Social Dynamics of Technology. Practice, Politics, and World View*. Washington DC: Smithsonian Institution Press, 46-70.

Schiffer, M.B. (ed.). 2001. *Anthropological Perspectives on Technology*. Albuquerque: University of New Mexico Press.

Tite, M.S., hortland, A.J. 2008. *Production Technology of Faience and Related Early Vitreous Materials.* Oxford, Oxford University School of Archaeology.

Torrence, R., van der Leeuw, S.E. 1989. Introduction: what's new about innovation?, in: van der Leeuw, S.E., Torrence, R. (eds.). *What's New? A closer look at the process of innovation*, One World Archaeology 14. London: Unwin Hyman, 1-15.

Uesugi, A., Nakai, I., Kumar, M., Yamahana, K., Abe, Y., Shirataki, J., Toyama, K., Dangi, V. 2017. A Study on Faience Objects in the Ghaggar Plains during the Urban and Post-Urban Indus Periods. *Heritage: Journal of Multidisciplinary Studies in Archaeology* 5, 140-164.

Vandiver, P. 1982. Technological change in Egyptian faience, in: Olin, J.S., Franklin, A.D. (eds.). *Archaeological Ceramics.* Washington DC: Smithsonian Institution Press, 167-179.

Vidale, M. 1986. Steatite cutting on glazing: relational aspects of two technological environments in Harappan urban contexts. *East and West* 36/4, 520-525.

Vidale, M. 1987. The paste plaques and cylinders of Chanhudaro: a descriptive report. *Annali (Estratto da Annali dell'Istituto Universitaro Orientale, Napoli)* 47, 57-66.

Vidale, M. 1990. Stoneware Industry of the Indus Civilization: An Evolutionary Dead-End in the History of Ceramic Technology, in: Kingery, W.D. (ed.). *The Changing Roles of Ceramics in Society: 26,000 B.P. to the Present*, Ceramics and Civilization, Volume V. Westerville: The American Ceramic Society Inc., 231-254.

Vidale, M. 2000*. The archaeology of Indus crafts. Indus craftspeople and why we study them.* Rome: Istituto Italiano per l'Africa e l'Oreinte (ISIAO).

Vidale, M., Miller, H.M.-L. 2000. On the development of Indus technical virtuosity and its relation to social structure, in: Taddei, M., De Marco, G. (eds.). *South Asian Archaeology 1997*, Proceedings of the 14th International Conference of the European Association of South Asian Archaeologists, 07 – 14 July 1997 Istituto italiano per l'Africa e l'Oriente, Palazzo Brancaccio, Rome. Rome: Istituto Italiano per l'Africa e l'Oriente (IsIAO)/Istituto Universitario Orientale Naples,115-132.

Wenger, E. 1998. *Communities of Practice: Learning, Meaning, and Identity.* Cambridge: Cambridge University Press.

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# Skill in high-temperature crafts. An artisanal perspective on fire

*Katarina Botwid*

## Abstract

Within high-temperature crafts there is knowledge that connects different technologies. Can this knowledge be utilized to pinpoint key features of the introduction of new technologies within a crafting community? Is it even possible to distinguish between skilful or lesser skilled high-temperature users? I am going to explain my ideas and theories about how to approach technological innovations in order to explain technological leaps and levels of skill in prehistoric Europe. This paper will address craft questions from an artisanal position, based on craft theories and archaeological experiments. I will provide a scientific artisanal view on the introduction of new innovative techniques and artefacts on metal-crafting in the Late Bronze Age (Sweden). This paper will hopefully contribute to an interesting discussion on how improvement, innovation and collaboration allow for more reliable archaeological interpretations.

*Keywords: skill, artisanal perspective, Bronze Age, technological innovation, high-temperature, craft, ceramics, metal, declarative knowledge, silent knowledge*

## Introduction

Different scientific fields and subjects tend to communicate in certain ways. According to my theoretical standpoint the answer to the question, "Can contemporary craft knowledge be utilized to pinpoint key aspects in the introduction of new technologies within an ancient crafting community?" would be "YES!"

Every researcher starts somewhere and, in my own experience, ceramic art was a way to express myself. In the process of learning to create ceramic art, it was of great importance to me to be a part of an artisanal tradition of ceramists. Later on, this experience-based knowledge was applied to the field of archaeology where I began to express myself in the academic arena. As an educated ceramist and archaeologist, I have an interesting role working as a consulting expert coop-

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erating in different collaborations and fields. This interdisciplinary position needs a theoretical framework and methods for conducting artisanal interpretations. This article starts by presenting theories and methods. After this, a brief research background will be given and questions concerning high-temperature skill will be addressed. The results of one experiment concerning high-temperature use and the traces this technology has left behind or shed light upon will be put forward from an artisanal skill perspective, and in conclusion, some of the traces of new technology in a specific prehistoric context will be explained and highlighted.

## Theories and framework

Harry Collins and Robin Evans (UK), researchers in social sciences, point out that there are ways to achieve a specific understanding of a practitioner's contribution to science (Collins and Evans 2002; 2007; 2014). The silent (practitioner's) knowledge must be accepted as knowledge in its own right. To be able to assure that the communication between practitioners and scientists is open-minded and respectful, new ways of understanding are needed. In this work it is necessary to clear or untangle communication between scientific fields. The aim is to visualise how often we (archaeologists and artisans) reach out to other fields for qualified analysis or verify our interpretations. There are some similarities: artisans often turn to natural science, as do archaeologists (Fig. 1, left).

Artisans and archaeologists do not meet regularly, perhaps because of the lack of a natural arena to do so, or because of the differences of social and/or cultural statuses between them and the alienation caused by this. This description is of course, simplified and generalised, but still needs to be taken into account. Why, then, do archaeologists so rarely design experiments and/or workshops together with artisans that carry with them valuable technical and practical knowledge? Archaeology, craft and science would all reap the benefits from trying to reconsider and change this condition. Working with theories about practical knowledge (Botwid 2009a; 2009b; 2014; 2016) and considering how such knowledge could be seamlessly introduced into the theoretical arena is clearly a path that is closed to the "third wave" of social science. *The Third Wave of Science Studies: Studies of Expertise and Experience* published and written by Collins and Evans (2002, 250-59) provoked many researchers in the scientific and academic community. By starting to address questions about how to re-think expertise and introduce concepts such as *interactive* or *contributory expertise* or so-called *uncertified expertise* (Collins and Evans 2000, 254), the authors also called for a new categorisation in, or of, science. The presented kind of experience-based expertise originates from working in generations of practise or being trained in terms of a master-apprentice relationship, where the knowledge is very specialised. Collins and Evans are aware that different languages (verbal/non-verbal) can be a hindrance and therefore call for what they term "translators". In my roles as archaeologist and skilled practitioner (with expertise in the craft of ceramics), I have addressed that challenge and have therefore been taking on the role between crafting and archaeology (in a contemporary Swedish theoretical discourse "craft science" [Almevik 2017]).

After considering what can be gained from such an exercise, I describe my own particular vision and view of fields connected in the artisanal perspective (Fig. 1, right) and present a case study concerning high-temperature skill and new technology. The disciplines overlap and cannot always be separated. Collaborations are a possibility in global interactive research more than ever before, and science cannot afford to exclude any kind of knowledge.

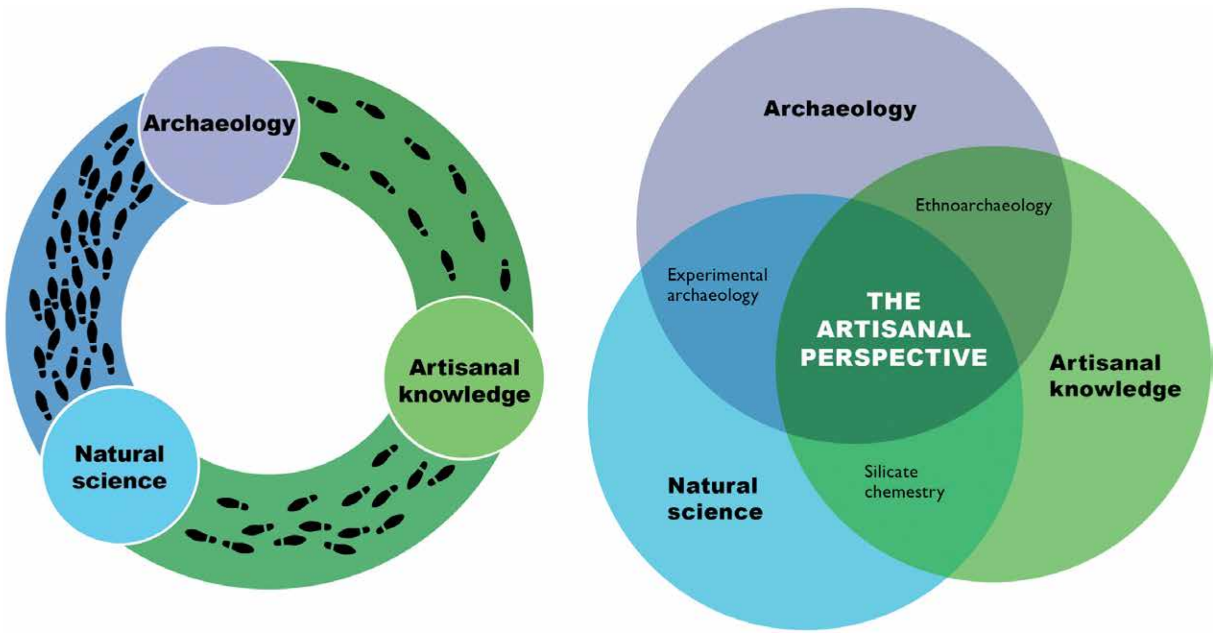


*Figure 1. The author's present view of collaboration within archaeology (left) followed by a diagram of the connecting fields viewed from the contemporary academic arena (right). In the middle of this, the artisanal perspective is striving to communicate with all fields (illustrations © Henning Cedmar Brandstedt 2018).*

## Artisanal interpretation

The method *artisanal interpretation* is used to examine artefacts and is developed in my earlier work (Botwid 2009a; 2009b; 2013; 2016). It is based on theories about tacit or silent knowledge. These forms of knowledge are explored within the fields of epistemological philosophy (Molander 1996), practical knowledge (Pye 1968) and in pedagogical research (Gustavsson 2002). Some research refers to this kind of knowledge as embodied knowledge, meaning that it is not possible to learn without practicing it until it gets into an individual's own physical motions, and becomes part of them (Polanyi 1966, 13); they react instinctively and immediately, without thought. This kind of knowledge is, of course, relevant in all practical work. The artisanal interpretations of the skill of ancient artisans, especially concerning ceramics, makes it possible to "read" the artefact when the craft is known and understood (Botwid 2013, 32-34; 2016, 55; 2017, 21-26; Collins 2014, 64; Medbo 2016). A pot could have been made yesterday or five thousand years ago. The impressions are crafted into the artefact, the traces are there, fired to be insoluble, and they represent a level of skill in so-called "frozen moments". The reading of crafted artefacts is an example of transferring knowledge not only from hand to hand but from time to time. The artisanal exploration is done by tacit, ocular and audial survey together with the experience of the work as an artisan. To be able to distinguish between the different levels of skill, it is valuable that the interpreter has experience of teaching the craft (Botwid 2016, 34).

## Different ways of detecting levels of skill in contemporary archaeology

In science theories concerning practice, the division in levels of skill is rough. There are only two levels: the excellent practitioner and then all the others (Molander, 1996, 2002, 33-56; Gustavsson, 2002, 88-90; Pye, 1978, 4-8). In crafting, it is instead proposed that it is possible to use three levels of skill for embodied experience-based knowledge. This makes beginners and untalented artisans clearly visible. It is important to detect learning processes in crafting. Evaluation of skill is a way to divide all kinds of practical or theoretical knowledge. This is very clear in the work of Sandy Budden, a ceramist and archaeologist in the UK who uses three divisions to evaluate every step of the manufacturing of pots. She uses the categories of *good*, *moderate* and *poor*. Budden uses these three categories for each of the seventeen steps of manufacturing a specific form and before making a statistical conclusion of skill for the material. Her work is an evaluation of every pot connected to the artisanal knowledge of the specific place and timespan in which the pot was made and the result is used to discuss social relations, skill investment in artisanal learning processes and communities (Budden 2008, 1-14; Budden and Sofaer 2009).

Maikel Kuijpers conducted interpretations using categories of level of skill in bronze crafting: amateur, common craftspeople, master crafters and virtuoso. Three of these four levels of skill bear the same signatures as those presented momentarily in this paper (see below), but the additional fourth level includes social status and context which, to my knowledge, makes that level more uncertain or dependent upon timespan or context (Kuijpers 2017, 13-14). I prefer to have Kuijpers' fourth level as a factor in the interpretation, which is grounded in the specific archaeological material and contexts at hand (see also Olausson 2008). It is the *embodied knowledge* of the artisan that places him or her at a certain level of *skill* which is present in his or her crafting traces. These are inherent in an artefact and can be analysed. The visual for identifying the skill level is in a manufactured artefact itself. In this way of evaluating levels of skill, not even timespan nor geographical location matters. Therefore, I stress that it is the technical knowledge – the knowledge and experience of the materials – that gives comparable analysis over time. In discussions or analysis between archaeologists and artisans of all kinds, the level of skill is a starting point and a way of understanding how the craft in focus relates to the ancient maker (ancient technologies). Further, the archaeologist can draw from these discussions some conclusions about society, context and status. The artisanal interpretation is an aspect of technical analysis which is similar to the analysis undertaken in natural science and will be a part of the archaeological interpretation. It is possible to use the evaluation of skill levels in any craft. The three levels that make up the observable evaluation criteria (Botwid 2013, 31-34; Botwid 2016, 32-34) are as follows:

- *Professional artisanal skill: The artisan has extensive experience and a very high level of knowledge. This individual is particularly skilful in her/ his craft and can, in addition, move unhindered within the relevant field of expertise. An artisan who has attained a professional skill level takes risks and is able to completely resolve new problems by using the assembled knowledge she/he possesses.*
- *Good artisanal knowledge: The knowledge that most artisans possess is traditional knowledge. The bearer of tradition is not particularly inclined to take risks even if very skilled at the craft in question. Though not willing to deepen or proceed in knowledge development, such an individual is secure at a lower level of practical knowledge, a knowledge that she/he possesses and refines.*
- *Artisanal knowledge: The lowest level of artisanal-technical knowledge displays craft that is performed by a beginner or by someone who cannot perform on an independent level. This individual can only work step by step on the basis of instructions, or proceed by trial and error without guidance. The execution shows clear technological deficiencies.*

## High-temperature skill

Some crafts are dependent on extensive knowledge of firing techniques. Even today, in contemporary craft, high-temperature skill is needed together with a broad knowledge of how to control heat for different purposes. Ceramic craft, metal craft, glass craft and related knowledge for cremation, tar-making or charcoal-production are all dependent on someone knowing how to use fire.

To widen the understanding of ancient practical knowledge, interpretations based on tacit knowledge are relevant. The collaboration of educated professional artisans and archaeologist is, in my view, one way to reach a clear, more valid interpretation of the craft at hand. In crafts where the archaeologist does not hold the necessary practical knowledge or cannot take on the role of "craft-translator," it is possible to collaborate with skilled artisans as a form of *uncertified expertise* to extract valuable knowledge that is a good foundation for archaeological synthesis concerning crafting issues. When it comes to high-temperature crafts, I am able to use my own expertise on firing wood up to 1350°C, and can give important information about vitrification in different clay bodies and choices of minerals to mix with the raw clay. Ceramic knowledge was applied in the following case study and proved to be relevant in melting bronze for casting (Botwid 2017, 53).

The aim of this article is to concentrate specifically on high-temperature skill traceable in prehistoric material. This case study focuses on the crafts of firing ceramics and melting bronze through four technological aspects of a certain pipe-formed tuyère, the Pryssgården tuyère (LBA).

Key questions to consider are as follows. In what way was the ceramic craft changing to meet the new requirements for metal craft? Could the decorative elements on tuyères be a technological design? Who made the tuyères – the ceramist or the bronze-smith?

## Presentation, background and outline

The site of Pryssgården is situated in South East Sweden and most of its finds are dated to the Late Bronze Age period IV-VI (*c.* 1100-500 BCE) (Borna Ahlqvist *et al.* 1998). There are traces of communication in ancient artefacts and craft materials which are often interpreted as the result of trading or import. Pryssgården could be described as an important node for new expressions and techniques in the late Bronze Age. In the monograph *Understanding Bronze Age Life: Pryssgården (LBA) in Sweden from an Artisanal Perspective* (2017), I described how travelling artisans and the sharing of their artisanship with new communities can be the reason for moving material or techniques over large geographical distances.

Learning and sharing knowledge develops new links between people. This might be one reason for ancient artisans trying new paths and techniques. In some cases, the traces of trial-and-error are visible in the findings. In other cases, the findings tell of knowledge established at Pryssgården over long periods of time. Ceramics which are well fired show that these artisans knew of, and had mastered high-temperature technology (Botwid 2017, 121-33).

The most famous artefact discovered at Pryssgården (1993-1994) was the so-called Pryssgård figurine (dated 902-807 BCE). It was interpreted as a unique find of a goddess figurine by Ulf Stålbom (1998, 130-32). Later, the artefact was reinterpreted as a possible tuyère by Henrik Thrane (2006) and Joakim Goldhahn (2007, I). A tuyère is a funnel or pipe-shaped object made of clay which is used to divert the airflow from a bellow or other air source into a kiln or hearth (Thrane 2006, 271; Stilborg 2002, 150; Tylecote 1976, 22, 190; Jantzen 2008, plates 56-57). There are several types of tuyère. In the present interpretation, the term refers to an elbow-shaped ceramic pipe (Tylecote 1976, 22). This find from Pryssgården can be contrasted to others from Late Bronze-Age Cyprus (1600 BCE), where elbow-shaped tuyères were found in the excavations of Politiko Phorades. Here, natural resources and suitable environments made metal craft possible. The find consisted of fifty almost complete tuyères and over 600 fragments made of clay that was composed to meet the requirements for high-temperature crafting.

(Knapp *et al.* 2001, 207-208). At the 2013 conference "Prehistoric pottery across the Baltic" in Lund, I suggested that the Pryssgården figurine should really be reinterpreted as a zoomorphic tuyère, a functional object manufactured with features


*Figure 2. Locations of Scandinavian sites with proposed tuyères that indicate bronze melting (illustration © Henning Cedmar Brandstedt 2018).*

of a horse (Botwid 2013b). I reconstructed it as a horse with flaring nostrils. The significance of the horse in the Bronze Age and the interaction between man and animal are clearly seen in artefacts and rock carvings (Ling 2013, 33; Skoglund 2006; Kristiansen and Larsson 2005, 324; Jennbert 2010). I suggested that making a tuyère in the shape of a horse had no practical importance – a simple, straightforward pipe-formed ceramic object would have served its technical purpose just as well (Botwid 2017, 42). Although there were no traces of bronze melting reported at the Pryssgården site (Borna Ahlqvist *et al.* 1998) or in the extensive material findings (about 9000 individual finds that I examined between 2013-2016), I suggested that the Pryssgården tuyère is evidence that bronze melting was taking place at the site (Botwid and Eklöv- Pettersson 2016). *Whilst I still support this conclusion, within this article I additionally discuss the interpretation of the meaning of the features of the horse and argue that the imprints around the rim can be of great importance.*

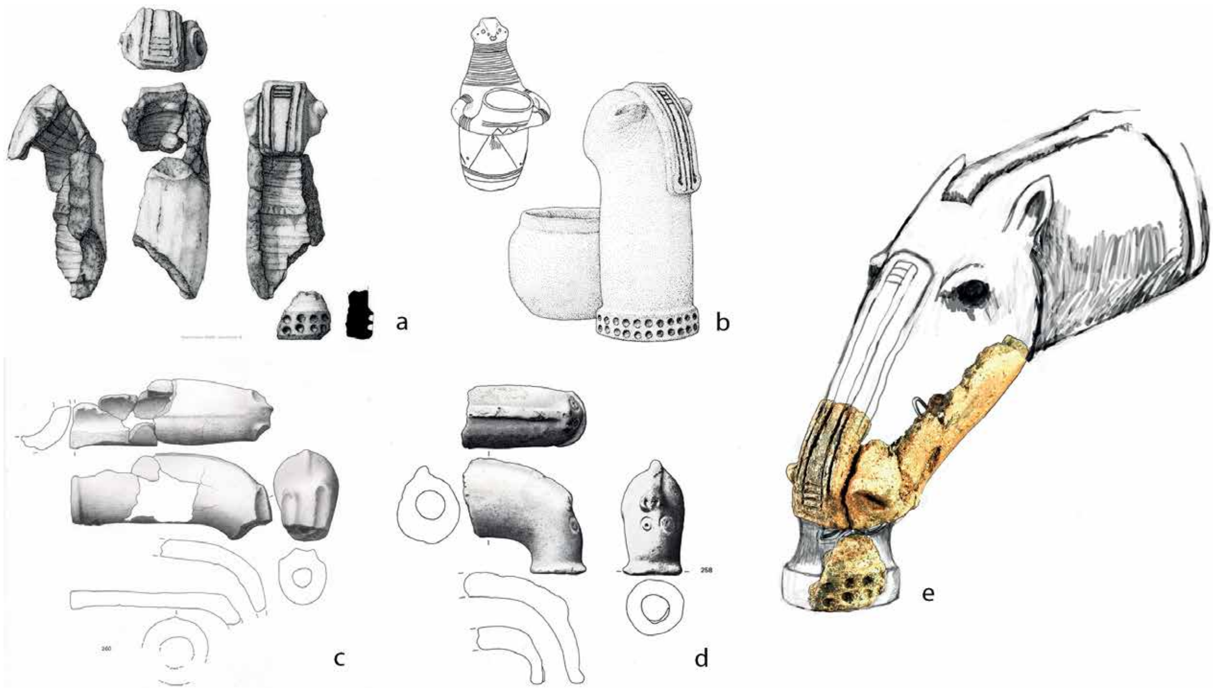


*Figure 3. (a) Find 5918, dated to 902-807 BCE (illustration © Ark. Doc.), (b) Stålbom's interpretation (1998) compared to a figurine from Deszczno LBA (illustration © Ark. Doc.), (c) Find from Stora Heddinge och (d) Baldslev (plates 57, 56 in Jantzen 2008) presented by Thrane and published in Fornvännen 2008, (e) Botwid's re-interpretation (illustration © Botwid 2013).*

## Case study: archaeological experiments

In short, the experiment and reconstructions of a Bronze Age smelting occasion were conducted at Lund University and the open-air museum, Vikingatider, in Sweden in May 2014. A hypothetical Bronze Age workshop was designed.[1] Three different tuyères and one crucible (a crucible from Brogården, reconstructed by Eklöv Pettersson) were manufactured out of ordinary brick-clay from south-west Sweden (Horn's brickyard in Skövde municipality). The clay is naturally tempered and is mixed with 10% of added sand. Two of the tuyères and the crucible were biscuit-fired in a controlled firing to 800°C in an electric kiln before use. One of the tuyères was left to dry completely and was not fired before use. The theoretical idea behind the workshop was as follows: the tuyère will direct the airflow from the bellows into the hearth from above, resulting in an airstream of unheated cold air being directed into the fuel, which results in raising temperatures to 1000°C and above, which melts the scrap-metal. The main question of this experiment was to explore how melting metal and using technical ceramics in a Bronze Age workshop could give answers to the question of whether artefacts without residues or sintering could possibly have been used in metalcraft (see Botwid and Eklöv Pettersson 2016).

Alongside the results that we expected would be generated from the experiment, there were several other interesting outcomes. These will form the basis of the present exploration concerning technical innovation in high-temperature craft.

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1 I am indebted to Paul Eklöv Pettersson, Andreas Nilsson and Simon Rosborg with whom I conducted the experiment.

## Four features of the tuyère in Pryssgården

High-temperature technical signs or innovations can be understood from many different starting points. The conscious use of fire is well known, and is acknowledged as extensive and important in processing materials and transforming them to serve mankind. In the artisanal approach, many crafts are connected through this use of heat. To practice high-temperature craft such as, in this case, ceramics, it is crucial to be able to take on new crafts such as bronze-smithing. To shed light on the relation between these two high-temperature crafts I have chosen to study an artefact existing in this overlap: the tuyère. For the purpose of this article, I am focusing on four of its main features.

### Clay Preparation

The first feature of the tuyère is the clay preparation. A high-quality end result starts with the preparation of a suitable clay body (Arnold 1985, 20-32, 61-65). To locate a good clay resource before weathering (Botwid 2017, 146 I:II) and maturing it (Botwid 2017, 148 I:IV) would have been fundamental skills which were well known to the ceramists at Pryssgården. Prepared clay was divided into suitable lumps and was stored in a sheltered place safe from freezing or drying out (Botwid 2017, 145-48 I-III). A prepared clay can be developed further through the addition of temper. Depending on its type, the temper can either alter the properties of the clay or the properties of the fired ceramic material. The choices in temper are many but narrowed down by natural resources, tradition or competence. Organic material such as straw, seeds or sawdust can offer armouring when building thin or very big pots, helping to ease both the forming and the drying process. As organic tempering burns away during firing, the pot will become more porous than a pot that is tempered with geological material.

Geological materials such as fired crystallized stone, sand or crushed and ground fired clay sherds make good temper for high-temperature purposes. Silica-rich minerals give the clay body a very strong resistance to vitrification. Artisans of high-temperature crafts are aware of the practical sides of silicate chemistry through experience, tradition, or sometimes through education. To make tuyères like those analysed via ocular survey and artisanal interpretations, it is determined that the first feature – knowledge in tempering the clay – is known. Both finds (F5918 and 511) are competently tempered to be sustainable for heat and cracking, and the clay body contains a higher amount of silica. The mineral has been combined with the ordinary mixes for clay suitable for domestic ware. It is obvious through a close ocular survey of the Pryssgården tuyère, in which the broken parts were analysed, that silica-rich stones or pure quarts have been fired to the point of crystallization, then ground to a powder before being added into the clay.

### Rolling from the inside

The second feature of the tuyère is a tucking or rolling technique that occurs together with the pipe form.

As can be seen in the drawing and the photo in Figure 4, the Pryssgården tuyère has clear traces of manufacture on its inside. It was not thumbed or drilled, but built around a padded organic core. Studying the imprints, paleo botanist Per Lagerås suggests this organic core was made from straw from a cultivated grain.

The rolling technique allows for a clay tube to be formed without seams. This is desirable as seams are more vulnerable to cracking in the stress that changing temperature exerts on ceramic material. The pressure through repeated rolling

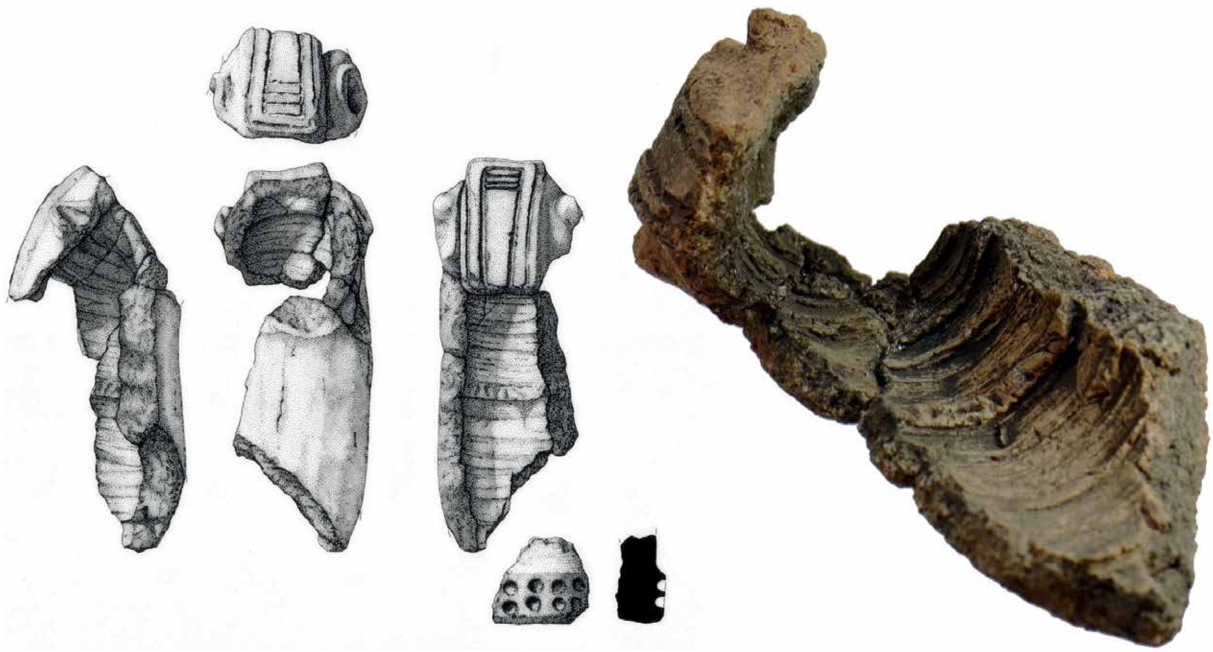

*Figure 4. Find 5918 archaeological (illustration ©arc.doc; inside-photo © Katarina Botwid).*

during manufacture would also strengthen the ceramic material as the clay particles are pressed firmly together.

To my knowledge, the rolling technique is not described in the ceramic literature but is quite common when rolling pipes. The series of pictures below (Fig. 5) show how the different stages result in a tube. The tube is formed around a wooden stick that is covered or wrapped with bast fibres. Bast fibres were specifically chosen for the experiment because this raw material existed in the Bronze Age and was easily accessible. The rolling technique is based on the clay being rolled from the inside of the tube (Botwid 2017, 43-46).

To the lower right (see Fig. 6) is a reconstruction of a rolled tube with fibre bast and twisted string wrapped around the stick. The bottom left shows the tube-shaped clay object at Malmö Historical Museum (MHM), excavated from the site Fosie IV in 1993, and interpreted as a tuyère (Björnhem and Sävestad 1993, 79). Notice that it was rolled from the inside with a twisted string and straw as padding.

In a newly conducted excavation outside Lund in southern Sweden, another tuyère was found (LUHM 32365:51). It was clearly manufactured using the earlier described rolling technique. It was similar to the Pryssgården tuyère in form and size allowing me to interpret the find as having been manufactured in the Late Bronze Age, even if the main finds in the context were interpreted as deriving from the pre-Roman Iron Age. One of the carbon dating results points to the Late Bronze Age which supports the interpretation of the pipe being dated to 790-540 BCE (CAL 2). The findings at this excavation imply, therefore, bronze casting (Brink and Larsson 2017, 105).

## Visual temperature measurement

The third feature of the tuyère stems from observing the tuyère in action during an experiment at Lund University in 2014. When melting the bronze, the pre-fired tuyère was placed with its mouth over the charcoal-covered crucible. A continuous airstream from the bellows heated the burning charcoal for three hours. For the exact temperatures presented below we used a simple digital field pyrometer programmed to stand 1200°C. The temperature rose up to 500°C, presenting a warm, dark red glow before rising further to 900°C and presenting an orange colour. In the final phase, the temperature reached about 1100°C and achieved an almost white glow. When reaching

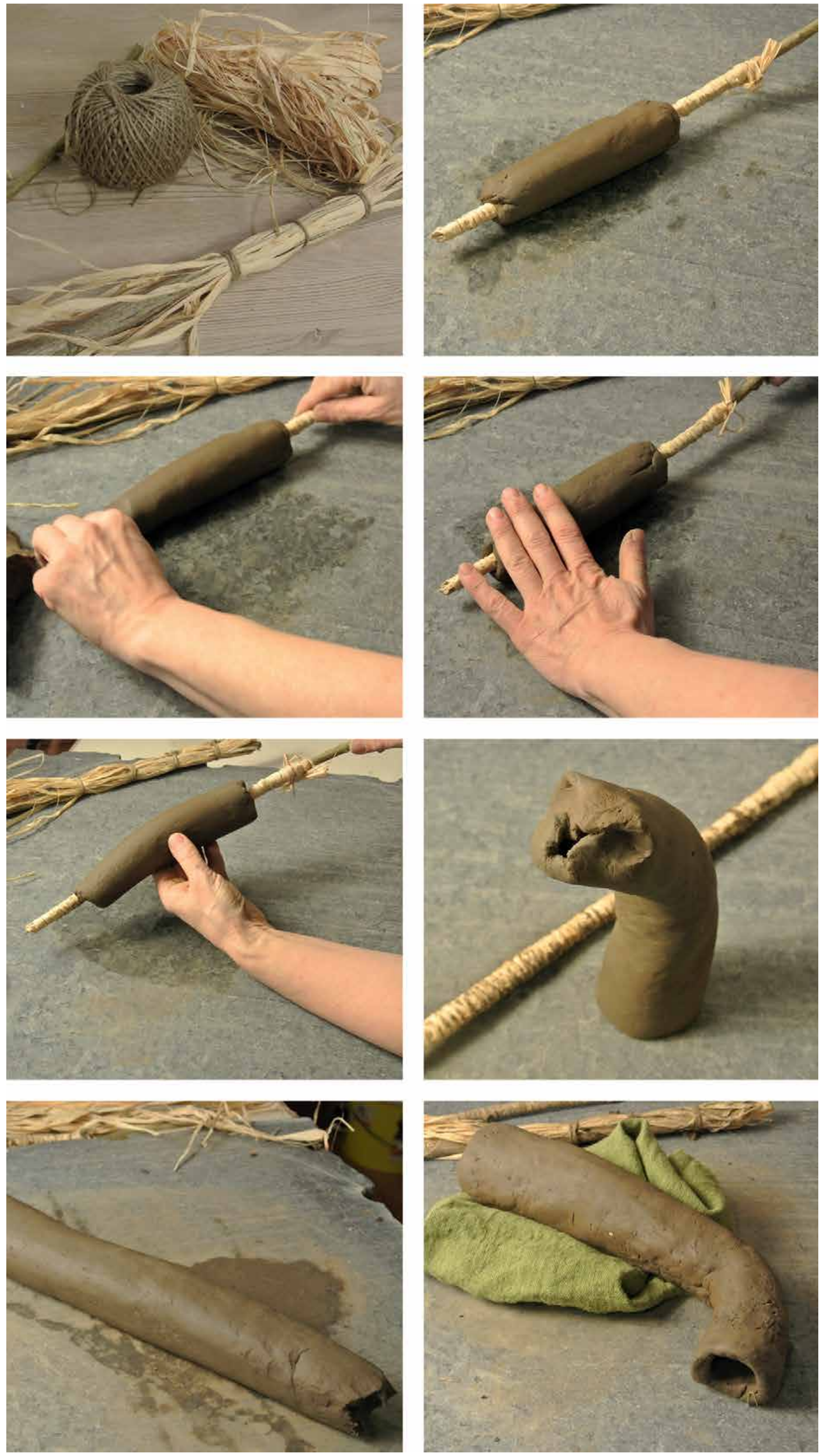

*Figure 5. Manufacturing technique for making tubes. This rolling technique is used to form the basic element of a reconstructed tuyère. It is a very convenient and sure technique for making a hollow tube without seams or joints (photo © Paul Eklöv Pettersson).*


*Figure 6. (a) Find 5918 (photo © Katarina Botwid), (b) F511(photo © Katarina Botwid), and (c) Fosie IV (courtesy of MHM ©) together with (d) an example of the rolling technique. (Photo © Paul Eklöv Pettersson).*

over 1000°C, the decor started to glow from the inside of the mouth and had a steady bright, pale orange glow in the oxidising atmosphere. One cannot assess the temperature by looking at the crucible or metal as it has to be covered with coal to achieve heavy reduction. Therefore, the colour changes of the mouth of the tuyère can serve as important indicators of temperature. Its pitted design allows the mouth to both show colour and be sturdy enough to withstand the extreme conditions. After the tuyère had cooled down, no coal, reduction or sintering traces were visible; a little soot on the mouth and inside the pipe was the only residue of the usage.

### Audial temperature measurement

The fourth feature of the tuyère concerns a surprising relation between its horse-like features and the sound of the air pushed from the bellows. The sound of the air meeting the blazing coal bed changes with increasing temperature and could well serve as another indicator of temperature to the experienced artisan. In the final stages of the firing process, the sound bears a striking resemblance to the heaving breaths of a horse exhausted from running.[2]

## Conclusion, interpretation and discussion

The prehistoric metal craft was not possible without knowledge about firing, and ceramists have had a long tradition of high-temperature skill. At Pryssgården, the artisanal-interpreted ceramic vessels indicate a high level of skill or categorised in my own terms, *good artisanal knowledge* (Botwid 2017, 32). Without venturing into how the bronze craft first came to the area, it was met, to a certain extent, by a craft community equipped to understand the high-temperature craft of another field. Prepared clay was at hand and tuyères and crucibles had much the same needs of tempering as cooking pots, which were made to last for a long time. Any specific requirements were easily met. The rolled tubes with the padded core, the

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2 Sound reference: © Katarina Botwid 2015 https://vimeo.com/137694259.

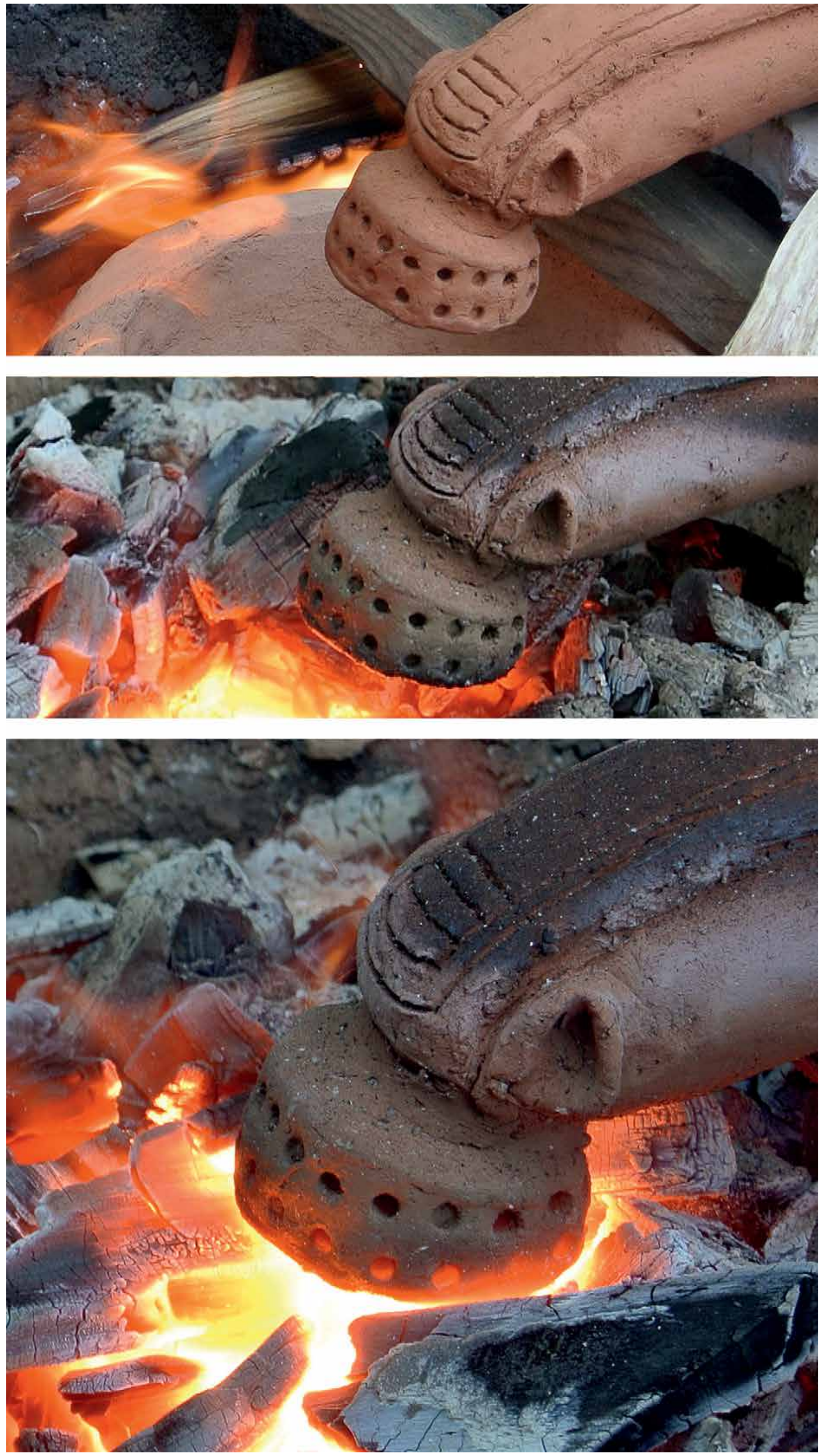

*Figure 7. Tuyère II in different stages of the firing process. Notice the bright orange glow appearing in the imprints in the last stage of firing (photo © Katarina Botwid).*

utilizing of the glowing imprints at the mouth of the tuyère, and the sound as an indicator of temperature all ought to have been something new at Pryssgården.

The rolling technique appears to be connected to the bronze craft. To my knowledge, it occurs at three different places in Sweden, all during the Late Bronze Age. Changes in the ceramic craft technique would be possible to trace and the fact that this technique seems to be linked to the bronze craft might help in detecting it in more places. As it is possible that the rolling technique is even linked to the introduction of bronze craft, it certainly deserves more attention.

Visual measurements of heat were formalized in modern days through the Munsell scale (http://munsell.com/about-munsell-color/) but were something which would have been well-known to artisans experienced in high-temperature crafts at the time. If the interpretation of the decor as a temperature indicator is valid, it hints at a developed knowledge of handling high temperatures that is specific to the bronze craft.

The sound of the tuyère is another indicator of temperature. We can only speculate about the reasons why the horse-like sounds are combined with the horse features of the tuyère. It is interesting, however, that this is seen in other tuyères in Europe. I suggest a double function based in the practical pedagogic transfer of knowledge. Metaphors are often used in the training of an artisan, and narratives can be helpful for sharing and remembering new knowledge. Perhaps audial input was crucial to the crafting process as the metal itself was hidden from view. Further study can explore whether the Pryssgården tuyère represents two traditions of controlling temperature: an audial and a visual.

When the "horse" is exhausted by the person at the bellows, the bronze is ready. A strong narrative can be part of the transferring of declarative knowledge. Therefore, the narrative can also be part of a strong artistic identity or can be a way of 'making special' or artifying (see Dissanayaki 2013, 90-95). Knowledge and craft performances can amaze people who are new to meeting and understanding a new technique, particularly if performed together with colourful fire experiences, the smell of metal, and the choreography of artisans moving and working together in the different stages of the process. The conclusions drawn from the four features of the tuyère help us to better understand the high-temperature skill present at Pryssgården. The clay body was performed with a good grasp of the technology and it is therefore clear that high-temperature skill was at least at the level of *good artisanal knowledge* and was already in place. In light of the experimental finds and results, I propose that pipe-formed objects indicate the introduction of metal craft and new ceramic techniques which could easily be adopted by a ceramist at Pryssgården. Both the ceramist and the bronze smith could have had the skills necessary to make such pipes. In this case, with the elegant work with the horse features, I propose that the artisan had at least *good artisanal knowledge* in the making which does not exclude a bronze smith who was trained in ceramics *and* metal craft.

Declarative knowledge is proposed to be transferred through a visual, audial and experienced occasion that gives strong impressions and creates memories of handling a new technique. Being a part of this narrative can apply to those with different levels of understanding. What an individual comprehends depends on three things: whether they are part of the artisan group, whether they have a specific understanding that is developed each time they perform the craft, and whether they belong to a group that, as spectators, develops an understanding of the course of events over time (Botwid in press). Events like this can open up an interest for learning or an eagerness to talk about this unusual experience and thus spread the word. The narrative helps to consolidate the knowledge.

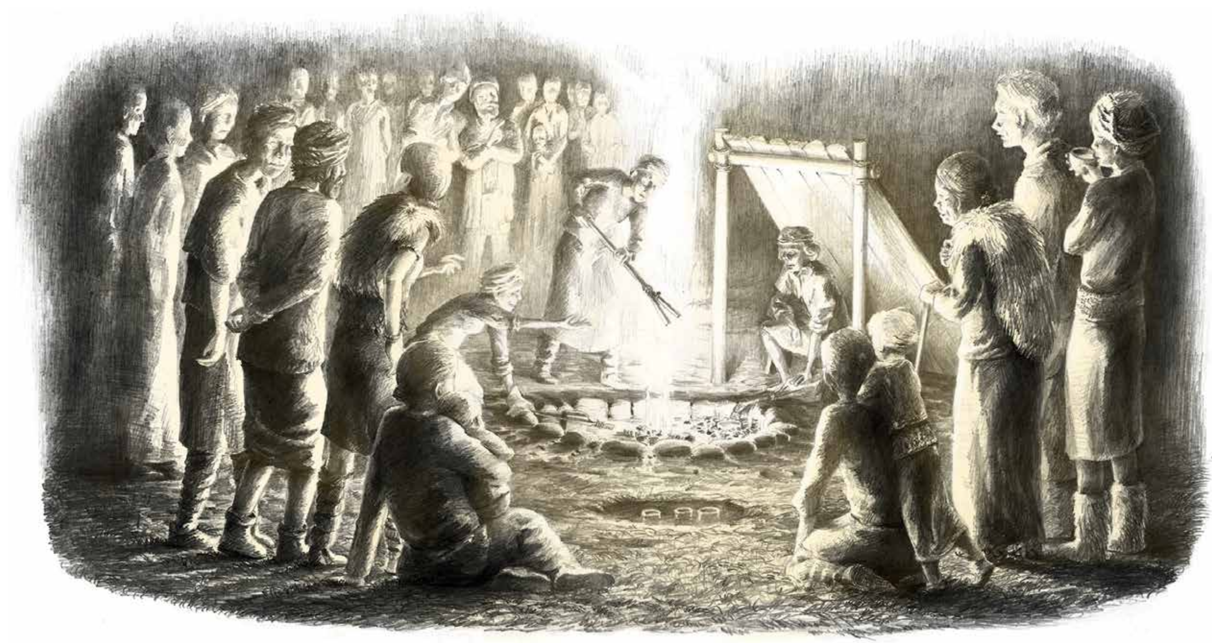

*Figure 8. Artisans' and spectators' interpretation of the event of bronze casting in Pryssgården LBA. (Illustration © Henning Cedmar Brandstedt 2015).*

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## References

Almevik, G. (ed.) 2017. *Hantverksvetenskap*. Göteborg: Hantverkslaboratoriet/ Göteborgs universitet.

Arnold, D. 1985. *Ceramic Theory and Cultural Process*. Cambridge: Cambridge University Press.

Björhem, N., Säfvestad, U. 1993. *Fosie IV: bebyggelsen under brons-och järnålder*. Thesis (PhD). Lund: Lunds universitet.

Borja Ahlqvist, H., Lindgren-Hertz, L., Stålbom U. 1998. *Pryssgården: från stenålder till medeltid: arkeologisk slutundersökning RAÄ 166 och 167, Östra Eneby socken, Norrköpings kommun, Östergötland.* Linköping: Riksantikvarieämbetet/ Byrån för arkeologiska undersökningar.

Botwid, K. 2013a. Evaluation of Ceramics: Professional artisanship as a tool for archaeological interpretation. *Journal of Nordic Archaeological Science (JONAS)* 18, 31-44.

Botwid, K. 2013b. *Archaeological ceramics in a new light: early results from artisanal interpretations of ceramics from Pryssgården, Östergötland in Sweden*, Conference paper Presentation at the Conference: Prehistoric Pottery Across the Baltic – regions, influences and methods, Laboratory of Ceramic Research, Lund University. 2013-03-08.

Botwid, K. 2014. *From Figurine to tuyère*, Conference paper Presentation at the Workshop:Teknisk keramik, bronshantverk och innovationsspridning i Skandinavisk förhistoria, Laboratory of Ceramic Research, Lund University. 2014-06-02.

Botwid, K. 2016. *The Artisanal Perspective in Action: An archaeology in practice*. Thesis (PhD). Lund: Lunds universitet. http://lup.lub.lu.se/record/8599027.

Botwid, K. 2017. *Understanding Bronze Age Life: Pryssgården (LBA) in Sweden from an artisanal perspective*. Lund: Institute of Archaeology and Ancient History.

Botwid, K., Eklöv Pettersson, P. 2016. Use Traces on Crucibles and Tuyères? An Archaeological Experiment in Ancient Metallurgy, in: Eklöv Pettersson, P. (ed.). *Prehistoric Pottery Across the Baltic. Regions, Influences and Methods*, BAR S2785. Oxford: Archaeopress.

Brink, K., Larsson, S. (eds.). 2017. Östra Odarslöv 13:5, ESS-området: forntid möter framtid: arkeologisk undersökning 2013: Skåne, Odarslövs socken, Lunds kommun, fornlämning Odarslöv 46, 49, 51 och 52, Vol. 3, Analyser och bilagor. Stockholm: Arkeologerna/Statens historiska museer.

Budden, S. 2008. Skill Amongst the Sherds: Understanding the role of skill in the Early to Late Middle Bronze Age in Hungary, in: Berg, I. (ed.). *Breaking the Mould: Challenging the Past through Pottery.* BAR British series S1861. Oxford: Archaeopress, 1-18.

Budden, S., Sofaer, J. 2009. Non-discursive Knowledge and the Construction of Identity Potters, Potting and Performance at the Bronze Age Tell of Százhalombatta, Hungary. *Cambridge Archaeological Journal* 19, 203-220.

Collins, H.M. 2014. *Are We all Scientific Experts Now*? Cambridge: Polity.

Collins, H.M., Evans, R. 2002. The Third Wave of Science Studies. *Social Studies of Science* [e-journal] 32 (2), 235-296. DOI: https://doi.org/10.1177/0306312702032002003.

Collins, H.M., Evans, R. 2007. *Rethinking Expertise*. Chicago: University of Chicago Press.

Dissanayake, E. 2013. Genesis and Development of 'Making Special': Is the concept relevant to Aesthetic Philosophy? *Rivita di Estetica* 54, (3) 83-90.

Goldhahn J., Østigård T. 2007. *Rituelle spesialister i bronse- og jernalderen I*. Göteborg: Institutionen för arkeologi och antikens kultur, Göteborgs universitet.

Gustavsson, B. 2002. *Vad är kunskap? En diskussion om praktisk och teoretisk kunskap*, Serien Forskning i fokus 5. Stockholm: Myndigheten för skolutveckling.

Jantzen, D. 2008 *Quellen zur Metallverarbeitung im Nordishen Kreis der Bronzezeit.* Mainz: Akademie der Wissenschaften und der Literatur.

Jennbert, K. 2010. Animal Mouthpieces for Human Properties and Identity: A Scandinavian perspective, in: Kucera, M., Kunst, G.K. (eds.). *Bestial Mirrors: Using animals to construct human identities in Medieval Europe.* Vienna: Vienna Institute for Archaeological Science, Vienna University, 39-45.

Knapp, A.B., Vasiliki Kassianidou V., Donnelly, M. 2001. Copper Smelting in Late Bronze Age Cyprus: The excavations at Politiko Phorades. *Near Eastern Archaeology* [E-Journal] 64 (4), 204-210. DOU: https://dx.doi.org/10.2307/3210830.

Kristiansen, K., Larsson, T.B. 2005. *The Rise of Bronze Age Society: Travels, transmissions and transformations*. Cambridge: Cambridge University Press.

Kuijpers, M.H.G. 2017. The Bronze Age – a World of Specialists? Metalworking from the Perspective of Skill and Material Specialization. *European Journal of Archaeology* 21 (4), 1-22. DOI: http://dx.doi.org/10.1017/eaa.2017.59

Ling, J. 2008. *Elevated Rock Art: Towards a maritime understanding of Bronze Age rock art in northern Bohuslän, Sweden*. Thesis (PhD). Göteborg: Göteborgs universitet.

Medbo, M. 2016. *Lerbaserad erfarenhet och språklighet*. Thesis (PhD). Göteborg: Göteborgs universitet.

Molander, B. 1996. *Kunskap i handling*, 2nd Edition. Göteborg: Bokförlaget Daidalos AB.

Olausson, D. 2008. Does Practice Make Perfect? Craft Expertise as a Factor in Aggrandizer Strategies. *Journal of Archaeological Method and Theory* 15, 28-50. DOI: http://dx.doi.org/10.1007/s10816-007-9049-x.

Pye, D. 1968. *The Nature and Art of Workmanship*. Cambridge: Cambridge University Press.

Polanyi, M. 1966. *The Tacit Dimension*. Chicago: University of Chicago Press.

Skoglund, P. 2006. *Hällristningar i Kronobergs län: motiv, myter och dokumentation*. Lund: Department of Archaeology and Ancient History, Lund University.

Stilborg, O. 2002. Blästermunstycke, in: Lindahl, A. Olausson, D., Carlie, A. (eds.). *Keramik i Sydsverige*, Institute for Archaeology and Ancient History, Acta Lundesia report Ser. 81. Lund: Institute for Archaeology and Ancient History, Lund University.

Stålbom, U. 1998. Fynden från Pryssgården, in: Borna Ahlqvist, Hélène (ed.). *Pryssgården: från stenålder till medeltid: arkeologisk slutundersökning RAÄ 166 och 167, Östra Eneby socken, Norrköpings kommun, Östergötland*. Linköping: Riksantikvarieämbetet/ Byrån för arkeologiska undersökningar.

Thrane, H. 2006. Figurinen fra Pryssgården -et alternativt tolkningsforslag. *Fornvännen – Journal of Swedish Antiquarian Research* 101, 268-273.

Tylecote, R.F. 1992. *A History of Metallurgy*. 2nd Edition. London: Maney Publishing.

## Personal communications

Lagerås, P. 2014. Per Lagerås on July 26, 2014: Paleoecologist at SHMM.

## Digital references

Botwid, K. 2015. Bronze Age Sound EAA Glasgow 2015, Lund University. Available from: https://vimeo.com/137694259 [accessed 14-05-2018].

Munsell (temperature definition by) Colour. Available from: http://munsell.com/about-munsell-color/. [accessed 14-05-2018].

# Notes on contributor

Katarina Botwid, PhD in Archaeology and Master of Fine Arts, works in interdisciplinary research. Botwid builds a solid theoretical and methodological framework to study crafts and skills of the past. The breadth of scope of her research became evident in her thesis *The Artisanal Perspective in Action: An Archaeology In Practice* 2016.

With her Master of Arts degree in Ceramics as a vantage point she has both revitalised the ceramic sherd as a source of knowledge of our past as well as developed more scientific ways to include contemporary craftspeople in the process of analysis of archaeological finds.

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