# Archaeological Evidence
# for Early Wool Exploitation
# in South East and Central Europe

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By

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*For Animal Rights*

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**ZUSAMMENFASSUNG**

Ziel dieser Untersuchung ist es, die wesentlichen Veränderungen der äneolithischen (kupferzeitlichen) Textiltechnologien unter räumlichen, zeitlichen und kausalen Aspekten zu aufzuklären, welche mit dem Aufkommen von Rohfasermaterialien in Zusammenhang gebracht werden können. Die Untersuchung berichtet über einen großen Bestand an Textilwerkzeugen, die in einer ausgedehnten Gruppe von 26 Fundstellen in der Pannonischen Tiefebene gesammelt wurden. Textilwerkzeuge, hauptsächlich Spinnwirtel, wurden gemäß dem methodologischen Standard des entsprechenden Teilgebiets der Textilarchäologie analysiert. Insbesondere wurde ihre funktionale Analyse als Ausgangspunkt gewählt, um verschiedene Verwendungen und Beschaffungsstrategien für Fasermaterial zu untersuchen und so das Aufkommen und die Verbreitung der Wollschafhaltung zu erhellen. Die Ergebnisse der Spinnwirtelanalyse ermöglichten es zu klären, in welchem Ausmaß Schafswolle sowie Flachspflanzen bei der untersuchten Textilproduktion verwendet wurden. Zusammen mit den Ergebnissen der Textilwerkzeuganalyse, die den Kern dieser Arbeit bildet, legt eine Reihe von Anhaltspunkten – darunter Anzeichen für eine Klimaveränderung und Wandel in den Versorgungsstrategien und der Viehhaltung – nahe, dass die Verwendung tierischer Produkte, höchstwahrscheinlich einschließlich der Nutzung von Fasern, bereits im vierten Jahrtausend v. Chr. von örtlichen Umweltbedingungen angetrieben wurde. Des Weiteren weisen archäologische und archäobotanische Befunde aus dem untersuchten Gebiet und aus angrenzenden Regionen darauf hin, dass auch das Sammeln und die Verarbeitung wilder und domestizierter Pflanzen eine bedeutende Komponente der örtlichen Textilproduktion darstellten. Darüber hinaus offenbarte ein Vergleich der untersuchten Sammlungen von Spinnwirteln, dass die äneolithische Textilproduktion „kulturspezifisch“ war. Genauer gesagt wiesen die typologischen Standards und die technologischen Spezifikationen dieser Werkzeuge eine statistisch signifikante Abhängigkeit von der „archäologischen Kultur“ auf. Als letzter Punkt wies die Betrachtung der sozialen Aspekte der Faserverarbeitungspraktiken auf eine Intensivierung und höchstwahrscheinlich eine frühe Spezialisierung des Webehandwerks hin. Dies erlaubt den Schluss, dass alle betrachteten und analysierten Anhaltspunkte eine Anpassung an neue Ressourcen von Rohfasermaterial während der äneolithischen Periode im untersuchten Gebiet anzeigen.

Diese kumulative Arbeit besteht aus drei Hauptteilen: Einführung, Veröffentlichungen und Synthese. Der Hauptteil des zweiten Kapitels "Veröffentlichungen" besteht aus fünf zuvor veröffentlichten Artikeln und Manuskripten. Die Anhänge bestehen aus vollständigen Datensätzen, die auch bereits über eine Open-Source-Publikation verfügbar sind. Für eine bequemere Verwendung der Primärquellen sind alle Veröffentlichungen in ihrer ursprünglichen Form enthalten und in einen umfassenden verbindlichen Text eingebettet, der aus einleitenden und abschließenden Kapiteln besteht.

**ABSTRACT**

This study focuses on elucidating spatio-temporal and causal factors of the major changes in Eneolithic textile technologies that might be associated with raw fibre material innovation. It reports on a large textile tool sample, collected within a broad 26-site cluster across the Pannonian Plain region. Textile tools, mainly spindle whorls, were analysed according to the methodological standards of the respective field of textile archaeology. More specifically, their functional analysis was chosen as a starting point for investigating different fibre material use and procurement strategies, in order to clarify the advent and spread of wool-bearing sheep husbandry. Results of the spindle whorl analysis illustrate the extent of the exploitation of both sheep wool and flax plant fibres within the contexts of the investigated textile productions. Together with the results of the textile tool analysis that build the central part of this thesis, different strains of evidence, such as indications of climate change, altering subsistence strategies and herding patterns, suggest that animal exploitation, most probably including fibre use, was driven by local environmental conditions already in the $4^{th}$ millennium BC. Archaeobotanical evidence from the investigated area and neighbouring regions propose that gathering and processing of wild and domesticated plants was also a significant component of the local textile productions. Furthermore, comparison of the investigated spindle whorl assemblages revealed that the Eneolithic textile productions were ‘culture-specific’. More precisely, both typological standards and technological specifications of these tools displayed a statistically significant dependence on the ‘archaeological culture’. Finally, the examination of social aspects of fibre processing practice indicated intensification and most probably early specialization of the spinning craft. It is possible to conclude that all the considered and analysed evidence argue an adjustment to new raw fibre material resources during the Eneolithic period in the investigated area.

This cumulative thesis is composed of three major parts: *Introduction*, *Publications* and *Synthesis*. The main part put forward in the second *Publications* chapter consists of five previously published articles and manuscripts. Appendices consist of complete datasets, which are also already available through an open-source publication. For more comfortable use of primary sources all the publications are included in their original form, while being embedded in a comprehensive binding text that consists of introductory and concluding chapters.

**CONTENTS**

# 1 INTRODUCTION[1]

The Eneolithic period is characterized by considerable economic and technological developments which spread across the territory of South East and Central Europe. Several of them were joined into an abstract package of innovation in animal husbandry, referred to as the *secondary products revolution*, initially proposed by Andrew Sherratt (1981, 1983) and later discussed extensively in different archaeological studies (Evershead, Dudd, Copley, & Mukherjee, 2002; Craig, 2002; Craig et al., 2005; Vigne & Helmer, 2007). Within the framework of textile archaeology and its research on early wool processing, these findings have been thoroughly considered as well (Rast-Eicher, 2005; Shishlina, Orfinskaya, & Golikov, 2003; Good, 1999, 2007; Rahmstorf, 2005; Becker et al., 2016). Unfortunately, major obstacles identified with any prehistoric textile research in the region, such as the absence of actual textiles and the fact that a significant part of the indirect proof of textile production stays unrecognized and unpublished, have left the topic of raw fibre material use unexplored. Questions related to raw material resources and their specialization for textile production have not been raised thus far. Need of better comprehension of changing patterns in fibre sustenance strategies during the Eneolithic period defined and shaped the main objectives of this research.

The intricacy of investigating innovation in fibre material production and use relies on various proxy indicators and the integration of different research fields. Incorporation of climate change modeling (Grabundžija & Russo, 2016) and investigation of vegetation developments (Schumacher, Schütt, & Schier 2015; Schumacher, Schier & Schütt, 2016; Schumacher, Dobos, Schier, & Schütt, 2018) aids in examining possible environmental factors, which influenced and shaped different raw material exploitation tendencies. Textile craft belongs to some of the oldest technologies and the variety of its products was vital in everyday life. It relied on raw material availability, so the introduction of new fibre options must have had a crucial impact on ancient economies. Since preserved textiles are so uncommon, the analysis of indirect proof of their production evolved into an alternative, but leading approach in textile research. It is largely built around investigation of tools and techniques used for textile production and greatly relies on the results of experimental archaeology.

[1] Parts of the subchapters on **Materials and Methods** and **Previous Research** are taken from the manuscript „Eneolithic Textile Production“ (Grabundžija, 2018a) published in an exhibition catalogue (Balen, Miloglav, & Rajković, 2018) that featured a substantial amount of previously unpublished textile tools used for this research.

# INTRODUCTION

The oldest actual textiles suggest that plant fibres were first used for making thread (Gleba & Harris, 2019), while wool was introduced later in time (Becker et al., 2016; Djurdjevac Conrad et al., 2018). Preserved textile remains confirm that wool as a raw material already exists and is in use in the 4th millennium BC (Shishlina et al., 2003). However, in Europe, the wool's leading role in textile production is not recognized before Bronze Age (Rast-Eicher & Bender Jørgensen, 2013).

## 1. 1 Objectives

The main objectives of this study were designed around elucidating the time of the appearance of new fibre production strategies, in particular concerning early sheep wool. The analytical segment of the work enabled a detailed evaluation of the impact these innovations in the raw material procurement and use had on the researched Eneolithic textile productions.

Comprised of five separate publications, this thesis aims to outline and explain both cultural and environmental factors behind the observed technological developments in the investigated region:

• First and foremost, the most cardinal objective of the study was to record and catalogue a substantial number of Eneolithic textile tools from South East and Central Europe.

The final Textile Tool Database (Grabundžija, 2019) contains details on, collectively, 1048 archaeological objects classified as textile tools, which were all sampled within a 26-site cluster stretching across the Pannonian Plain. Archaeological objects, namely spindle whorls, loom weights and spools, were examined and catalogued according to the methodological standards of the respective field of textile archaeology. The recording protocol was adopted from the methodological model established by the Centre for Textile Research in Copenhagen. In chronological terms, the dataset covered a period between the Late Neolithic and the Early Bronze Age, which spans roughly from the first half of the 5th till the beginning of the 2nd millennium BC (Raczky, 1995). ***The Textile Revolution - Textile Tool Database*** publication (Grabundžija, 2019) addresses the examined materials and applied methods in detail. It also breaks down the geographical and chronological frame of the study, making this open-source dataset widely available for future research. The complete dataset is published on the research platform *Edition Topoi* as a standalone, citable and sustainably secured data publication.

• Thesecond objective was to statistically evaluate the textile tool dataset.

Since shape and size of textile tools reflect applied techniques, used materials and desired end products, these factors can be investigated by analysing the tools morphometric data. This approach was published in ***Two sides of a whorl. Unspinning the meanings and functionality of Eneolithic textile tools*** (Grabundžija, 2018b). The paper examines and compares technological specifications of thread making tool samples associated with nine different culture-historically defined groups. Statistical analysis and comparison of the investigated tool assemblages revealed that Eneolithic thread making had a 'culture-specific' technological signature. Furthermore, the deposition of tools in human burials was approached as a separate, additional variable. It indicated that major developments in fibre production and use acted as a generator of symbolical meanings for the thread making aspects of the production process.

• Thethird objective was to address environmental factors which influenced the particular raw material introduction.

With this general aim, an incorporation of the climate model simulation for the investigated area, which covered the entire period of study was undertaken. The influence of climate change on the observed developments in textile technology is published in ***Tools tell tales - climate trends changing threads in the prehistoric Pannonian Plain*** (Grabundžija & Russo, 2016). In this joint paper, the results of the spindle whorl functional analysis were correlated with the climate modelling results. The comparison of the two sets of data revealed interesting correspondences, as the main climate trends are shown to be in concurrence with the observed changes in the examined techno-typological traits of the tools used for thread manufacture. Both datasets appear to be in sync with new tendencies in subsistence strategies, proposed by zooarchaeological and archaeobotanical studies.

• The fourth objective was to investigate aspects of economic and social flux connected to the recorded technological developments and intensified production.

Textile craft is one of the oldest technologies, after all its products were essential in everyday life. All aspects of the production heavily relied on raw fibre material availability, thus the introduction of new resource options had a serious impact on the prehistoric economies. Consequently, both the raw material resources and the textile craft rose to a higher level of management. The publication ***Threads that bind the establishment. Housing Eneolithic textile craft*** (Grabundžija, 2018c) investigates these advancements and their relation to other socio-economic changes which are occurring during the Eneolithic period. The paper includes both the techno-typological and spatial analysis of textile tools used for thread manufacture. Additionally, it presents an inter-site comparison of spinning activities, which revealed that, at certain localities with heightened production, a significant level of craft organization occurred already in the 4$^{th}$ millennium BC.

• Thefifth objective was to experimentally evaluate alternative tool options and their versatility. From the 5$^{th}$ millennium BC onwards the frequency of textile tools used for manufacturing threads increased, but the frequency of textile tools which indicate weaving activities decreased in both the inspected and surrounding regions. The complexities of recognizing and interpreting textile tools, which often have a multifunctional character is addressed in ***Bones for the Loom. Weaving Experiment with Astragali Weights*** (Grabundžija, Schoch, & Ulanowska, 2016). This article presents the results of a weaving experiment which was performed as a remote part of the tool analysis. The experiment was designed to explain the disappearance and absence of conventional loom weights in the inspected Eneolithic contexts.

## 1. 2 Materials and Methods

Textile tools are, unlike actual textiles, well represented in prehistoric contexts across South East and Central Europe. This especially holds true for spindle whorls, commonly used for manufacturing thread, which become numerous during the course of the Eneolithic period. Elizabeth Barber’s book “Prehistoric Textiles” (Barber, 1991), immensely changed the perception of textiles in archaeology, since it raised the awareness of tools and their potential for addressing issues of raw fibre materials, techniques and final products.

During the data recording process, morphometric traits of textile tools were given special attention. In the respective field of research, a tool’s shape, size and weight are held responsible for its performance with raw materials of different fibre traits (Grömer, 2005; Chmielewski & Gardyński, 2010; Mårtensson, Andersson, Nosch, & Batzer, 2005-2006, 2007a, 2007b).

Applied methods of recording textile tools are explained in detail in ***The Textile Revolution - Textile Tool Database*** publication (Grabundžija, 2019), making the dataset opportune for future research.

Statistical methods used for comparing different textile tool assemblages are outlined in detail in the ***Two sides of a whorl. Unspinning the meanings and functionality of Eneolithic textile tools*** publication (Grabundžija, 2018b).

The importance of bringing together various scientific disciplines is validated through successful correlation of different datasets in the joint article ***Tools tell tales - climate trends changing threads in the prehistoric Pannonian Plain*** (Grabundžija & Russo, 2016). Distinct methods that were applied and presented in this interdisciplinary study include climate modeling and techno-typological analysis of textile tools.

Purpose and details of applying an inter-site spatial analysis of textile tool distribution and combining it with an intra-site comparison of different tool sets are presented in ***Threads that bind the establishment. Housing Eneolithic textile craft*** (Grabundžija, 2018c).

Experimental approach employed in the ***Bones for the Loom. Weaving Experiment with Astragali Weights*** paper (Grabundžija et al., 2016) is reported and described through an elaborate experiment protocol, making the results of the weaving tests verifiable and conclusive.

### 1.2.1. Spindle whorls

A common method of making thread is by using a spindle whorl. Spindle whorls are relatively small and typically rounded symmetrical objects, which are centrally perforated for easier attachment onto a handheld stick, called a spindle. Preserved prehistoric examples are most often made from burnt clay, pottery fragments, bone or stone. They essentially provide inertia for a steady and prolonged rotation during the thread manufacturing process.

To spin a thin, tight yarn, the tool must rotate faster as compared to spinning a thick, looser thread. Whorls of a small diameter, suitable for thin threads and/or shorter staple lengths, like wool, spin faster than the whorls of a large diameter, suitable for thicker threads and/or longer staple lengths, like flax (Barber, 1991, p. 52).

Judging by the preserved textiles and threads, two techniques of thread making existed during the 4$^{th}$ millennium BC (Rast-Eicher & Dietrich, 2015): with a spindle whorl, or by using fingers only. Technique which does not include a tool is called “splicing” and it was used for bast and stem plant materials (Leuzinger & Rast-Eicher, 2011). Splicing is ineffective with short seed plant or animal fibres (Gleba & Harris, 2019, p. 2342).

Since spindle whorls can be used for imparting twist to a spliced yarn, making it more stable, or for plying two or more spliced threads together, they are not necessarily a clear evidence of draft spinning fibres into thread (Gleba & Harris, 2019, p. 2341). Nonetheless, spindle whorls can be regarded as an indication that weaving was performed on the site, since the resulting spun (or plied) threads, through their properties of increased tensile strength and unlimited length, were most likely usable in a loom device (Mazăre, 2012, p. 125).

Shape, size and weight of a whorl are the main factors which determine the tool's rotational properties, influencing its moment of inertia, which is crucial for the spinning process. Although the weight has more influence on tension, namely the strength that pulls the fibres (or threads) during the spinning process, the height and the diameter have a greater impact on the speed of the rotation. Consequently, the higher the rotation the more tightly the yarn is spun (Andersson Strand, 2003, p. 25). Perforation diameter and position are another two properties that effect a whorl's rotation on a significant level, later also being accountable for a spindle whorl's stability while it rotates (Crewe, 1998, p. 12). Perforation is to some extent indicative of a spindle on which a whorl was used, therefore its dimensions and properties should be considered, since they too influenced the spinning (Gleba, 2008, p. 3). The weight of the whorl is given a central role, mainly because it can be connected with both the raw material and the spun thread properties (Anderson Strand, 2003, p. 25). Longer, heavier and coarser fibres, like those of plant origin, are more often considered to be spun with heavier weights, while shorter and lighter fibres, such as animal ones are brought to connection with lighter whorls (Barber, 1991, p. 25; Gleba, 2008, pp. 103-106). Additionally, if general properties of the spun thread are considered, then heavier and thicker yarns necessitate heavy whorls, while lighter and thinner yarns call for light whorls (Costin, 1993; Ryder, 1983).

The mentioned standards ought to be taken with caution, since the actual spinning process is influenced by many combined factors. Besides the already mentioned weight, size, and shape of a whorl, additional traits such as the accumulated thread on a spindle (Barber, 1994, p. 37), the whorl's position on it (Barber, 1991, p. 66; Breniquet, 2008, pp. 110-112), the spinning technique used (Mazăre, 2014, p. 21) and finally the spinner's skill and preference (Kania, 2015) should be considered as well.

Experimental research established the main morphological specifications accountable for the tool's performance with different types of raw material (Verhecken, 2010). The results of spinning experiments are held to have a significant analytical potential for investigating fibre production strategies, at least on the level of determining whether the staple has been based on plant or animal cultivates. This is due to a significant difference in the expected tensile strength and length of the main two cultivated fibre resources used in the European prehistory: fibre flax and wool.

### 1.2.2. Loom weights

Based on the general definition of what constitutes a woven fabric, Andersson Strand gives a short and precise explanation of the weaving technology that covers all types of techniques and looms that might have been used during prehistory: '*A fabric is created by weaving together two thread systems. One of these systems, the warp, runs parallel to the side of the loom and is kept stretched during weaving. The other system, the weft, lies at right angles to the warp and runs alternately over and under the warp threads'* (2012, p. 34).

The intensified production of threads, which is generally attested by a higher frequency of spindle whorls raises a question of the loom and weaving technology.

Methods of stretching the warp threads vary among different cultures and time periods, and several types of looms are proposed to have been used for weaving in the prehistoric times. The horizontal ground loom is one of the oldest loom types, even though the earliest depiction is dated to the Late Neolithic and comes from Badari, Egypt (Broudy, 1979, p. 38; Barber, 1991, p. 83). Another early type is the warp-weighted loom, which is considered to be the characteristic loom of prehistoric Europe (Hoffman, 1964) and is proposed to have been used in the Early Neolithic Körös culture of Hungary, already in the late 7$^{th}$, or early 6$^{th}$ millennium BC (Barber, 1991, pp. 93-94). Finally, the two-beam loom, or tubular loom, which is proposed to have originated in Syria or Palestine, is considered to have been developed during the introduction of wool, due to its convenience for colorful tapestry weaving (Broudy, 1979, p. 44; Barber, 1991, p. 113).

Unfortunately, looms themselves have not been preserved, since they were made of perishable, organic materials. Besides depictions (Wright, 2013, p. 406; Barber, 1991, pp. 83-116; p. 295) and texts (Maekawa, 1980; Waetzoldt, 1987) that provide indispensable information about the prehistoric weaving technologies, both of which are lacking in European contexts, other common evidence for their use are loom weights. Although quite discriminatively, since these are only indicative of the warp-weighted type of loom. Exceptionally, other textile tools, like weaving swords or weaving combs, also get preserved in prehistoric contexts (Bazzanella, Mayr, Moser, & Rast-Eicher, 2003; Kapeller, 2003, p. 229) as an indirect proof of weaving.

A warp-weighted loom might have also been utilized at Çatal Höyük, thus, both Anatolia and Central Europe may be considered as possible origins of this particular technology (Barber, 1991, p. 254). Findings of in situ loom weights are a common occurrence in Neolithic contexts across Europe (Barber, 1991, pp. 91-100) and Barber even describes weaving with a warp-weighted loom as a '*central cultural activity'* during the period (Barber, 1991, p. 97). With this in mind, their disappearance in Late Eneolithic contexts raises an important question of technological change.

Exceptionally rare, Late Eneolithic weights largely differ from earlier, more conventional upper-perforated, for example conical, discoid or elliptical types, since they have a cylindrical or ovoid shape and are usually lengthwise-perforated (Grabundžija et al., 2016).

The disappearance of loom weights in specific areas and periods, for example in Troy V and Early VI (Pavúk, 2012, p. 126) puzzles textile archaeologist. Likewise, in the case of their interrupted use throughout the Bronze Age in the Aegean, it has been proposed that a new type of loom or weaving technology might have been introduced (Nosch, 2014, pp. 6-7). Nonetheless, there are several plausible explanations for the absence of conventional loom weights in archaeological contexts, besides the change of the loom type. First and foremost, loom weights could be lacking in archaeological contexts due to the nature of the perishable materials used for their production. Additionally, according to some authors, more unconventional forms such as spools might have been applied for providing the necessary tension for warp threads (Pavúk, 2012, pp. 123-124; Rahmstorf, 2005, p. 156; Mårtensson et al. 2007b, p. 15). This issue of recognizing textile tools, which often have a multifunctional character is addressed in experimental research (Grabundžija et al., 2016).

It is possible to find sustainable arguments which would connect the use of all three types of looms with woolen threads. Since it can be operated much faster than the vertical loom (Hoffmann, 1964, pp. 130-131, p. 225, p. 258), the horizontal type fits the intensified production scenario, which is the proposed scenario for the Mesopotamian textile industries that developed and strived on wool fibre exploitation (McCorriston, 1997; Kimbrough, 2006).

Nonetheless, wool is quite easy to dye, especially in comparison to flax, and this particular characteristic could have promoted tapestry weaving, for which the two-beam loom is considered to be the most convenient type (Broudy, 1979, p. 44; Barber, 1991, p. 113).

Finally, numerous results of weaving experiments on a warp-weighted loom (Mårtensson et al., 2005-2006, 2007a, 2007b; Schierer, 2005) and its use for producing woolen fabrics in modern times (Hoffmann, 1964) connect this particular type that utilizes loom weights with woolen fabrics as well.

If the research on changes in textile production would solely depend on indirect evidence for weaving, all across the South East and Central Europe, Late Eneolithic could be considered as the period of major adjustments. Established and developed use of the warp-weighted loom during the Neolithic period, simply seems to diminish or even disappear in the second half of the 4th millennium BC. Nevertheless, the warp-weighted loom becomes the most commonly used type again by the Middle Bronze Age (Sofaer, Jørgensen, & Choyke, 2013, p. 480), which is clearly the point in time when new aspects of textile production are already widely spread and completely consolidated on a technological level. This is suggested by more elaborate techniques of weaving, dyeing and most of all, spinning, since different yarn types are the main variable of the European Bronze age textiles (Sofaer et al., 2013, p. 479), as evinced by the actual textile remains (Grömer, Rösel-Mautendorfer, & Bender Jørgensen, 2013).

One of the main features of the recorded Late Eneolithic textile tool assemblages is the rarity of loom weights (Grabundžija et al., 2016), but it is even more interesting that a similar observation can be made for complexes of the late 4th and subsequent 3rd millennium BC in neighboring regions (Petrova, 2016), where all the rare loom weight finds almost exclusively belong to the same massive and elongated (lengthwiseperforated) types. Parallels in shape and size are known from Gomolava (Petrović & Jovanović, 2002, p. 126, p. 211), Sitagroi 4 (Renfrew, Gimbutas, & Elster, 1986, Pl. XXXIV), and from Proto-Bronze and Early Bronze Age settlements in Bulgaria (Petrova, 2011).

## 1. 3 Previous Research

Besides the oldest woolen textile, dated between 3700-3200 cal. BC (Shishlina et al., 2003), recovered at North Caucasus in Central Asia and attributed to the Majkop culture, random fibres preserved on a twined cloth from Lagozza di Besnate, Varese (Bazzanella et al., 2003, p. 184) dated to the recent Neolithic, roughly between 3800-2800 cal. BC (Skeates, 1994, pp. 222-223), indicate that wool can be expected in European contexts just as early as in the Near East. Textile fibre studies that focus on prehistoric Near Eastern productions gather additional data from written sources. For example, wool production is mentioned already in the late 3$^{rd}$ millennium BC cuneiform scripts (Völling, 2012), some of which even report on textile production techniques

(Steinkeller, 1980; Waetzoldt, 1972, 2007, 2010, 2013). Specifics of textile production, in particular spinning, weaving and dyeing, are discussed in research based on Ur III texts (Andersson Strand & Cybulska, 2012; Firth & Nosch 2012; Firth, 2013).

Unfortunately, this kind of approach is not possible in the context of prehistoric Europe, where research heavily relies on textile tools as main proof of textile production.

### 1.3.1. Direct Evidence of Textile Production

Preservation of organic material in archaeological contexts mainly depends on soil conditions and microbial activity. Survival of textiles in prehistoric deposits is especially rare, so their past existance and importance is oftentimes overlooked by archaeologists. The soil's pH-value influences the conservation of animal and vegetal fibres differently. Neutral soils (pH=7) favour animal fibres that are protein-based, which causes them to decay in alkaline conditions, while vegetal fibres dissolve in acidic milieu and are better preserved in alkaline environment, mainly due to their cellulose composition (Cybulska & Maik, 2007).

The preservation of both types of fibres, vegetal and animal, in the same context is very unlikely and rare, whereas it occurs in special circumstances of reduced microbial activity due to desiccation (Good, 1999), permafrost (Winiger, 1995) or high salt concentration (Bichler, Grömer, Hofmann-de Keijzer, Kern, & Reschreiter, 2005).

Since textiles had a relatively short period of use, they are suitable for radiocarbon dating, especially after the development of accelerator mass spectrometry (AMS) which allows dating of smaller samples. Accordingly, several projects have carried out systematic radiocarbon dating of archaeological textiles, which established a solid chronological framework for important textile collections, and more importantly, resulted in an online database of dated textiles established by the Rheinische Friedrich-Wilhelms-Universität in Bonn (http://textile-dates.info).

The main fibre analysis includes the identification of fibres, measurement and assessment of fibre quality, while further measurements of fibres can be used for determining how they were processed, e.g. whether the plant fibres were retted or not, or whether they have been spliced or spun (Leuzinger & Rast-Eicher, 2011). The composition of wool fibres can indicate the type of sheep they derive from (i.e. primitive hairy sheep or more developed ones), whether the wool was shorn or plucked, if it had been sorted or even if it had been combed. This is done by a combination of light microscopy and scanning electron microscopes (SEM), used for investigating pigmentation, scales, fibre surface, medulla and indications of dye, although if it is not possible to take samples, an Optilia Flexia microscope may be used as an alternative (Gleba, 2012).

Only a few textiles have survived within the scope of South East and Central Europe. The majority was recovered at Ljubljansko Barje moors, however, the existing data on these particular examples remains scarce.

Pieces of threads and cord from Dežman's excavations are kept in the National museum in Ljubljana. Other threads and cords, as well as tiny pieces of woven textiles are found at Blatna Brezovica. According to chemical analyses, they are made of either flax or hemp (Greif, 1997, p. 41). But, in contrast to the use of flax (*Linum usitatissimum*), the textile use of hemp (*Cannabis sativa*) in Europe is so far not sufficiently attested prior to the Iron Age (Barber, 1991, p. 15). The fair amount of evidence from Ljubljansko barje, most of which is unfortunately insufficiently published, includes textile products of different character (yarn, cords and woven fabrics). These are all, according to the available data, of plant origin, although, for most of the finds nothing is known about technological parameters, like thickness and spin direction of the thread, weaving techniques, etc.

Archaeobotanical data from the moors (Greif, 1997, p. 29, Fig. 4 & 5) attested the presence of a few wild and cultivated species that might have been used for textile, mat and basketry products, including marshy grass (*Typha angustfollia*) and lime-tree (*Tilia sp*.). Flax was only recently added to the list, due to the use of an appropriate archaeobotanical method of sampling and examination (Tolar & Velušček, 2009). The presence of flax was recorded at Stare Gmajne, one of the moor sites that also yielded a preserved example of a spun yarn, wound into a ball and prepared for weaving, or rope making (Pajagič-Bregar et al., 2009, p. 310). The performed fibre analysis was based on the SEM images, results of which suggest that this high-quality yarn, dated to the end of the 4$^{th}$ millennium BC was most probably spun from fibres found in fruits and stems of plants belonging to the family of grasses (*Poaceae*) (Pajagič-Bregar et al., 2009, p. 318).

Another important piece of evidence from the region is a technically complete textile, found in a Bronze Age burial mound at Pustopolje in Bosnia and Herzegovina, dated to the middle of the 2$^{nd}$ millennium BC (Marić Baković & Car, 2014, p. 42). The woolen cape from Pustopolje, Kupres now consists of almost 600 fragments, but as all four edges are preserved it was possible to establish its original size and design, and most importantly, how it was made (Hoffmann, 1964). Fortunately, the find itself is still organic, meaning it consists of wool rather than being mineralized, which enabled the scientific analyses of fibres and dyestuffs. The textile itself is a wool tabby- complete with starting and finishing borders as well as salvages (Bender Jørgensen & Grömer, 2012, Fig. 4). It is proven to be well made; the evenness of yarns and fabric shows that Bronze Age manufacturers from the Balkans were skilled craftsmen, able to produce high-quality fabric, most likely using drop spindles and the warp-weighted loom (Bender Jørgensen & Grömer, 2012, p. 52). Technical analysis of the textile structure made it possible to identify the starting border, "*a type of transverse border that is usually associated with the warp-weighted loom*" (Bender Jørgensen & Grömer, 2012, p. 61).

Samples of the Pustopolje textile have been subjected to fibre analysis by Dr. Antoinette Rast-Eicher, who used the Light microscopy and SEM to determine that, based on a combination of very fine and very coarse fibres (kemp), a 'typical' unsorted Bronze Age wool was used (Bender Jørgensen & Grömer, 2012, p. 56).

Analogies for the textile recovered at Pustopolje can be found among Bronze Age woolen finds from the copper and salt mines at Mitterberg and Hallstatt, both dated between 1600 and 1200 BC (Grömer, 2006). These finds suggest "*a fully developed wool textile culture*", and even though the woolen tabbies are made of single yarn and are coarser than the Early Bronze Age linens, they offer a particular novelty- color (Bender Jørgensen & Grömer, 2012, p. 50).

### 1.3.2. Indirect Evidence of Textile Production

During the past decade textile tools have become the main focus of studies explaining technological developments connected to craft specialization (Andersson Strand, 2011), intensified production (McCorriston, 1997) and introduction of new raw fibre materials (Kimbrough, 2006). In order to elucidate the original use and function of textile tools in connection to different fibres, textile studies often combine two different methods. The first includes a morphometric analysis of textile tools (i.e. Belanová-Štolcová & Grömer, 2010) and the second, which complements it, is based on the results of experimental archaeology (i.e. Andersson Strand, 2010) that provides analogies necessary for determining functional parameters.

Apart from pioneering studies on textile traditions in Romania (Mazăre, 2014) and Bulgaria (Petrova, 2011), which only took into consideration archaeological evidence from confined geographical sections, diagnostic objects from a large area of South East and southern Central Europe have not been systematically studied. Although Mazăre's study (2014) of textile tools from the Transylvanian region covers a long period (between 6000 and 3500 BC), it left the Late

Eneolithic textile production unaddressed. Unfortunately, the ‘transitional’ centuries of the second half of the 4th and the first half of the 3rd millennium BC, which are not covered by the particular study, are the most interesting for the research of the new fibre material practice. Firstly, in regard to animal fibre resources, as it is proposed by Sherratt’s model (Sherratt, 1981, 1983), and secondly, in regard to flax fibre cultivation, as it is indicated by recent studies on botanical evidence (Jacomet, 2009; Herbig & Maier, 2011; Harris, 2014).

On the other hand, Petrova’s study (2011) of textile tools from Bulgaria covers mainly later contexts, focusing more precisely on Bronze and Iron Age tool samples. This again did not allow a more detailed study of the major advancements in the fibre material procurement strategies that are expected for the Eneolithic period. Incidentally, the drawback of both bodies of research is that while focusing on separate periods and confined areas, they left little room for cross-regional comparison of the results.

However, another case study of textile tools, which incorporates a fair number of Eneolithic sites in Poland (Chmielewski, 2009), offers a reference for technological changes observed on the Eneolithic tool sample from South East and southern Central Europe (Grabundžija & Russo, 2016). Chmielewski’s extensive research on textile production covers not only spinning and weaving aspects of the technology but also incorporates zooarchaeological and archaeobotanical data relevant for the textile fibre research. Furthermore, his and Gardyński’s functional analysis of spindle whorls, based on the moment of inertia calculations (Chmielewski & Gardyński, 2010), made a valuable methodological asset to the investigation of a tools’ rotational properties and their possible correlation to different raw fibre materials.

The main setback in investigating prehistoric textile technologies and, in particular, developments in fibre production and processing is the lack of published data. Those tools that do get published are often not reported in their complete assemblages or are lacking the most important data, which include size and weight information. This makes them eligible for typological comparisons but does not provide the needed information for performing a functional analysis.

The already mentioned Ljubljansko Barje pile-dwelling sites, which yielded several pieces of textile, also produced a large amount of textile tools, mainly spindle whorls. Unfortunately, no systematic study of textile production has been published so far. Some of the finds have been reported, among them a part of the sample from Maharski Prekop (Bregant, 1974a, 1974b, 1975), a site synchronized with the Baden-Boleráz complex (Parzinger, 1984), and dated in absolute terms to the period between ca. 3500-3300 BC. The particular sample typologically corresponds spindle whorl sets of the Baden-Boleráz cultural group (Ruttkay, 1995, pp. 145-160), although strong parallels can be also made with the tools from Horgen site Arbon-Bleiche 3 in east Switzerland (Leuzinger, 2002, Fig. 2). This site is absolutely dated between 3384 and 3370 cal. BC, which makes it roughly contemporary to Maharski Prekop (de Capitani & Leuzinger, 2001, p. 721). The basis for comparison of the two tool sets is supported by the pronounced Baden-Boleráz influence (de Capitani & Leuzinger, 2001, p. 723). All types of whorls from Maharski Prekop reveal parallels with Arbon-Bleiche 3 sample. Although, these two samples obviously differ in size of the whorls. Spindle whorls from Maharski Prekop appear significantly larger than the examples belonging to the Arbon-Bleiche 3 sample. Another Ljubljansko Barje site, Blatna Brezovica (Korošec, 1963), also yielded a spindle whorl sample that could be considered roughly contemporary to the Maharski Prekop assemblage (Greif, 1997, Tab. 1). The site produced some actual textile remains that remain unpublished, although a selection of large biconical and conical spindle whorls (including a fragment of an ovoid longitudinally pierced loom weight) was reported in the literature (Korošec, 1963, pp. 17-20).

One of the biggest sets of spindle whorls in the wider region was recovered at Ig-Ljubljansko barje. The tools in question originate from Dežman's excavations (Dežmnanova kolišča) that were carried out at the end of the 19th century and were published without weight values (Korošec & Korošec, 1969). Unfortunately, both chronological and cultural attribution of these tools remains uncertain. According to the authors (Korošec & Korošec, 1969) it is more than likely that the collection belongs to more than one settlement and it can be established that the tools belong to the period from the very end of the Eneolithic (Vučedol culture) till the Early Bronze Age (Somogyvár-Vinkovci /Ljubljana culture).

Typological (biconical and high conical spindle whorls) and morphological (large and heavy spindle whorls) analogies for the Ig sample can be traced among rare published examples of Late Eneolithic spindle whorls from Vučedol-Gradac (Schmidt, 1945, Taf. 48) and Sarvaš (Balen, 2005, T. 58, 73, 74) in eastern Croatia, or Gomolava in Serbia (Petrović & Jovanović, 2002, p. 221, 279, 319, 321).

## 2 PUBLICATIONS

The following five publications are included in their original, published form[2]. They are ordered according to the outlined content as opposed to the date of publication.


Grabundžija, A. (2019). The Textile Revolution – Textile Tool Database, Edition Topoi. Retrieved 20 December 2019, from http://repository.edition-topoi.org/collection/WOLL .
DOI: 10.17171/2-17-4


Grabundžija, A. (2018b). Two sides of a whorl. Unspinning the meanings and functionality of eneolithic textile tools. In M. Siennicka, L. Rahmstorf, and A. Ulanowska (Eds.), *First Textiles: The Beginnings of Textile Manufacture in Europe and the Mediterranean*. Ancient Textiles Series 32 (pp. 129-142). Oxford & Philadelphia: Oxbow Books.
ISBN 978-1-78570-799-5


Grabundžija, A., & Russo, E. (2016). Tools tell tales – climate trends changing threads in the prehistoric Pannonian Plain. *Documenta Praehistorica, 43,* 301-326.
DOI: 10.4312/dp.43.15


Grabundžija, A. (2018c). Threads that bind the establishment. Housing Eneolithic textile craft. In J. Balen, I. Miloglav, and D. Rajković (Eds.), *Back to the past - Copper Age in Northern Croatia*, 287-323. Zagreb: Arheološki muzej.
DOI: 10.17234/9789531758185-15


Grabundžija, A., Schoch C., & Ulanowska, A. (2016). Bones for the Loom. Weaving Experiment with Astragali Weights. *Prilozi Instituta za arheologiju u Zagrebu, 33,* 287-306.
ISSN 1330-0644

[2] The second publication from the list titled ***Two sides of a whorl. Unspinning the meanings and functionality of Eneolithic textile tools*** (Grabundžija, 2018b) is available in its full length only in the printed version of this thesis. The on-line version of the thesis does not include the entire offprint from *The Ancient Textiles Series 32*, since the publisher (Oxbow Books) withholds the copyright for unlimited access on the World Wide Web for three years from publication (November 2021). The fourth and the fifth publication (**Threads That Bind the Establishment. Housing Eneolithic Textile Craft** (Grabundžija, 2018c) and **Bones for the Loom. Weaving Experiment with Astragali Weights** (Grabundžija et al., 2016) were published in two languages, English and Croatian.

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## ARCHAEOLOGICAL EVIDENCE FOR EARLY WOOL EXPLOITATION IN SOUTH-EAST AND EAST CENTRAL EUROPE: TEXTILE TOOL DATASET

This summarized and catalogued dataset was recorded and analyzed during the Topoi PhD Research Project (A-4-1-1) on Archaeological Evidence for Early Wool Exploitation in South-East and East Central Europe. It contains textile tools sampled within a site cluster that stretches accross the Pannonian Plain. The research study was focused on elucidating spatio-temporal and causal factors of the major changes in Eneolithic textile technologies, which might have been associated with raw fibre material innovation (Becker et al., 2014). The final Catalogue of Finds contains details on, collectively, 1048 archaeological objects classified as textile tools.
Archaeological objects, namely spindle whorls, loom weights and spools, were recorded and analysed according to the methodological standards of the respective field of textile archaeology.
The main objectives of the study are presented in a manuscript published uder the title "Eneolithic Textile Production", which provides insight into the state of the art of textile archaeology, while dealing with actual textile remains and textile tools from the region separately (Grabundžija, 2018a).
Results of the techno-typological analysis performed on the assembled material clarified that animal fibre use, possibly being driven by local environmental conditions, intensified already in the $4^{th}$ millennium BC (Grabundžija & Russo, 2016). Furthermore, comparison of the investigated spindle whorl assemblages revealed that Eneolithic thread making had a 'culture-specific' technological signature. Both the typological standards and the morphometric specifications of these tools display a statistically significant dependence on what is in the traditional culture-historical discourse, meant by the term 'archaeological culture' (Grabundžija, 2018b). Examination of the social aspects of thread production pointed to intensified fibre processing and plausibly the early specialization of the manufacture during the Eneolithic period (Grabundžija, 2018c).
An experimental method was performed as a remote part of the tool analysis, with the main purpose of investigating alternative tool options and their versatility which could explain the absence of loom weights in some of the inspected contexts (Grabundžija et al., 2016).

### GEOGRAPHICAL AND CHRONOLOGICAL FRAME OF THE STUDY

In a broader geographical perspective, the 26 sampled sites (Fig. 1, Tab. 1) are spread across the southern parts of the Pannonian plain, at the edge of the South-East and East Central Europe, covering most of the Western Balkans area (including parts of Slovenia, southern Hungary, northern and eastern Croatia and northern Serbia). The geomorphological term Pannonian Plain is preferred over the 'Carpathian Basin', since the investigated archaeological material was recovered in the lowlands. The dataset does not include higer altitude archaeological sites from the mountain ranges that surround the plain which formed after the Pliocene Pannonian Sea dried out.
In a traditional cultural-historical discourse, textile tool samples that were collected for the study can be attributed to 10 regional and supra-regional Late Neolithic (i.e. Vinča), Eneolithic (i.e. Balaton-Lasinja, Furchenstich, Retz-Gajary, Proto-Boleráz, Boleráz, Baden, Kostolac, Vučedol) and Early Bronze Age (Somogyvár-Vinkovci) cultures.

The chronological timespan covers the Late Neolithic to the Early Bronze Age periods, which spans roughly from the first half of the 5th till the beginning of the 2nd millennium BC (Raczky, 1995).
The upper chronological limit of the research corresponds with the period of the gradual disintegration of the large Neolithic complexes (i.e. Vinča, Sopot, Tisza and Herpály cultures) somewhere around 4600 cal. BC (Borić, 2015; Burić, 2015; Raczky et al., 2014). At the same time some of the Late Neolithic communities, i.e. Lengyel culture in the Hungarian Transdanubia (Bánffy, 1994; Regenye, 2013), and Sopot culture in parts of western Croatia and Slovenia (Balen & Čataj, 2014) continued to live well into what is now considered to be the Early Eneolithic period.

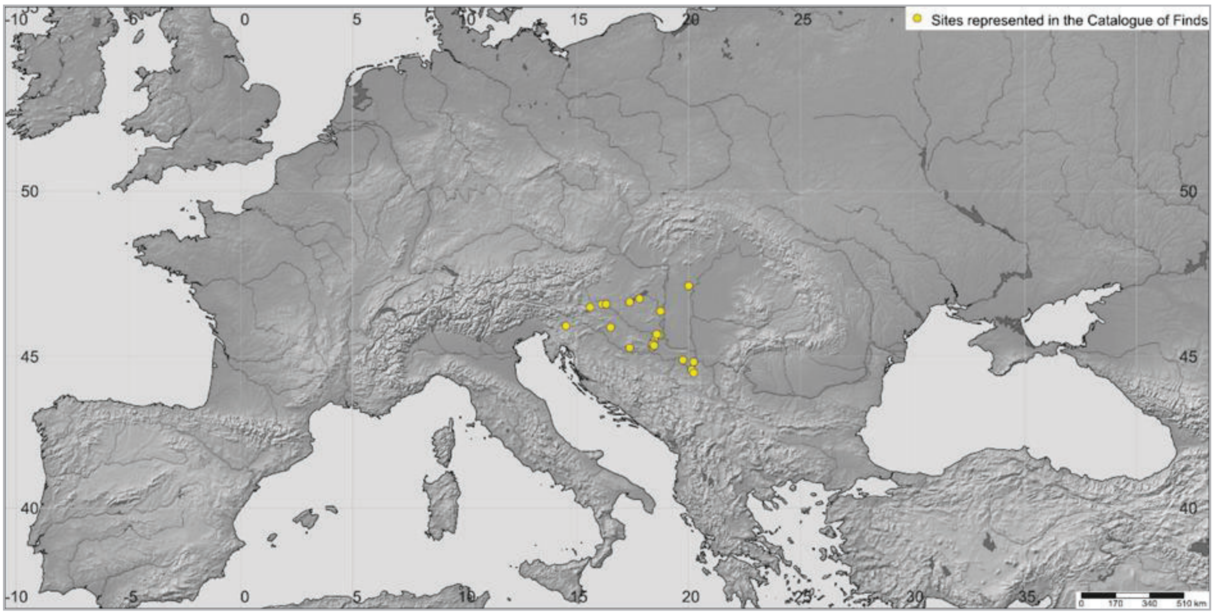


**Figure 1.** Map of the investigated site cluster represented in the final Catalogue of Finds.

Different "grand narratives" describe the shift between Neolithic and Eneolithic periods in Europe, either as gradual or abrupt transformations of local sociocultural and economical systems. Transformations were not mutual and were not simultaneously occurring throughout the whole of Europe. Settlements in some regions were nucleated in Neolithic and dispersed in Early Eneolithic (Parkinson et al., 2004; Gyucha et al., 2015; Raczky et al., 2014), tell settlements in major parts of the South Pannonia and Central Balkans were abandoned after the Late Neolithic (Link, 2006), burial customs also differed in some areas (Raczky et al., 2014: 328–331), while material culture patterning followed local traditions with significant tendency toward regional formal homogenisation. Characteristic shapes of copper tools and similar pottery forms occur over the vast territory of Europe. The same forms of Early Eneolithic copper axes were produced from the southern Balkans to Central Europe (Diaconescu, 2014), distribution of Early and Middle Eneolithic hollow-foot vessels, incised beakers and lobate vessels of Tiszapolgár and Bodrogkeresztúr cultures point to connections between the far peripheries of the continent (Spasić, 2008; Czekaj-Zastawny at al., 2011). Broad distribution of Late Eneolithic Baden culture cups and so-called Bratislava lids (Maran, 1998; Spasić, 2008; Jovanović & Blagojević, 2014) also speak in favour of intensification of contacts and merchant routes in 4th and 3rd millennium BC Europe. Schier has evaluated the concept of Eneolithic (Copper age) as an historical epoch, as well as all supposed transformations that occurred during the Late Neolithic/Early Eneolithic shift (Schier, 2014). Through his analysis, he implied that the period in question should be investigated on a local and absolute temporal level, and that "the time of grand narratives may be over, but local and regional stories are equally fascinating and more adequate reflections of the dynamic cultural diversity in prehistoric Europe" (Schier, 2014: 432).

A minor part of the recorded textile tool corpus can be dated to the Late Neolithic period which was not in the main chronological focus of the study. Earlier textile practices were analysed in order to establish the degree and the nature of technological change as well as other indications and consequences of it. Therefore, tool assemblages from three Late Neolithic Vinča culture settlements in Serbia were recorded. The biggest sample comes from the tell site of Gomolava (Jovanović, 2011), while significantly smaller samples come from the sites of Masinske Njive (Blagojević 2014) and Crkovne-Stubline (Spasić, 2012; Crnobrnja, 2014). Late Neolithic Vinča culture had a strong textile tradition (Chapman, 1981: 122-124; Tringham & Stefanović, 1990: 325-336). This is reflected in the size of the Vinča culture textile tool sample, in particular, its loom weight segment. Additionally, the amount of textile imprints recovered on numerous Vinča culture ceramic finds (Mazăre, 2012: 23-26; Ninčić, 2011: 181-184; Crnobrnja et al., 2009: 17; Vasić, 1936: 44-45) support this argument.

The Middle Eneolithic sample can be dated to the Balaton-Lasinja culture sites in Croatia and Slovenia (Kalinovnjek pri Turnišću, Turnišče, Pajtenica-Velike Livade, Tomašanci-Palača, Zgornje Radvanje), and to various manifestations of the so called Furchenstich horizon (such as Retz-Gajary) in Sloveina, Croatia and Hungary (Kalinovnjek pri Turnišću, Turnišče, Pod Kotom-jug pri Krogu, Tolna-Mözs Kenderföldek-dűlő, Čeminac-Vakanjac, Ivandvor, Jagodnjak-Napuštene njive, Josipovac Punitovački-Veliko polje). A broad range of different types of Balaton-Lasinja material culture, settlement patterns and burial practices seem to have good analogies and roots in earlier Late Neolithic/Early Eneolithic Sopot and Lengyel traditions but are also very similar to the partly contemporary Bodrogkeresztúr, Salcuţa and Ludanice cultures. In the collected dataset, the Balaton-Lasinja specimen highlights the transition from the Late Neolithic/Early Eneolithic textile production technologies. On the other hand, various manifestations of the so called Furchenstich horizon represent a turning point between Middle and Late Eneolithic (Kalicz & Horváth, 2010), and much of its characteristic textile tool assemblage could be observed in the earliest Late Eneolithic period, i.e. Proto-Boleráz specimen from Abony-Turjányos dűlő site.

The focus of interest for the study of technological change was the Late Eneolithic period, i.e. 3600-2500 BC. The sequence of three consecutive and partly contemporary cultural horizons are typical for the Late Eneolithic of the Southern Pannonian plain, i.e. Boleráz/Baden-Kostolac-Vučedol (Petrović & Jovanović, 2002). The material artefact of all three Late Eneolithic cultures is rather homogenous over the vast territory of Southern Pannonia, especially regarding basic forms of pottery, while settlements, economy and burials differ significantly from region to region and are mainly of local tradition.

The Late Eneolithic period witnessed further social, cultural, economic and technological transformations. Changes in animal husbandry, the use of secondary animal products, changes in textile production, the invention of wheeled vehicles and the plough, the domestication of horses, as well as the appearance of new forms of burial (i.e. tumuli) and material culture were sought in the context of Andrew Sherratt's "Secondary Products Revolution" (SPR), as the joint package of innovations that spread from the proto-urban and urban societies in the Near East (Sherratt, 1981, 1983, 2002). Although significant parts of the mentioned novelties seems to appear much earlier than Sherratt has originally proposed (especially milk products: Evershead et al., 2002; Sherratt, 2002; Craig, 2002: 102-104; Craig et al., 2005; Vigne & Helmer, 2007), his concept remains as one of the most used grand narratives that defines the socio-cultural and technological trajectories of the European Late Eneolithic (Greenfield, 2010).

The vast part of the catalogued corpus dates to the Late Eneolithic period. The Gomolava tell settlement in Serbia stands out as the only site in the cluster with clear vertical stratigraphy comprising of samples dated to four different chronological phases (Petrović & Jovanović, 2002; Jovanović, 2011). This allowed high resolution insight in the development of textile production of both Neolithic (Vinča culture) and Eneolithic period (Baden, Kostolac and Vučedol cultures). Samples from other studied Late Eneolithic sites mainly come from temporal settlements with developed horizontal stratigraphy (i.e. Dobanovci, Masinske Njive, Đakovo-Franjevac, Balatonkeresztúr Réti-dűlő). The majority of Late Eneolithic settlements were investigated during the rescue excavations (i.e. Balatonőszöd–Temetői-dűlő, Tolna-Mözs Kenderföldek-dűlő, Štrosmajerovac-Pustara) which meant that large parts of the settlements were revealed, thus enabling a variety of taphonomical and spatial analyses.

The beginning of the Early Bronze Age, marked by the ending of the Vučedol culture and the onset of the Somogyvár-Vinkovci culture, is the last phase that was included in the chronological timespan of the recorded dataset. Chronology based on 14C absolute dates sets the beginning of the Early Bronze Age around 2500 BC and its end around 1700 BC. (Forenbaher, 1993: 235-236). According to calibrated dates the end of the Vučedol culture is placed around 2500 BC, although somewhat shorter duration is assumed (Forenbaher, 1995: 22).

The Early Bronze Age is the least documented period in the sample, with specimens collected from the Josipovac Punitovački-Veliko polje (Čataj, 2009), Tomašanci-Palača and Viškovci sites in Eastern Croatia. The Ljubljansko Barje specimens come from older excavations which did not allow exact dating of tools, although they can be roughly placed in the 3$^{rd}$ millennium BC, Late Eneolithic/Early Bronze Age period, i.e. Vučedol/ Somogyvár-Vinkovci cultures (Korošec & Korošec, 1969).

A short reconsideration of this study's spatial and temporal frame indicates that the Pannonian plain was neither a uniform homogenous space nor a completely divided heterogeneous area during the Late Neolithic and Eneolithic periods. Rather, it consisted of a myriad of different communities with strong local subsistence and production traditions, intermingled with many common and above-regional characteristics. The textile tool corpus supports such a claim, since the majority of the analized technologies display both common and exceptional features (Grabundžija, 2018c).

| ARCHAEOLOGICAL SITE | PUBLICATION |
|---|---|
| Abony-Turjányos dűlő | Fábián & Serlegi, 2009; Köhler et al., 2017; Fábián et al., 2018 |
| Balatonkeresztúr Réti-dűlő | Fábián, 2007; Fábián, 2014; Fábián et al., 2018 |
| Balatonőszöd–Temetői-dűlő | Horváth, 2010; Horváth, 2012a; Horváth, 2012b; Horváth, 2014 |
| Brezje pri Turnišču | Novšak et al., 2013 |
| Čeminac-Vakanjac | Kalafatić & Hulina, 2016 |
| Čepinski Martinci-Dubrava | Kalafatić, 2009 |
| Crkvine-Stubline | Crnobrnja et al., 2009; Crnobrnja, 2014 |
| Cugovec-Barbarsko | Balen & Drnić, 2014 |
| Dobanovci | Tasić, 1995 |
| Đakovo-Franjevac | Balen, 2011 |
| Gomolava | Petrović & Jovanović, 2002 |
| Ivandvor | SHORT REPORT ONLY: Leleković, 2008 |
| Jagodnjak- Napuštene njive | Dizdar et al., 2016 |
| Josipovac Punitovački-Veliko polje | Čataj, 2009 |
| Kalinovnjek pri Turnišću | Kerman, 2013 |
| Ljubljansko Barje-Ig | Korošec & Korošec, 1969 |
| Masinske Njive | Blagojević, 2014 |
| Pajtenica-Velike Livade | Zorić, 2018 |
| Pod Kotom-jug pri Krogu | Šavel et al., 209 |
| Slavča-Nova Gradiška | Skelac, 1997; Mihaljević, 2006 |
| Štrosmajerovac-Pustara | SHORT REPORT ONLY: Hršak & Bojčić, 2008 |
| Tolna-Mözs Kenderföldek-dűlő | MENTION ONLY: Fábián et al., 2018 |
| Tomašanci-Palača | SHORT REPORT ONLY: Balen, 2008 |
| Turnišče | Tomaž et al., 2012 |
| Viškovci | SHORT REPORT ONLY: Balen, 2013 |
| Zgornje Radvanje | Kramberger, 2014 |

**Table 1.** Archaeological sites represented in the final Catalogue of Finds together with relevant bibliographical references.

**TEXTILE TOOL DATASET AND THE APPLIED METHODS OF RECORDING**

The guidelines for the textile tool recording protocol were adopted from the methodological model established by the Centre for Textile Research (CTR) in Copenhagen. The final Catalogue of Finds contains 901 archaeological objects classified as **spindle whorls** (Catalogue Numbers 1-901), 125 archaeological objects classified as **loom weights** (Catalogue Numbers 902-1026) and 22 archaeological objects classified as **spools** (Catalogue NumberS 1027-1048).

Recorded material originated from 26 **archaeological sites.** Besides being associated with one of the ten different **culture-historical contexts** dated to Neolithic, Eneolithic and Bronze Age periods, each archaeological object was placed in one or more **time slices.** Quarter millennium time slices enabled easier comparison with other datasets within the project (Becker et al., 2014).

Besides their contextual information (such as **archaeological site** where they were found, or **cultural-historical context** to which they belong to) and a reference to where they are stored (such as **inventory number** or **holding institution**), all archaeological objects were classified according to

their **preservation condition** in one of the four different categories: complete, half, partial and small fragments missing (more than 90% of the archaeological object is preserved).
Any presence of **decoration** or decorative design on an archaeological object was noted. For each category of finds (spindle whorl, loom weight, spool) separate set of measurements was taken in millimeters (Fig. 2).

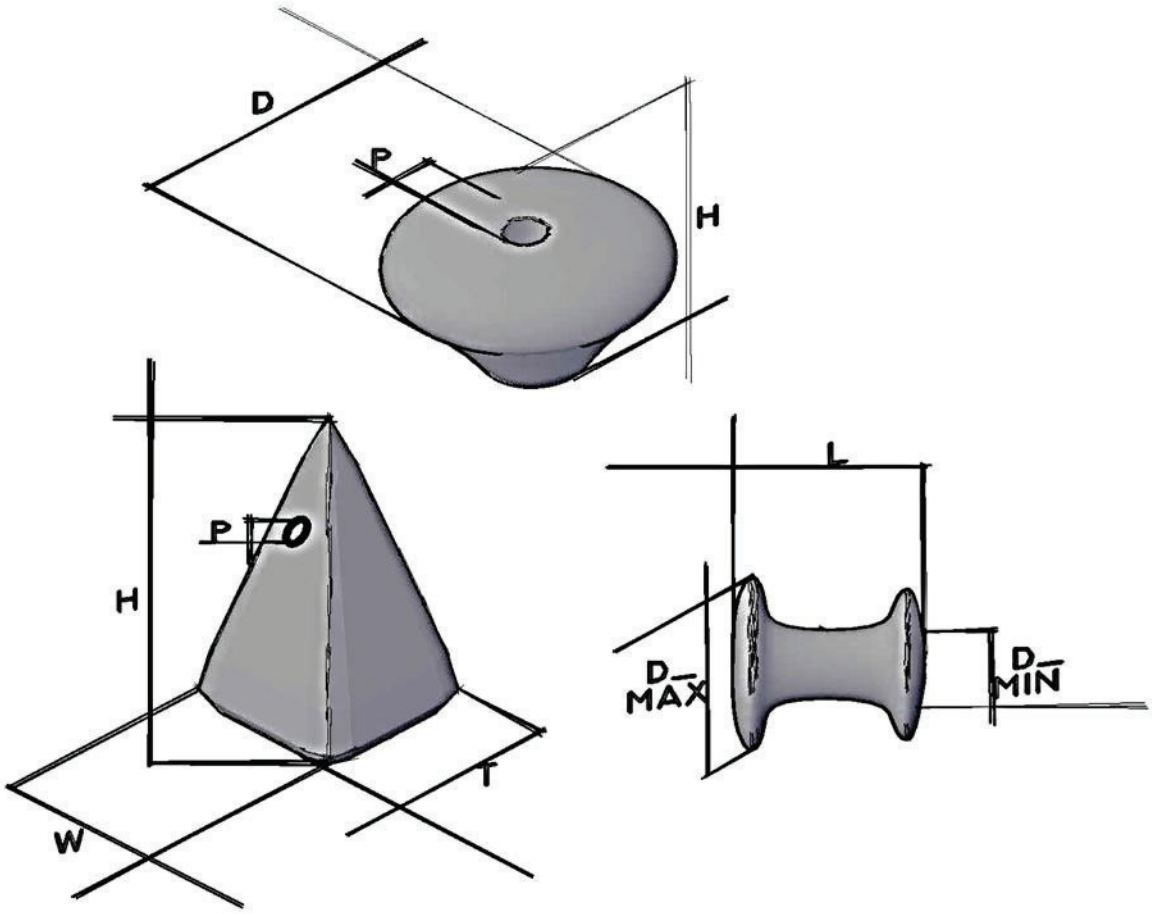


**Figure 2.** Illustration of the main morphometric parameters measured for each category of finds. Up: three main measurements taken for spindle whorls ("H"- complete height, "D"- complete diameter and "P"- perforation diameter); down left: four main measurements taken for loom weights ("H"- complete height, "P"- perforation diameter, "T"- complete thickness, "W"- complete width); down right: three main measurements taken for spools ("L"- complete length, "D MAX"- maximum diameter and "D MIN"- minimum diameter).

In addition, each archaeological object was weighted with its weight parameter being noted in grams. All archaeological objects in the collected dataset are made of ceramic, fired clay **material**, except one spindle whorl (Catalogue Number: 524), which was made out of bone (Čataj, 2009: 31; Grabundžija & Russo, 2016: 312-313).
A comprehensive spindle whorl analysis, which was enabled by composing this dataset, resonated regional trajectories of thread production at the expense of accounting for site-specific

developments (Grabundžija & Russo, 2016; Djurdjevac Conrad et al., 2018; Grabundžija, 2018a; Grabundžija, 2018b; Grabundžija, 2018c).

Sampled loom weights were recorded mainly with the purpose of addressing typological variability and frequency trends, since the changes in weaving technology were approached and explored primarily as reflective of possible innovations in earlier stages of textile production, namely in fibre processing and thread making segments of the manufacture.

Due to a substantial amount of published experiments involving spindle whorl performances (Grömer, 2005; Kania, 2015; Laurito et al., 2014; Andersson Strand, 2010), no experimental method has been applied for further testing of the spindle whorls' functional parameters.

**Spindle whorls**

The final Catalogue of Finds contains 901 spindle whorls that were typologically divided into ten **types**: biconical, conical, concave conical, convex, cylindrical, discoid, wheel-like discoid, lenticular, spherical and perforated ceramic fragment (Fig. 3).

The weight values of spindle whorls were documented in two different reliability classes, depending on their preservation condition. Weights of complete samples were documented in the **weight if complete** class and weights of samples that were in any way damaged (whorls preserved in half, whorls with small fragments missing and whorls that were recorded as partial) were recorded in the **weight if not complete** class. Weights of almost complete samples with small fragments missing were additionally documented in the **estimated complete weight** category (estimated complete weight= weight if not complete), weights of samples preserved in half were documented in the **calculated complete weight** category (calculated complete weight = weight if not complete doubled) and finally, weights of partial samples were documented in the **reconstructed complete weight** category (reconstructed complete weight = **density** x **volume**).

Virtual three-dimensional reconstructions of partially preserved spindle whorls were created based on their section drawings by using the Autodesk 3D modeling software. The orto-photo records of the preserved fragments served as a basis for modeling the breakage surface. Knowing the weight of the fragment (weight if not complete) and its volume (**volume of the fragment**), taken from the geometry of the virtual fragment model, the spindle whorl's density parameter was easily calculated (density = weight if not complete / volume of the fragment). Finally, from the calculated density parameter and the **complete volume** parameter (taken from the geometry of the virtual three-dimensional reconstruction), a calculation of the reconstructed complete weight was possible (reconstructed complete weight = density x complete volume). This method has not been applied so far, so its accuracy was tested on a smaller spindle whorl sample. Ten replicated spindle whorls were documented, broken and virtualy reconstructed, in order to test the possibility of miscalculation and to estimate the range of the reconstructed complete weight error. The test sample included ten spindle whorl replicas (Fig. 4, Tab. 2).

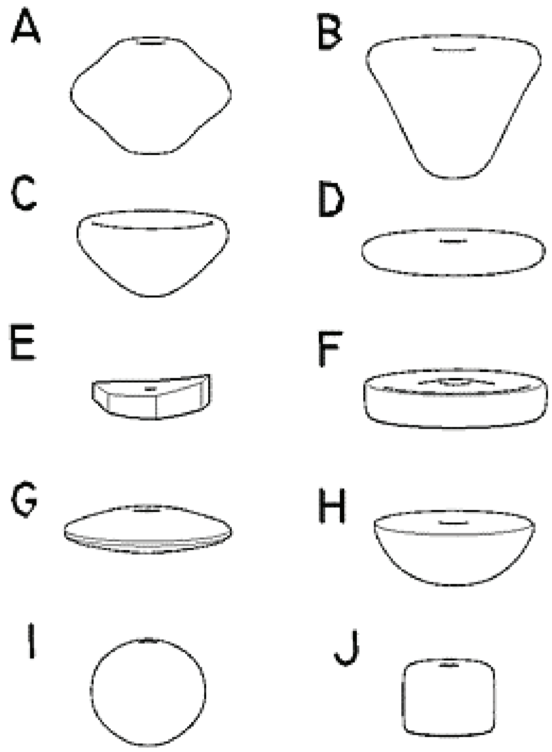


**Figure 3.** Ten recorded spindle whorl types: biconical (A), conical (B), concave conical (C), discoid (D), perforated ceramic fragment (E), wheel-like discoid (F), lenticular (G), convex (H), spherical (I) and cylindrical (J).

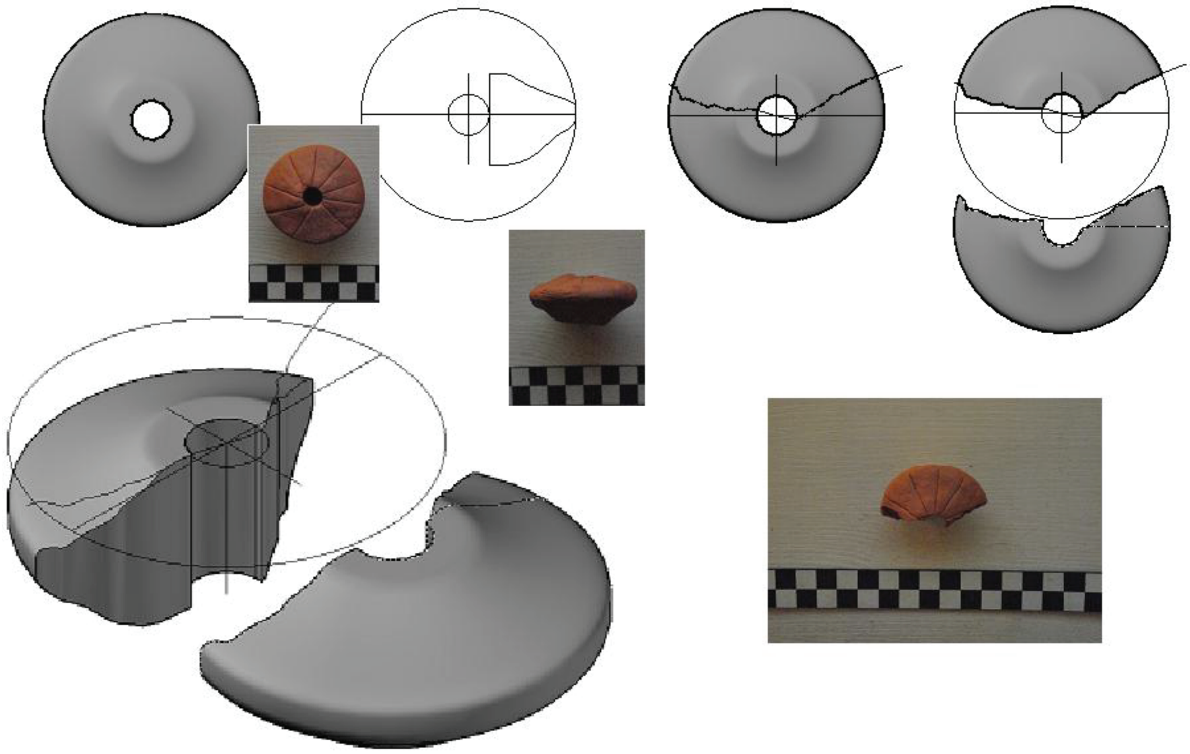

**Figure 4.** Three-dimensional model of a virtualy reconstructed spindle whorl used for testing the reliability of the applied weight reconstruction method.

| TEST_SW_ID | W_C | W_I | V_C | V_F | DEN | W_REC | ERROR (g) | ERROR (%) | MATERIAL |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 96.5 | 46.3 | 70098 | 32757 | 0.00141344 | 99.079201 | 2.57 | 2.66 | UNFIRED CLAY (DRYED) |
| 2 | 39.4 | 17.4 | 29801 | 12754 | 0.00136428 | 40.656845 | 1.25 | 3.17 | UNFIRED CLAY (DRYED) |
| 3 | 16.6 | 10.3 | 12483 | 7877 | 0.0013076 | 16.322826 | 0.28 | 1.68 | UNFIRED CLAY (DRYED) |
| 4 | 13.6 | 8.6 | 11809 | 7891 | 0.00108985 | 12.870029 | 0.73 | 5.36 | UNFIRED CLAY (DRYED) |
| 5 | 45.3 | 35.5 | 36555 | 30226 | 0.00117449 | 42.933319 | 2.37 | 5.23 | UNFIRED CLAY (DRYED) |
| 6 | 13.6 | 3.6 | 16466 | 4591 | 0.00078414 | 12.911697 | 0.68 | 5.06 | UNFIRED CLAY (DRYED) |
| 7 | 13 | 5.9 | 10707 | 5148 | 0.00114608 | 12.271037 | 0.73 | 5.61 | UNFIRED CLAY (DRYED) |
| 8 | 12.8 | 6.7 | 11006 | 6085 | 0.00110107 | 12.118357 | 0.69 | 5.39 | UNFIRED CLAY (DRYED) |
| 9 | 91.6 | 36 | 51346 | 21053 | 0.00170997 | 87.800124 | 3.8 | 4.14 | CERAMIC (FIRED CLAY) |
| 10 | 7.9 | 4.5 | 4487 | 2491 | 0.0018065 | 8.1057808 | 0.2 | 0.01 | CERAMIC (FIRED CLAY) |

**Table 2.** Spindle whorl test sample given with actual (weight if complete – before damage; weight if not complete – weight of a fragment post damage) and reconstructed complete weight values, showing the calculation error range (in grams and percentage).

**Loom weights**

The final Catalogue of Finds contains 125 loom weights that were typologically divided into five **types**: conical, pyramidal, discoid, elongated ovoid and elongated cylinder (Fig. 5). Only the measured weight (**weight if complete** or **weight if not complete**) was recorded for the loom weight specimen.

The biggest majority (68 specimen, which is more than 54%) of the loom weight sample belongs to the Neolithic (Vinča) contexts. Fewer examples (48 specimen, which is more than 38%) are dated to the Middle Eneolithic, whereas only a small number of occurrences (9 specimen, which is less than 8%) can be associated with the Late Eneolithic and Early Bronze Age contexts (Fig. 6)**.** Rare Late Eneolithic weights largely differ from earlier, more conventional upper-perforated types. They all have an elongated shape (elongated ovoid/elongated cylinder) and are perforated longitudinally.

Between the Neolithic and the Eneolithic samples there are some obvious differences in the distribution of the measured **thickness** parameter. Middle Eneolithic (Balaton-Lasinja and Furchenstich) examples of the conical and pyramidal type are much thicker than the typical Neolithic Vinča culture discoid specimen. The same is the case with the rare later examples dated to the Late Eneolithic/Early Bronze Age, which have an even greater thickness.

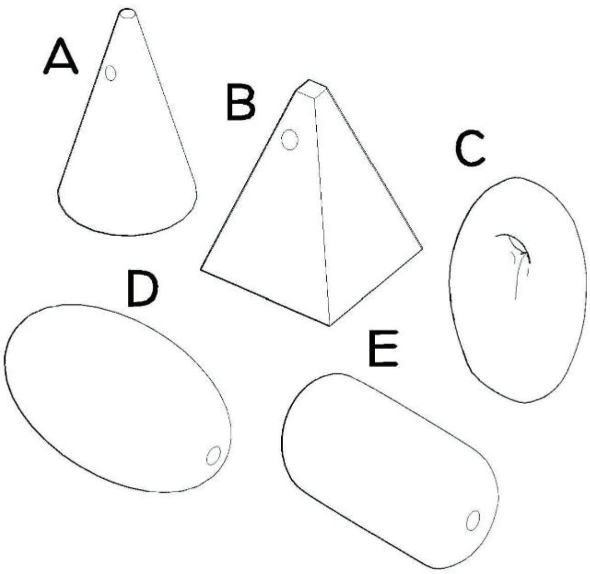


**Figure 5.** Five recorded loom weight types: conical (A), pyramidal (B), discoid (C), elongated ovoid (D) and elongated cylinder (E).

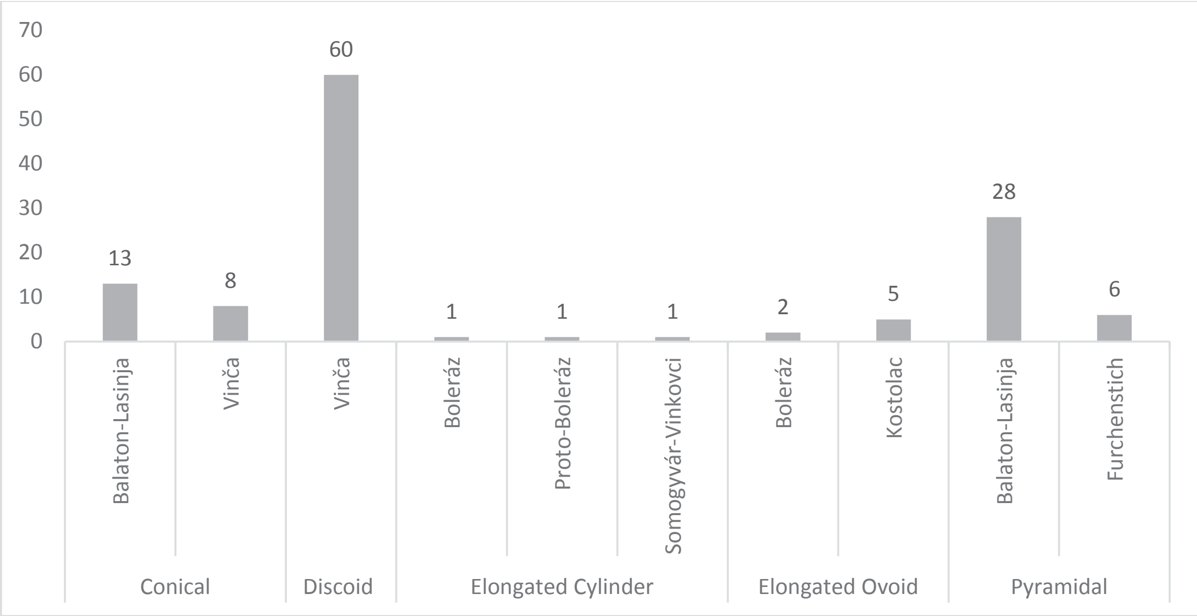


**Figure 6.** Frequency of loom weight types according to culture-historical contexts.

**Spools**

All together 22 spools are recorded in the final Catalogue of Finds. Same as for the loom weights, only the measured weight (**weight if complete** or **weight if not complete**) was documented for spools.

All documented specimen come from the Late Eneolithic (Kostolac and Baden) contexts (Fig. 7). Their occurance in the Late Eneolithic material coincides with the observed dissaperance of conventional loom weight types. Spools from the Boleráz/Baden settlement at Balatonőszöd–Temetői-dűlő site in Hungary were not available for recording at the time of the data sampling but are all published in detail by the excavator (Horváth, 2012b).

**Figure 7.** Kostolac spools from Đakovo-Franjevac (Catalogue Numbers: 1031, 1034 and 1035).

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Two sides of a whorl. Unspinning the meanings and functionality of Eneolithic textile tools

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# Tools tell tales – climate trends changing threads in the prehistoric Pannonian Plain

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ABSTRACT – *This study of prehistoric textile production on the Pannonian Plain is based on indirect evidence dated to the period between the 5th and 2nd millennium BC; the study of technological trends and changes that occurred in manufacturing traditions concentrates on fibre processing and production. The functionality analysis of spindle-whorls served as a basis for comparing textile production trends with the results of the climate change model. Climatic changes in the area were simulated by means of a moderate-resolution Global Circulation Model (GCM). The simulation covered the mid-to-late Holocene, from 7000 years BP to the pre-industrial period.*

IZVLEČEK – *Predstavljamo študijo izdelave tkanin v prazgodovini na območju Panonske nižine, ki temelji na posrednih dokazih, ki datirajo v čas 5. in 2. tisočletja pr. n. št.; pri študiju tehnoloških trendov in sprememb, ki so se zgodile v tradicijah izdelave tkanin, se osredotočamo predvsem na procesiranje in izdelavo vlaken. Analiza funkcionalnosti predilnih vretenc nam je služila za osnovno primerjavo med proizvodnjo tkanin in rezultati modela klimatskih sprememb. Klimatske spremembe na tem območju smo simulirali s pomočjo svetovnega modela cirkulacije (ang. GCM) pri srednji resoluciji. Simulacija pokriva čas med srednjim in poznim holocenom, torej od 7000 let pred sedanjostjo do časa pred industrijsko revolucijo.*

KEY WORDS – *textile production; spindle-whorls; functional analysis; climate forcing; climate modelling*

## Introduction

### *Reconstructing the resources*

Textile fibres can be roughly divided into two main categories, vegetal and animal. At least according to the textile evidence from both Europe (*Barber 1991; Rast-Eicher 2005; Médard 2006; 2012*) and the Near East (*Schick 1988; Alfaro 2002; Burnham 1964; Helbaek 1963*) flax (*Linum usitatissimum L.*) and tree basts were the most frequent sources of textile fibre during the Neolithic period. Although most of the direct findings suggest that the early raw materials used in textile production were mainly of vegetal origin, their preponderance should be considered with caution. Despite the fact that animal fibres are made of protein and therefore are more resistant to decay than vegetal ones, which are composed of cellulose, one should keep in mind that linen preserves better in alkaline conditions, while animal fibres such as wool require acidic environments for preservation (*Cybulska, Maik 2007*). The fact that they are not found in the contexts investigated might not account for a genuine absence, but rather for the fact that the conditions for preservation were not met.

### *From the plant*

The wetland settlements of the Alpine region facilitated the investigation of fibre from the flax plant (*Linum usitatissimum*) and its use in textile production, revealing details of both the plant's development and its dynamics. However, since animal fibres cannot survive in the alkaline soils of circum-Alpine dwellings, the possibility of wool use in these rich contexts remains elusive. Flax has been defined

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as one of the 'founder crops' that started agriculture in the Near East (*Zohary 1996*). Its early and simultaneous use for linen fibre production already in the 8th millennium BC has been attested by textile remains from Nahal Hemar cave in Israel (*Schick 1988.31*). In Central Europe, linseed specimens from the Jevišovice site at Hundssteig (3100–3010 cal BC) in Lower (eastern) Austria were incidentally found within a row of loom weights (evidence of the oldest in situ weaving loom in Austria. Although there is certainly a long way to go between seed-bearing flax plants and the fibres woven on a loom, this coincidence might well point to the use of flax in textile production (*Kohler-Schneider, Cannepele 2009. 67*). The earliest surviving linen cords from the circum-Alpine area of Europe attest to its use for textiles in the 4th millennium (*Barber 1991.11–15; Médard 2012.386–9; Rast-Eicher 2005.118–20*), although the earliest flax seeds in the same area predate the textile finds by almost two millennia.

However, the importance of flax in Eneolithic contexts within the investigated area of South East Europe has also been well documented in more recent reports (*Reed 2016*). In several studies based on differences in linseed sizes, archaeobotanists have made an effort to clarify the dynamics and patterns of its exploitation (*Maier, Schlichtherle 2011; Herbig, Maier 2011*). Since it is possible to distinguish between domestic and wild flax seeds (*Linum bienne*), mainly on the basis of features such as seed size (*Herbig, Maier 2011; Zohary* et al. *2012.101*), a similar methodological principle is used to distinguish between the two different varieties of domesticated flax.

Ancient Near Eastern seeds have a length of approx. 4.0 to 4.7mm and a width of approx. 2.3 to 2.7mm, their size remaining unchanged from 5000 BC to 1800 BC (*Helbæk 1959.109, Tab. 1*). Interestingly, in Central Europe, flax seems to have split into two varieties at an early stage, one with the large seeds used for linseed oil, and another with smaller seeds specialised for making textile fibres.

An extensive study of 4th and 3rd millennium waterlogged flax seeds from a series of wetland settlements in the Alpine region revealed that in the early phase (4000–3700 BC) seeds were significantly larger in comparison to samples from the ensuing periods (*Herbig, Maier 2011.529*). This difference in size cannot be correlated with natural or climatic variations and, according to the research, two flax varieties may be considered as possible proof of fibre specialisation. In the early phase, a flax type with larger seeds was cultivated for both oil and fibre production, similarly to the Near East (*Maier, Schlichtherle 2011.571*). At the same time, already in the middle of the 4th millennium BC (around 3400–3300 BC) a small seed fibre type appeared, which was introduced and cultivated to fit the needs of textile production (*Herbig, Maier 2011.529*).

The effects of osmotic stress on long fibre flax (*Chemicosova 2006; Dash* et al. *2014*) and its preference for colder and wetter conditions could offer an explanation as to why this new fibre variety of improved length and quality became the primary resource in Europe. Indeed, a central European 'flax-boom' (*Herbig, Maier 2011.531–532; Maier, Schlichtherle 2011. 571*) occurred at the end of the 4th millennium BC, when textile production intensified.

Spindle-whorls, spindles, loom weights, and finished fragments of netting and fabric allowed for the reconstruction of textile techniques throughout the wetland settlements. Well-preserved layers like those at Arbon-Bleiche 3 and Pfyn-Breitenloo contain the remains of flax processing, which provided valuable information on its preparation and handling. There is sufficient evidence to show that certain villages focused on growing it and processing the fibres (*Schlichtherle 2009*). Furthermore, the spatial distribution of textile tools within settlements points to the organisation and specialisation of textile work (*Maier 2001; Lauzinger, Rast-Eicher 2011.539–540*). Archaeological and botanical evidence suggest that in addition to the division of labour, certain socioeconomic differences developed whereby goods and economic factors, including flax, were not available to the same extent to all inhabitants (*Schlichtherle* et al. *2010*).

***To the animal***

Although the intensified use of animal fibres, namely wool, in textile production, was initially discussed in the context of Sherratt's model (*Sherratt 1981*), new evidence for milk consumption (*Evershed* et al. *2008; Bartosiewicz 2007; Craig* et al. *2005; Vigne, Helmer 2007*) and animal traction (*Fabiš 2005; Isaakidou 2006; Johannsen 2005*) does not support a big time lapse between the initial domestication, focused mainly on meat consumption, and the later use of secondary animal products. No such arguments for the early use of wool have been established so far, since the first woollen textiles are exceptionally rare and appear only from the 4th millennium BC (*Rast-Eicher 2014; Shishlina* et al. *2003*). Furthermore, linguistic research suggests a common root for the word 'wool' in Indo-European languages, pointing out that the notion of its soft and spinnable characteristics appeared prior to its departure from west-central Asia around 4000 BC (*Barber 1991; Chantraine 2009*).

Some attempts to place the beginnings of wool use earlier (*Rooijakkers 2012*) focus primarily on the Near East. New zooarchaeological investigations of sheep husbandry in Northern Mesopotamia (*Vila, Helmer 2014*) point to fleece exploitation shortly after initial domestication (around 6500 BC), suggesting that several breeds were involved in the selection process. Thus multi-origins and trade are considered important factors for the cross-breeding process.

Although the first use of wool was suggested to be parenthetical in the context of fibre production and processing, at least as far as spinning is concerned, it does account for the early knowledge both of the resource and its properties. It is thus considered plausible that sheep fleece developed new desired properties gradually (*Rast-Eicher, Bender Jørgensen 2013*), as a cumulative result of animal selection, involving out-breeding and cross-breeding practices by shepherds. Already developed and established Mesopotamian wool economies in the 3rd millennium BC, known from the numerous cuneiform sources (*Charvát 2011*) raise the argument that wool's first appearance should be dated much earlier.

An analysis of textile tools from Arslantepe (*Laurito* et al. *2014*) proposed household wool spinning already in the 4th millennium BC, and ethnological research in Greece showed that unspecialised herding can, and did, account for an ample amount of spun thread (*Rokou 1994*). In addition, both 'Neolithic' and 'Bronze Age' wool types occur in Iron Age contexts. Sheepskins and textiles from Hallstatt in Austria (dated to the 1st millennium BC) show a range of fleece qualities, with a selection of finer wool for weaving (*Ryder 1990a; 1990b; 1992*). This direct evidence confirms that the development from 'hair' to coarse wool and finally to fine wool in sheep was successive. Consequently, a definition of a single temporal horizon for the introduction of woolly sheep can be considered unconvincing (*Halstead, Isaakidou 2011*). Considering that multiple genes account for fleece development (*Ryder 1982*), Paul Halstead and Valasia Isaakidou proposed that the better fleece qualities might have been selected unintentionally and on diverse occasions (*Halstead, Isaakidou 2011. 67*).

Moreover, an important argument that additionally supports the idea of the multiple origin of the desired traits was a consequence of the dynamic gene flow – rather than of developed wool economies focused on increased production – is based on the fact that the better qualities of wool, regarding its finesse, are often found in places and periods remote from those interpreted as more specialised and established[1].

### *And 'back to the roots'*

The definite separation of farming and foraging has been fairly criticised, and it is plausible that both strategies were practiced simultaneously (*Cummings, Harris 2011*). The use of foraged plant fibres before, during and beyond the Neolithic is supported by the substantial amount of direct evidence attesting to the common use of indigenous plants, including reeds, grasses and bast fibres from trees (*Harris 2014*). The best examples from the Pannonian Plain region were found at the Ljubljansko Barje dwellings in Slovenia, with preserved fibres of the grass family (*Poaceae*) (*Pajagič-Bregar* et al. *2009*) and leaf fibres of lesser bulrush (*Typha angustifolia*) (*Greif 1997.41*). Nonetheless, the result of the plant macro remains study of the late 4th millennium Stare Gmajne lakeshore settlement at Ljubljansko barje, should be mentioned, since they revealed that, besides poppy (*Papaver somniferum*), flax was the highest represented oil plant, which could also have been used for its fibres (*Tolar, Velušček 2009; Tolar* et al. *2010*).

Fabienne Médard concluded that, overall, there are more preserved cords, threads and cloth made from tree bast fibres than those made from flax (*Médard 2010.57*). She noticed that tree bast fibres (predominantly lime) were used mainly for twined cloth,

1 Commenting on Bronze Age wool quality, Michael Ryder compared contemporary Scandinavian and Egyptian produce: "*The wool in North Europe was naturally brown, while that in Egypt was white. Surprisingly, however, the Egyptian wool was coarser. This theme of finer wool in more primitive areas, or in earlier periods, is repeated throughout subsequent history*" (*Ryder 1974.110*). Subsequently, this was explained by experts (*Rast-Eicher, Bender Jørgensen 2013*) as indeed a finer wool quality from 'Nordic' sheep (genetically different from central European and Near Eastern sheep breeds). The Bronze Age 'Nordic' type wool of superior fibre quality to that of contemporary Egyptian production thus provoked a revaluation of the 'improvement through intensification' principle.

whereas flax was used mainly for woven textiles. (*Médard 2012.368*). This led to the conclusion that most of the tree bast fibres from the Neolithic lake dwellings in Switzerland were spun without a spindle, a technique characteristic especially of spinning long vegetal fibres (*Médard 2006.99–102*).

The use of both early wool and flax for textiles could be considered in this category. Collected wool tufts and wild flax fibres were probably competitive with the aforementioned plant resources, along with other materials, such as frequently disregarded goat hair (*Frangipane* et al. *2009*). Wild flax fibres were identified in a series of Upper Paleolithic layers at Dzudzuana Cave in Georgia (*Kvavadze* et al. *2009*), indicating that prehistoric hunter-gatherers were already using its fibre to make thread. There was certainly a substantial time lapse in sequential adaptations of fibre use before it become a primary resource for textile production.

Finally, if considered in a wide-scale process that involved gradual modifications and a refinement of practices, it is extremely difficult to decide when and where these secondary products were first recognised and exploited. Although Hans Helbæk suggested that flax was initially used for its seeds and then for its fibre (*Helbæk 1959.104; McCorriston 1997*), linen evidence is direct proof of its early use for textiles. Preserved textiles confirm that flax was used for its fibre already in the Early Neolithic in the southern Levant (*Schick 1988.31*).

Alternatively, the quality of early wool could have been controlled to a certain degree through fibre preparation. Sampling and manual sorting of fleeces and tufts could have resolved its hairiness and coarseness, resulting in a selection of spinnable material. This selection practice has been demonstrated with an analysis of Bronze Age skins and textiles from Hallstatt (*Rast-Eicher, Bender Jørgensen 2013*), revealing how a skilled wool-sorter could identify and categorise a range of wool qualities even with a flock of highly mixed sheep.

Due to gradual specialisation and the secondary product character ascribed to these fibres, it is extremely difficult to investigate the origin of their use and dynamics of their development. On the other hand, following their importance and representation in textile production, it is to some degree possible to determine when, where and why they became a primary resource, as their intensified exploitation was more culturally and environmentally dependent.

### *Theory and time*

Apart from investigating the biological origins and developments of both wool and flax fibres, social and technological changes connected to their intensified exploitation could be approached through cultural historical narratives and theoretical frameworks. The economies of prehistoric communities across the Pannonian Plain would alter with specialisation in either of the resources, transforming fibre material into a commercial good, possibly involved in export and exchange. Both strategies, if intensified, would imply an increased anthropogenic factor. Maintaining large herds calls for opening the primeval forest vegetation in parts of Europe, where forest cover is not limited by climatic factors. The high water and high-quality agricultural land requirements of flax suggest direct competition with food crops. Thus, the benefits of developing traditional technologies and production as sub-branches of the fragile and not fully formed economies of the period seem even more reasonable.

The processual archaeology approach would argue that this next step was determined by a successful cultural adaptation to climatic and environmental conditions (*Binford 1968*), while the opposing post-processual approach would focus on explaining all changes in the past as a result of human agency (*Hodder 1986*). Regardless of the approach, the fact remains that developments of the technological aspect were the main determinant of 'success'.

Andrew Sherratt assembled different strands of evidence from archaeology and zooarchaeology into a consolidated model of the Secondary Products Revolution (*Sherratt 1981*). By suggesting that the main by-product of domesticates (traction, riding, milk and wool) occurred simultaneously, first in a narrow time span in the 4$^{th}$ millennium BC, he conceptualised them as economic achievements that developed several millennia after primary, meat-focused consumption. In this model, the main commodity, namely meat, was the objective of Neolithic herders, against the full range of exploitation, an achievement of the Eneolithic. Consequently, the model addressed the secondary products' potential for cultural evolution and social complexity in the transition from the 4$^{th}$ to the 3$^{rd}$ millennium BC. Interestingly, it is not the main postulate of the theory which is criticised, but the contemporaneous occurrence or intensification of different types of exploitation (*Vorsteen 1996; Halstead, Isaakidou 2011*). One of the biggest supporters of Sherratt's model, Haskel Greenfield, argued for a revision of the contemporaneity of its parts (*Greenfield 2005*), underlining the importance of intensification in scale, rather than origin of use. The initial critique of the model contributed to further questions on causality: were these 'innovations' a cause or a consequence of social and economic developments, did they influence each other, and finally, how?

The economic importance of secondary products, even if known for a long time, as proved in the case of milk (*Evershed* et al. *2008; Bartosiewicz 2007; Craig* et al. *2005; Vigne, Helmer 2007*), increases during the 4th millennium BC, which further shaped our research objectives. The 'competition of fibres' found its place in the paradigm due to the contemporaneity of the specialisation of both resources and the influence on economic factors that accompany their intensified use.

The wide time frame of our investigation, which encompasses two millennia, gave us the opportunity to pattern technological trends and changes on a large scale, rather than addressing culture-specific questions and particular inter-site dynamics. The focus on 4th and 3rd millennium BC textile production in the Pannonian Plain placed the research within the context of three periods: the Middle Eneolithic, Late Eneolithic and Early Bronze Age. The transformation from Middle to Late Eneolithic and from Late Eneolithic to Early Bronze Age societies in the Pannonian Plain from the final 5th to the ending of the 3rd millennium BC, and the role of local and exogenous influences, remain controversial. Further, all three periods are characterised by a number of partly overlapping 'cultures' whose definition is based primarily on pottery inventories and burial rites, so they do not necessarily represent social or economic communities. The 'Chronological framework for the Copper Age cultures of the Carpathian Basin and neighbouring territories' outlined by Pál Raczky (*1995.60, Fig. 1*) was chosen as the basis for the periodisation of investigated textile tool samples.

The chronological division we used placed spindle-whorl samples from the 1st half of the 4th millennium BC in the Middle Eneolithic and samples from the 2nd half of the 4th and the very beginning of the 3rd millennium in the Late Eneolithic assemblage. Samples from the advanced 3rd millennium contexts thus entered the Early Bronze Age assemblage. The classification of the investigated cultural-historical groups within these three periods remains arbitrary, especially due to the transitional character[2] of the particular 'cultures'.

***Changing threads***

In the process of hand spinning, the spinner continuously rotates the spindle and the spun yarn attached to it. As the tool rotates, the hands are used to draft the prepared fibres, while the weight of the tool pulls them, and its rotation twists them into a yarn. Tension and speed are the two main factors affecting the transformation from fibre to yarn. Smoother and shorter fibres call for a shorter, lighter draft and more twist to enter the fibres fast enough, while on the other hand, coarser and longer fibres allow for longer and heavier down-pull and less twist without causing a break.

As textile tools for fabricating yarn, spindle-whorls are the most commonly preserved evidence of fibre processing and production practices found in prehistoric contexts. The same proved to be the case with the sites studied in regions of South East and East Central Europe. Fortunately, they are also the most efficacious of textile tools for studying the differences of fibres. It has been widely accepted within the respective field of textile archaeology that the morphological features of the spindle-whorl relate to its functionality. A good number of reports from experimental archaeology have supported this dependency (*Grömer 2005; Mårtensson* et al. *2006; Verhecken 2010*). Nevertheless, the real impact and conditioning of these determinants continue to be questioned and investigated (*Kania 2015; Laurito* et al. *2014*).

As mentioned above, both whorl size and weight account for the rotational properties, while determining the tool's moment of inertia. Perforation diameter and position are two other features that have a significant influence on rotation, later also accoun-

2 Despite its integration with the Boleráz group (*Stadler* et al. *2001.543*) and mainly due to its transitional character (*Horváth 2001.83*), typological fusion with Lasinja and Furchenstich (*Horváth 2009.105*), its stylistic affiliation with the 'stab and drag' or 'Furchenstich' decoration complex (*Kalicz 2001*) and absolute dates that cluster between 3700 and 3500 BC (*Horváth 2009.104*), the Proto- Boleráz sample recorded from the Abony site was placed within the Middle Eneolithic assemblage together with Lasinja and Furchenstich spindle-whorls. The Vučedol sample recorded from the Gomolava and Slavča-Nova Gradiška sites was placed within the Early Bronze Age assemblage together with Somogyvár-Vinkovci spindle-whorls. Mainly because the big sample recorded from the Ljubljansko Barje-Ig site, which is only relatively dated (*Korošec, Korošec 1969*) to the 3rd millennium BC, did not permit finer classification according to the particular cultural-historically defined phases.

ting for the whorl's stability during the process. Perforation is to some extent indicative of the spindle on which the whorl was used, thus its dimensions and properties have to be considered, since they also influence rotation.

In the context of the proposed functionality, the moment of inertia and weight of the whorl are given the central role, mainly because they are connected with both the raw material (*Verhecken 2010*) and the properties of the spun thread (*Bohnsack 1981; Crewe 1998*). It is generally accepted that lighter weights would be preferred for thinner and lighter threads and heavier for thicker and heavier yarns (*Andersson 2015.47*). This quality standard is thus taken as the parameter which has the most influence on the end products and their characteristics. The fact that the fibre flax plant would have provided fairly long fibres, especially compared with the much shorter length of wool expected for the early woolly sheep, is the main reason this distinction of raw materials resonated in the dichotomy between spindle-whorl types, with an emphasised contrast between big and heavy and small and light categories.

### *Climate trends*

In recent decades, the media have taken a great interest in future climate change and its possible impact on society. Adaptation and mitigation policies have become main discussion topics in scientific research. Analyses of past events are often referred to for predictions of future developments, so archaeological and historical data substantially contribute to our understanding of the effects of climate change and its influence on culture and society. Most importantly, the way civilisation reacted or adapted to different environmental conditions in the past could give us vital information on how to respond to the effects of renewed climate stress (*Riede 2014*).

In order to interpret altering technologies by distinctions between fibres and their reliance on cultural and environmental contexts, our research analysed Eneolithic and Early Bronze Age textile tools in the light of the results of a climate simulation for the period of interest. This comparison of the two sets of data revealed that climate changes might have significantly influenced the observed dynamics of production traditions. Thus, our approach is a valuable interdisciplinary case study that incorporates bi-univocal examples of the suitability of archaeological analysis, firstly, regarding its use as a comparison data frame for climate modelling results and, secondly, for evaluating the effects of past climate change on culture, particularly innovation and technology.

The results of climate model simulations are particularly suitable for analysing cultural and technological dynamics, since they reveal trends which can explain certain continuities, as well as changes at a higher temporal resolution. This means they enable a wider understanding of the climate's impact on prehistoric societies, since their coverage builds an environmental context for the study of both adaptation processes and their consequences.

## Materials and methods

### *Scope of the study*

In order to avoid the absence of contextual data and uncertainties regarding 'cultural' and chronological assignments, the choice and collection of material used in this research focused as much as possible on recent excavations, with the exception of several sites[3]. A textile tool database was created that comprises spindle-whorls from over 20 archaeological sites[4], which gave a presentable transect from the northern slopes of the Central Balkan Mountains in the south and the Danube River in the east to the foothills of the Carpathian Mountains and the South East Alps in the north and west (Fig. 1).

The period of interest, beginning with the Middle Eneolithic (Lasinja spindle-whorl sample representing the earliest tools) and ending with the Early Bronze Age (Somogyvár-Vinkovci spindle-whorl sample representing the latest tools) falls roughly between the middle of the 5$^{th}$ and the end of the 3$^{rd}$ millennium BC. Within the geographically defined region, changing environmental conditions were investigated with the use of moderate-resolution climate simulations. In the investigation of change and possible innovation in fibre production and processing, both climate information and the recorded archaeological evidence were considered, analysed, compared and finally discussed for possible correlations.

3 Ljubljansko Barje-Ig and Dobanovci were excavated during the 1880s and the 1960s, while Gomolava and Slavča-Nova Gradiška are the only systematically excavated sites included in the study.

4 Kostolac: two sites (172 tools), Classical Baden: eleven sites (147 tools), Boleráz group: two sites (32 tools), Furchenstich complex: ten sites (205 tools), Lasinja: six sites (47 tools), Proto-Boleráz: one site (37 tools), Vučedol: two sites (38 tools), Somogyvár-Vinkovci: four sites (17 tools), Late Vučedol/Somogyvár-Vinkovci: one site (141 tool).

The results of the comparative analysis present the impact of dynamic climatic conditions on two changes in textile production which influenced spinning technology: firstly, through the adaptation of the fibre material resources, and secondly, through the modification of final product demand. Both trends, occurring in the 4th and becoming more pronounced in the 3rd millennium BC, were mainly quantitatively observed and discussed as the adjustment of tools' morphological, and thus functional features. Therefore, both their typological and functional variability were addressed.

The recorded trends in tool assemblages presented in this paper can be attributed to more than two suggested factors that may be equally culturally and environmentally promoted. Nonetheless, from the technological point of view, they are the most frequently discussed and considered in the framework of archaeological textile research as being the factors responsible for determining a tool's functionality (*Loughran-Delahunt 1996; Grömer 2005; Mårtensson* et al. *2006; Verhecken 2010*). The approach presented here draws attention to prehistoric textiles in the archaeological record, which enables a closer insight into manufacturing traditions and production technologies that can benefit our understanding of social and cultural realities and their changed economic strategies.

Our main objectives were intended to:

❶ Explore and detect trends of change within the Pannonian Plain textile tool sample.
❷ Elucidate the chronological, cultural-historical and, to some extent, environmental context of these trends.
❸ Model and interpret the main climate change trends within the geographical and chronological range of the research.
❹ Correlate both sets of trends and consider their connection.
❺ Explore the idea of climate conditions within the spatio-temporal context of the textile production structures.

### *Spindle-whorl analysis*

The metrical standards outlined above have to be considered cautiously, because the spinning process is influenced by a combination of many factors. In fact, recent extensive spinning experiments (*Kania 2015*) designed to shed more light on how fibre and yarn depend on the tool's weight and moment of inertia revealed how both of these variables have little to no influence when compared to the human

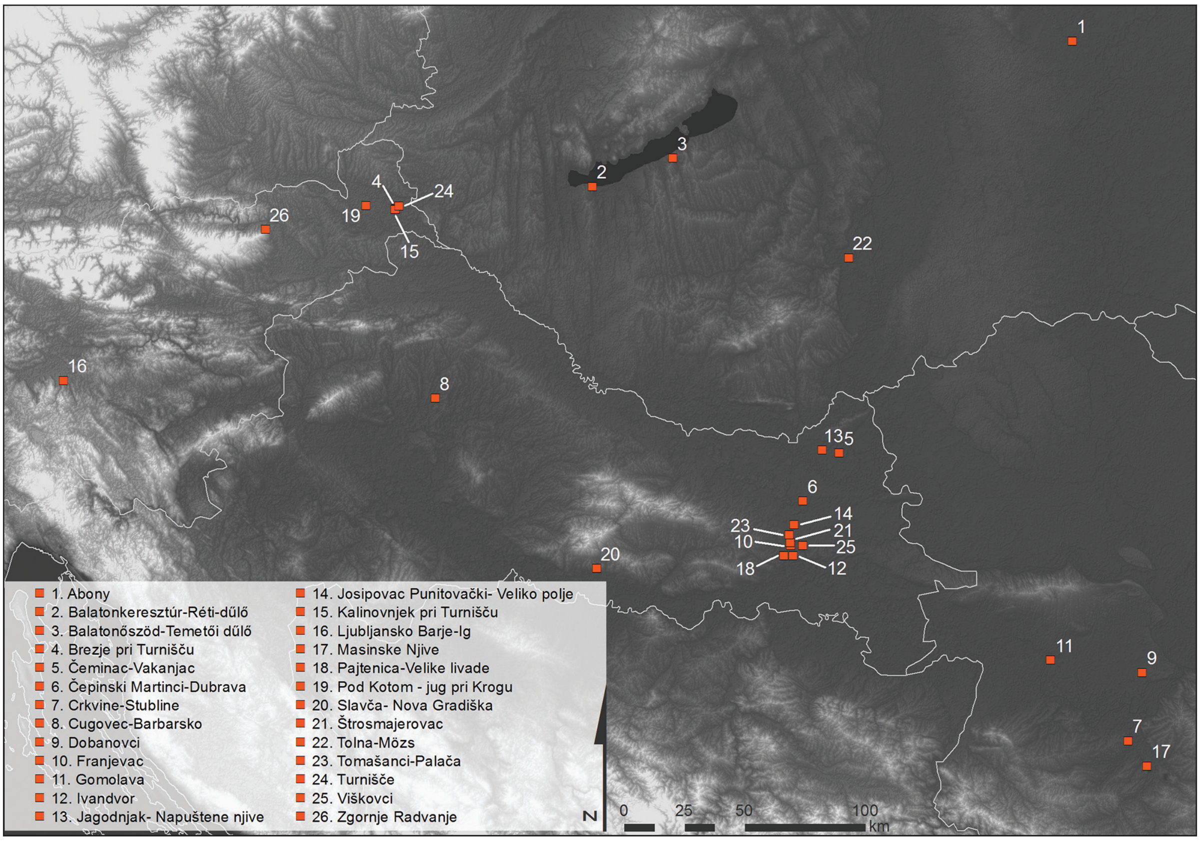


***Fig. 1. The distribution of the sampled sites.***

factor. In other words, a skilled spinner can spin a variety of fibres with a variety of spindle-whorl types and produce a proportional variety of different yarns. In addition, Karina Grömer's experiments (*Grömer 2005*) showed that although very heavy suspended spindle-whorls (120–140g) were not suitable for very fine yarns and light whorls (8–20g) were not efficient for thicker yarns, a medium weight (40g) would be suitable for almost every thickness documented in prehistoric Europe.

Although the influence of the tool's weight and its moment of inertia can to a certain degree be overcome by the spinner's skill, the substantial difference in tensile strength between the two fibres investigated (fibre flax and early wool) should be distinguishable, if not in the distribution of medium spindle-whorl types, then in the distribution of extremely different tool categories. The functionality analysis was thus chosen as appropriate with regard to the big size of the considered sample and big difference in tensile strengths of the raw materials investigated. The sampling method accounts for the robust patterning; its purpose was to reveal interpretable trends in textile technologies within a broad chronological context. Although moderate spindle-whorl types are especially difficult to interpret, the significant difference between the distributions of extremely different tool types should be considered as an indication of substantial differences in spinning technologies.

During the three-year study, 1152 spindle-whorls were recorded in a textile tools database. Initially, the study included tools from 34 archaeological sites, but subsequently the final analysis was conducted on a limited sample of 836 spindle-whorls[5]. Each investigated cultural-historical group was documented at two or more sites, with the exception of the Proto-Boleráz group. Middle Eneolithic tools account for 34.6% (289), the Late Eneolithic for 42.0% (351) and Early Bronze Age for 23.4% (196) of the entire sample of spindle-whorls. The recording protocol was based on four main measurements (whorl diameter, perforation diameter, height and weight) and by calculating weight/diameter and height/diameter ratios. The ranges and mean values for all the recorded variables are given in the chart (Fig. 2).

The analysis segment of this paper reports on 328 whorls which were completely preserved, 163 whorls preserved in half, 223 partially preserved whorls and 122 whorls that had small fragments (less than 10%) missing[6]. All spindle-whorls in the database were documented in order to provide three separate categories of information: contextual, morphological and illustrative. Not all specimens provided equal amounts of information, and for the purpose of the functionality analysis a minimum criteria was applied: reliable chronological assignment, typological determination and the above-mentioned measurement standard.

In order to investigate the change in the metrical features of the spindle-whorls, the tools were divided into height-diameter and weight classes. This kind of typology served as a basis for their functionality analysis. The entire sample (836 spindle-whorls) was divided into three main weight types (light, medium, heavy) and height types (flat, high, and steep), according to the distribution of the spindle-whorl's height-diameter ratio and weight values (Fig. 3).

Additionally, due to the extremely high values, a fourth weight type was defined. The weight values

| Valid Number 836 | Min. | Max. | Mean |
|---|---|---|---|
| diameter | 26.00 | 96.00 | 56.4011 |
| height | 5.00 | 77.60 | 25.5841 |
| perforation diameter | 3.50 | 17.00 | 7.9317 |
| weight | 6.39 | 317.70 | 68.3354 |
| height-diameter ratio | 0.10 | 1.32 | 0.4559 |
| weight-diameter ratio | 0.14 | 4.25 | 1.1400 |

***Fig. 2. Table showing ranges and mean values for all the recorded variables in millimetres and grams.***

5 The sample standard was set at a minimum of three recorded spindle-whorls with complete metric data and chronological placement. Furthermore, the Neolithic spindle-whorl sample was not included in the study. No Early Eneolithic spindle-whorls were recorded in the database, thus no continuity or change in textile production could be thoroughly investigated. Also, the climate simulations did not cover a substantial part of the period.

6 The weight values of the spindle-whorls in the sample were documented in four different reliability categories depending on their preservation status. The weights of complete samples were documented in the complete weights category; weights of almost complete samples with small fragments missing were documented in the estimated weights category (estimated weight ≈ weight if not complete); weights of samples preserved in half were documented in the calculated weight category (calculated weight = weight if not complete doubled), and finally, weights of partially preserved samples were documented in the reconstructed weight category (reconstructed weight = density x volume). Volume and density variables were provided from virtual (three-dimensional) models created for the partially preserved spindle-whorls.

| N | 836 | height/diam. | | | weight |
|---|---|---|---|---|---|
| | | (mm) | | (g) | |
| (%) | 10 | 0.20 | | 22.00 | |
| | 20 | 0.23 | FLAT | 27.40 | LIGHT |
| | 30 | 0.30 | | 33.00 | |
| | 40 | 0.35 | | 41.30 | |
| | 50 | 0.43 | HIGH | 56.00 | MEDIUM |
| | 60 | 0.52 | | 68.00 | |
| | 70 | 0.60 | | 82.00 | |
| | 80 | 0.68 | STEEP | 104.40 | HEAVY |
| | 90 | 0.80 | | **140.00** | **(>VERY HEAVY)** |

***Fig. 3. Table of height-diameter ratios and weight classes with considered values.***

of very heavy spindle-whorls are generally connected to substantially long fibres and plying (*Barber 1991.52; Hochberg 1979.21*) heavier thick yarns or ropes (*Vakirtzi 2014.53*). Represented in 10% of the entire sample, spindle-whorls weighing above 140g were considered appropriate for the addition of the very heavy weight type, making this class associable with very long, presumably plant fibres and plying (Fig. 4).

As already mentioned, early wool was expected to have shorter fibre lengths, thus the 33g upper limit for light spindle-whorl category was considered reasonable (making this weight type associable with wool)[7].

### *Model simulations*

To our knowledge, the results of climate simulations have not been employed so far to investigate changes in climatic conditions for a chosen region and determined period. The decision to adopt this particular approach as support for our analysis was made for several reasons. Firstly, the model allows full coverage of the area investigated for the entire period in question. Furthermore, the temporal resolution of such analysis allows us to focus on different temporal scales, leading to the representation of inter-annual to millennial climate variability. But, most importantly, besides allowing the simulation of possible changes of different climatic parameters, the model also allows us to find plausible physical interpretations for them. Nonetheless, as support for the conclusions based on the model results, we additionally address several studies which rely on proxy reconstructions.

A transient continuous climate simulation was performed with the coupled atmosphere-ocean circulation model ECHO-G, composed by the ECHAM4 (*Roeckner* et al. *1996*) and the ocean model HOPE (*Wolf* et al. *1997*), at a spectral resolution of T30 (_ 3:75o_3:75o). The model was driven by changes in the Earth's orbital configuration calculated by Andre Berger and M. Loutre (*2002*), changes in solar activity as reconstructed by Sami K. Solanki *et alii* (*2004*) and variations in GHGs concentrations deduced from air trapped in ice cores (*Flückiger* et al. *2002*). Further information on the simulation realisation is provided in Sebastian Wagner *et alii* (*2007*). The results of the aforementioned simulation have been used in different studies: within these Wagner *et alii* (*2007*) used the model results in order to investigate the Mid-Holocene hydrological climate in Southern Patagonia. Bijan Fallah *et alii* (*2015*), Jonas Berking *et alii* (*2013*) and Emannuele Russo *et alii* (*2016*) used the model's outputs in order to run a time-slices experiment for different areas and periods of study.

The region considered in our analysis extends from longitude 14W to 21W and from latitude 42N to 48N, covering most of the Pannonian Plain region from the southern borders of Serbia in the south to Northern Hungary in the south. The analysis covered the period between 7000 BP and 3000 BP, taking into consideration the different variables that were particularly relevant for plant growth, such as near surface temperature, humidity balance (*i.e.* precipitation minus evaporation) and rising temperature

***Fig. 4. Late Eneolithic spindle-whorl (from the Kostolac context) beside a Late Neolithic loom-weight from the Sopot context found at Slavča-Nova Gradiška, demonstrating the large size of the very heavy spindle-whorl type.***

7 Compared to wool, plant fibres are more often considered to be spun with heavier weights Barber (*Barber 1991.25*). Very heavy whorls, respectively 100g and above, could be connected with full-length flax or long-staple wool of later specialised breeds, while this amount of tension is supported only by very long fibres. For spinning medium to heavy wool more moderate weights would be more adequate, at around 30g, respectively (*Gleba 2008.103–106*).

of days with above 5 degrees (*Masson* et al. *1999*). Sea level pressure anomalies were also considered.

## Results

### *Adapting technologies*

Regarding the robust period to period comparison, the observed differences in spindle-whorls' weight and diameter distributions pointed to a significant increase through time in values for both variables. The lowest weight variability is obvious in the earliest (Middle Eneolithic) and the highest in the latest (Early Bronze Age) assemblage. Nevertheless, in the case of Early Bronze age tools, it is noticeable that the previously wide distribution of the Late Eneolithic values was limited to a noticeable degree in the frequency of the large diameter sizes (Fig. 5).

A similar trend can be observed regarding the correlated height-diameter and weight categories. In the earliest, Middle Eneolithic assemblage, light and medium weight types are convincingly predominant, and appear to be clustered in only one height group: the lowest category or the flat spindle-whorl type. Almost the opposite distribution is evident in the latest, Early Bronze Age assemblage. Here, again, most of the tools cluster in one height group, but this time in the highest category of the steep spindle-whorl type. Although in this period all four weight groups appear to be more evenly distributed in this category, heavy and medium spindle-whorls are the most represented. The Late Eneolithic assemblage seems to fit the transitional period between these two extremes. First, because it shows the increase in the amount of heavy weight types, a trend which displayed continuity in regard to the Early Bronze Age period. Second, because the category of medium weight spindle-whorls revealed the most balanced distribution across all three different height groups, with the highest frequency occurring in the moderate (high type) height group (Fig. 6).

When analysed in the context of shape variability, the largest weights (heavy and very heavy spindle-whorl types) are mostly represented in the biconical and conical groups, those of the moderate size (medium weight spindle-whorl types) in biconical, conical, convex and discoid groups, while, finally, the

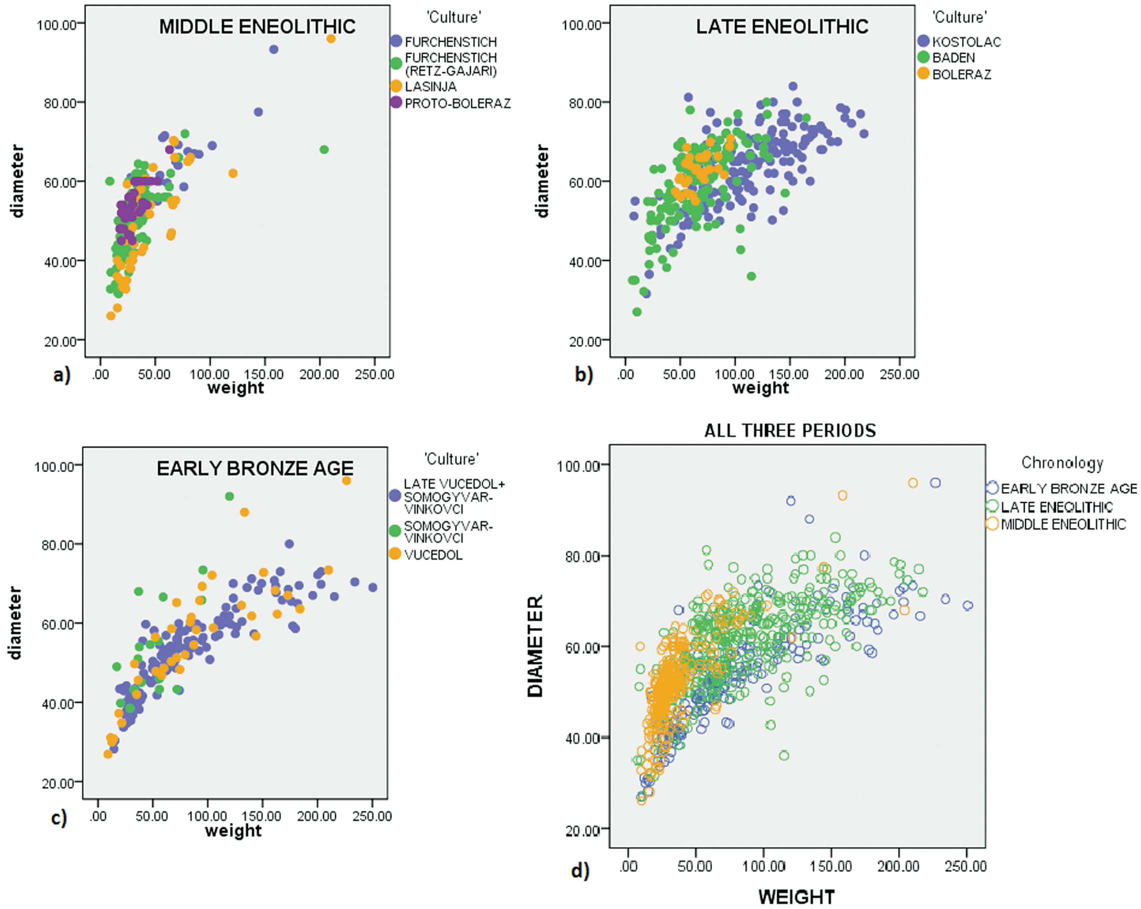


***Fig. 5. The weight-diameter distribution for each period separately (*a*, *b* and *c*) and diameter-height distribution chart shown for all respective periods together (*d*).***

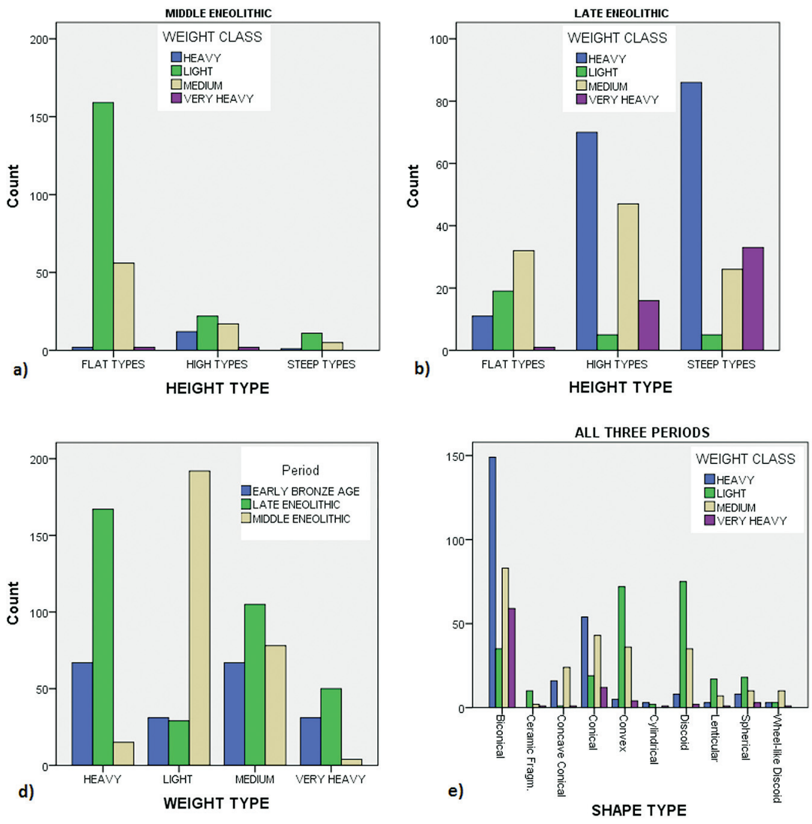


***Fig. 6. The distribution of weight classes according to height type (a, b and c) and shape type (d), shown for each respective period separately.***

smallest weights (light weight spindle-whorl type) appear to be characteristic of the discoid, convex, and, again, biconical groups. Finally, it is obvious that biconical and conical spindle-whorl shapes account for the greatest weight variability in the sample (Fig. 6). Both types are most represented in the Late Eneolithic sample, while the biconical type is the single predominant type in the later, Early Bronze Age assemblage. Convex, followed by discoid types are convincingly the groups most typical of the earlier Middle Eneolithic assemblage (Fig. 7).

Although the maximum diameter and perforation diameter variables seem to behave quite proportionally to one another, it is possible to distinguish some preferences and tendencies when comparing periods. Smaller maximum diameters and smaller perforation diameters seem to be more typical of the Middle Eneolithic period, while the Late Eneolithic values cluster towards the higher spectrum in the case of both variables. Early Bronze Age values show the greatest variability in their distribution, but even in this case, the inspected variables still correspond proportionally (Fig. 7). This parameter was primarily tested for samples with significantly non-proportioned correlations, since they would influence the ensuing assumptions, attributing a greater influence of spindles to the tools' rotation. These would substantially change generalisations regarding rotational properties, which are based solely on the whorls' morphological and weight parameters.

If we consider how the spindle-whorl's rotational characteristics, particularly its moment of inertia, depend on the tool's geometry and weight, a heavier whorl of significant height could have similar rotational properties to a much lighter tool of smaller height and bigger maximum diameter. The principals of this approximation, presented by Tomasz Chmielewski and Leszek Gardyński (*2010*), were used to compare widely defined height and weight categories of tools, not specific objects and values[8].

8 Corresponding correlations were suggested by Chmielewski and Gardyński (*2010.876*): "*the height-diameter ratio corresponds quite accurately with the modulation of the basic technical parameters of the tool that is its weight and angular mass. Changing both of the qualities influences the functional characteristics of a given spindle-whorl. For the increase in the angular mass of the tool, in order to slow down its rotational speed, it is purposeful to increase its maximum diameter (whereas this parameter will be characterised with the higher variability). On the other hand, if a high increase in the mass moment of inertia is undesirable (due to the use of shorter fibres that require more twist), but is needed to enlarge the mass of the spindle itself in order to create better yarn tension, the height of the spindle-whorl will increase rapidly, whereas diameter variability will be reduced.*"

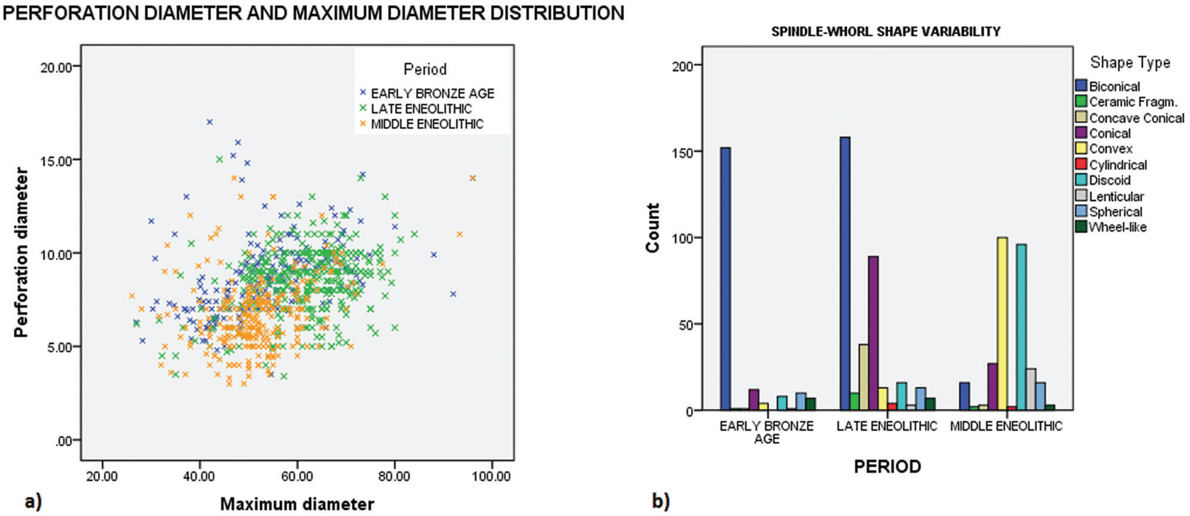


***Fig. 7. The distribution of spindle-whorl maximum diameter and perforation diameter values (*a*). Histograms presenting their ratio variable distribution against period (*b*). The spindle-whorl shape type distribution for all three periods separately (*c*).***

The differences in geometry among recorded spindle-whorl shapes enabled only rough comparisons and general assumptions. These were based on the expectation that a substantial increase in the spindle-whorl's height (Fig. 8) would lower the tool's moment of inertia if its weight remained constant.

Acceptance of this relational principle allowed further correlations between different weight and height types (medium-steep with light-high type, medium-flat with heavy-high type, heavy-steep with medium-flat type and light-flat with medium-steep type), based on their comparatively corresponding or rather similar rotational traits. If we consider these assumptions in the fibre material context it becomes obvious that the medium weight type from the middle-high height class is the most 'flexible' among all groups of spindle-whorls, presumably affording a comparable twist or tension performance with the greatest number of different category types (Fig. 9).

This accounts for the Late Eneolithic transitional character in the technological sense, since it shows how the most 'flexible' spindle-whorl category is highly represented in its assemblage when compared to samples from the other two periods (Fig. 6). The greatest height type variability in the Late Eneolithic assemblage could be interpreted as the intentional manipulation of the tool's height properties, possibly due to the avoidance of a drastic increase in the spindle-whorl's mass moment of inertia. This kind of tool adaptation is desirable, for example, in processing shorter and lighter fibres which require more twist, while the enlargement of the mass of the spindle itself is intended, for instance, to obtain better yarn tension (*Chmielewski, Gardyński 2010.876*).

During both the Middle and Late Eneolithic period, light steep types of spindle-whorls are under-represented, but in the case of the light high types, the Middle Eneolithic shows an increase in frequency, which could be associated with wool spinning. Additionally, the recently reported results of a technological analysis of 4th and early 3rd millennium BC textile tools from Arslantepe in Turkey (*Laurito* et al. *2014*) support this conclusion. Furthermore, the above-mentioned spinning experiments were designed to prove that the wider hemispherical and heavier spindle-whorls (comparable to the light high type) were the most efficient tools in terms of quantity and quality of yarn. Also, this category proved to be proficient in processing both vegetal and woollen fibre and suitable for all thread thicknesses[9]. Interestingly, the single bone spindle-whorl in our sample[10] closely resembles (in shape, method of production, and recorded size and weight values) the aforementioned 4th millennium bone tools from Arslantepe, proposed for spinning wool (Fig. 10). It

9 Surprisingly, it has been suggested that the smaller and lighter clay spindle-whorls from Arslantepe were unsatisfactory for spinning wool. Furthermore, authors explain how their moment of inertia was too small for short animal fibres, pointing out that wool used in the experiment had presumably longer fibre lengths than early wool. They do propose that metal spindles might have been used to increase the moment of inertia of the small whorls, making them suitable for spinning animal fibres (*Laurito* et al. *2014*).

10 Bone spindle-whorls are very rare in the Pannonian Plain during this period, and the particular find was initially published as a bone pendant (*Čataj 2009.31*).

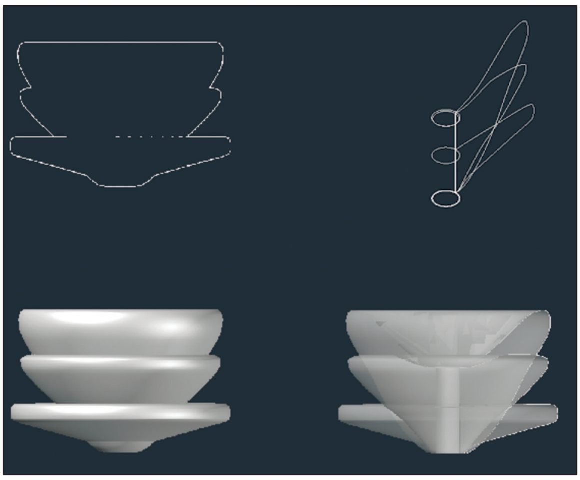

*Fig. 8. Reconstructed three-dimensional models of a flat, high and steep spindle-whorl type, based on published conical spindle-whorls found at the Balatonoszod-reti dulo site (*Horváth 2013*).*

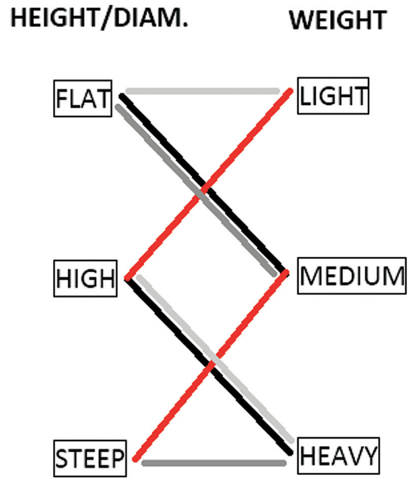


*Fig. 9. Diagram of corresponding height and weight types.*

should be mentioned how the results of another recent analysis (*Vakirtzi 2014*) of North Aegean Early Bronze Age tools from Thasos also suggest that this particular spindle-whorl weight class was used for spinning wool.

Both light high and light steep tool categories become significantly more represented in the course of the 3rd millennium, as shown by the Early Bronze Age assemblage. These types, including the medium steep type (if we accept the approximated comparisons explained), which is more substantially represented in the Late Eneolithic sample, and the second most frequent type in the Early Bronze Age sample, could be appropriate for spinning shorter fibres, presumably wool (Fig. 6). These medium steep types, although heavier, are expected to have a significantly lower moment of inertia due to their geometry, or more precisely, their higher height-diameter ratio.

On the other hand, heavy and very heavy types could be connected to processing long plant fibres. Although they have larger height-diameter ratio values and tend to cluster in the high and steep height groups, their weight leads to significantly larger moment of inertia values (too big for processing short or even moderately long fibres that call for more twist). Additionally, their weights alone are too big for the lower tensile strengths of animal fibres. Thus they can be considered appropriate for spinning long plant fibres such as full-length flax. These spindle-whorl types become predominant in the late 4th millennium and continue to be highly represented in the ensuing 3rd millennium assemblage, as shown by the distribution charts for the Late Eneolithic and Early Bronze Age samples (Fig. 6).

The technological development did not reveal a linear process leading 'from plant to animal' fibre production. As shown by the trends in maximum height-maximum diameter and maximum height-weight correlations, the dynamics of the use of fibre material was more complex (Fig. 11). The greatest height value variability apparent in the Late Eneolithic period is lowered in the 3rd millennium BC sample. Frequency of the lowest height values is decreased, while the maximum diameter distribution clusters towards the lower values.

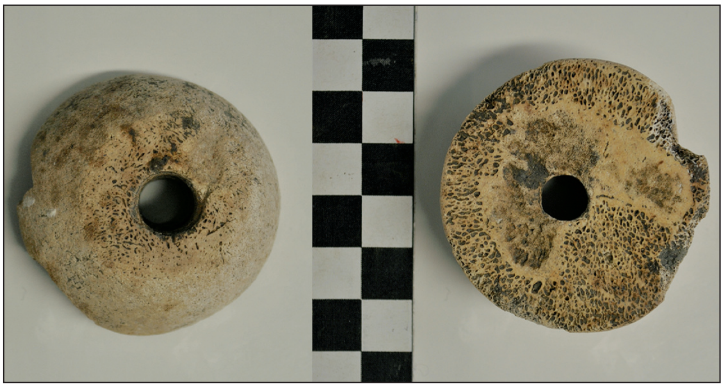

*Fig. 10. A convex spindle-whorl made from the head of a cattle femur bone, weighing 24.6g, from a Furchenstich (Retz-Gajary) context found at Josipovac Punitovački-Veliko polje, dated to the 1st half of the 4th millennium BC (Middle Eneolithic period).*

### *Climate conditioning*

The climate of the Holocene was highly variable, and multiple controls must have been responsible for this variability (*Mayewski* et al. *2004*). According to Heinz Wanner *et alii* (2009), the Holo-

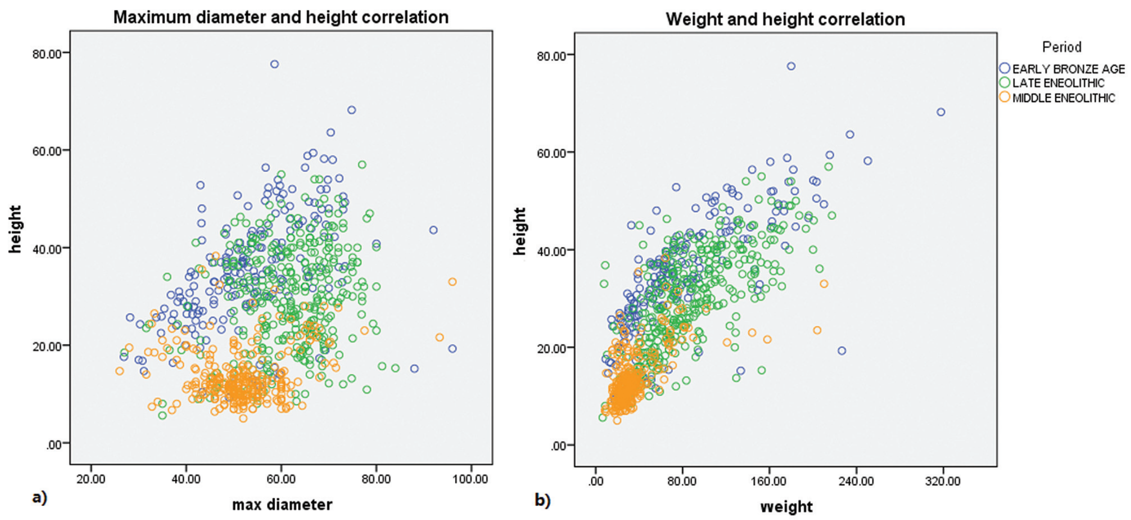


***Fig. 11. The distribution of correlated:* a *maximum diameter and height values;* b *weight and height values, for the three period assemblages together.***

cene climate was dominated by the influence of summer season orbital forcing; our results are in accordance with this interpretation. In particular, our model simulations revealed that from the 7th millennium BP, summer climatic conditions started to deteriorate in the middle latitudes of the Northern Hemisphere (NH), mainly due to a decrease in summer insolation, which reached its maximum at around 9000 BP (not shown). For all the simulated climatic parameters, a pronounced trend is evident for the summer season, which resembles one of a complete decrease in insolation (Fig. 12), although the humidity balance reveals an opposite, increasing trend, mainly due to the effect of evapotranspiration as a consequence of the enhanced insolation in the mid-Holocene.

Such conclusions are also supported by other studies based on proxy reconstructions for the investigated area and its surroundings. In particular, by analysing Holocene conditions through pollen reconstructions from several lakes, in Southern to Northern Italy and the Alpine region, Michel Magny (*Magny* et al. *2012*) concluded that the mid-Holocene summer precipitation regimes appear to have been opposite between the south- and north-central Mediterranean: a maximum was present in Sicily and a minimum in north-central Italy. Later, Magny *et alii* (*2013*) analysed a time series of wetness for the Lake Ledro basin in Northern Italy spanning the last 10 000 years: while the early and mid-Holocene periods show relatively low flood frequency, the late Holocene, from *c.* 4500 cal BP onwards is characterised by an increase, which is in full agreement with the reconstructions from neighbouring Lake Iseo. The pattern of contrasting mid-Holocene summer precipitation regimes was confirmed by Odile Peyron *et al.* (*2013*) on the basis of pollen-inferred quantitative estimates and a multi-method approach that revealed minima (maxima) of summer precipitation and lake levels to the north (south) of *c.* 40° N. Summer temperature showed a similar partition for the mid-Holocene in the central Mediterranean, with warmer (cooler) conditions to the north (south). Mónika Tóth *et alii* (*2015*) presented a Holocene summer air temperature reconstruction based on fossil chironomids from Lake Brazi, a shallow mountain lake in the Southern Carpathians, with results suggesting that from *c.* 8500 cal BP, chironomid-based summer temperatures decreased in the area. In particular, the period between 6000 and 3000 cal BP was characterised by cooler temperatures in comparison to the earlier period.

Conversely, winter-time model results do not show a clear trend and the data are characterised by significant multi-decadal to inter-centennial fluctuations (Fig. 13). For winter, the trend of insolation during the mid-to-late Holocene at the mid-latitudes of the NH is not particularly pronounced (Fig. 13). The behaviour of the simulated data is probably a result of the system's internal variability. In winter, climatic conditions in Europe are mainly driven by changes in atmospheric circulation (*Hurrel 1995; Hurrel* et al. *2003*). In particular, the first mode of winter atmospheric variability over the North Atlantic is represented by the North Atlantic Oscillation (NAO), which explains one third of the total variance in the sea-level pressure (SLP) field over the area (*Hurrel* et al. *2003*). A positive phase of the winter NAO is associated with an increase in strength and a northward shift in westerly winds. This results in moist

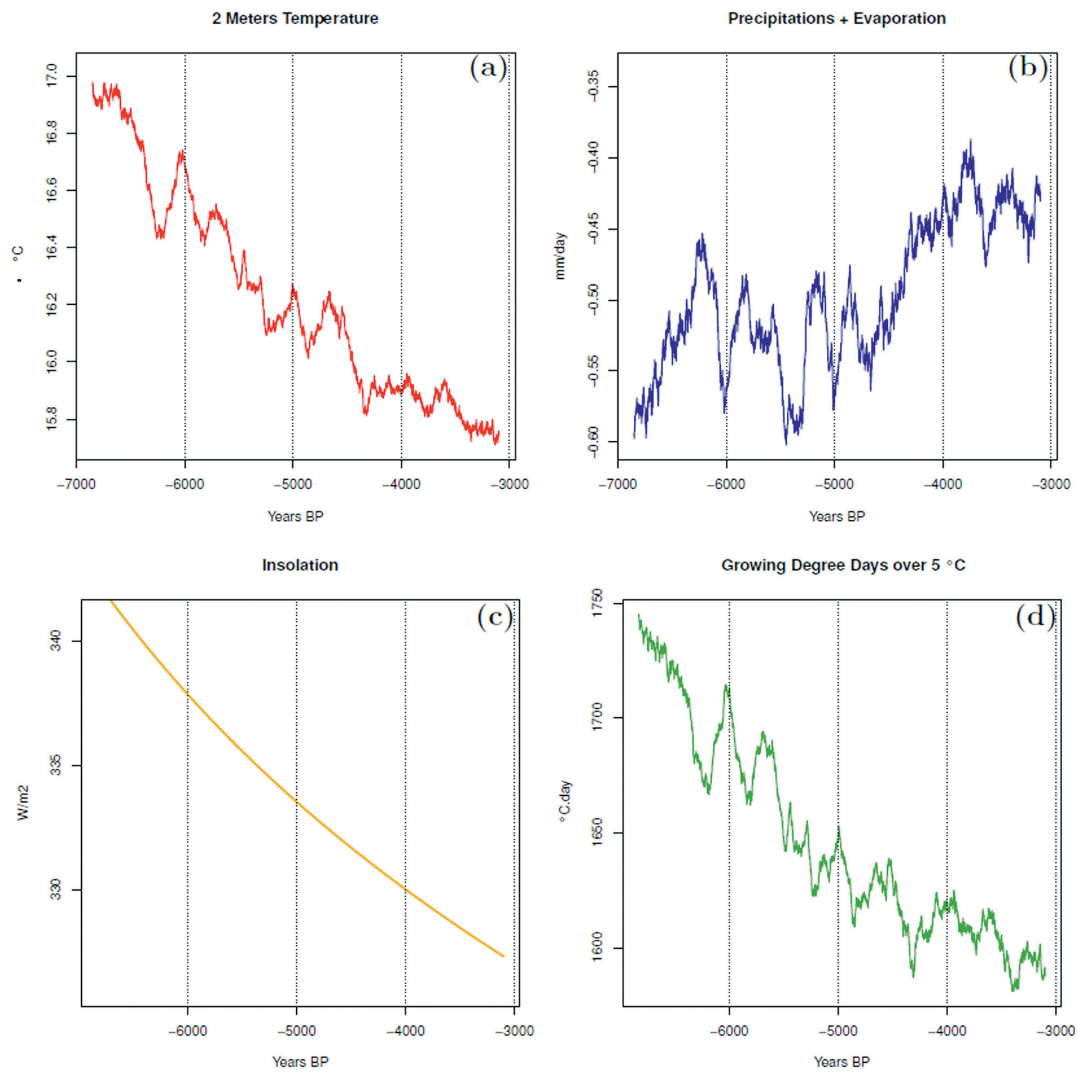


***Fig. 12. Graphs presenting:* a *summer temporal evolution of near-surface temperature regional mean computed over the area of study;* b *time series of summer precipitation + evapotranspiration calculated in mm/day;* c *insolation changes over the period of study;* d *time series of rising temperature days above 5 degrees. All the time series are smoothed using a 200-year running mean.***

and warm air advection from the Atlantic to Northern Europe (55°–70° N) and, consequently, in drier and colder conditions over Southern Europe. Conversely, the negative phase of the NAO is accompanied by weaker and southward shifted (35°–50° N) westerlies, responsible for wetter and warmer winter conditions over Southern Europe. The use of the NAO index (Fig. 12.a), which is based on the principal component time series of the leading Empirical Orthogonal Function (EOF) of the winter SLP anomalies (*Hurrel* et al. *2003*), allows us to speculate that the oscillations of the simulated winter temperature and precipitation are caused by the variability between positive and negative phases of this atmospheric pattern. The simulated winter temperature, and particularly humidity, present an extremely high anti-correlation (~ –0.7) with the calculated NAO index.

Different studies hypothesise that at around 6000 BP the NAO was in a more pronounced positive phase in comparison to present-day conditions (*Bonfils* et al. *2004; Braconnot* et al. *2007a; 2007b; Davis* et al. *2003; Mauri* et al. *2014; Russo* et al. *2016*). This is not directly evident in our results and seems to be a problem characteristic of climate models. Nevertheless, the changes in the simulated winter conditions can be considered physically consistent: the model simulates a reasonable and internally consistent climate (*Goosse 2012; Von Storch 2004*). Other events often reported in studies that are based on proxy-reconstructions are the so-called Rapid Climate Changes (RCC) (*Mayewski* et al. *2004; Budja 2015; Weninger* et al. *2009; 2015; Wanner* et al. *2011*). They are abrupt cooling events, lasting from a century to millennia, for which large drifting ice debris has been registered. The complexity of our model

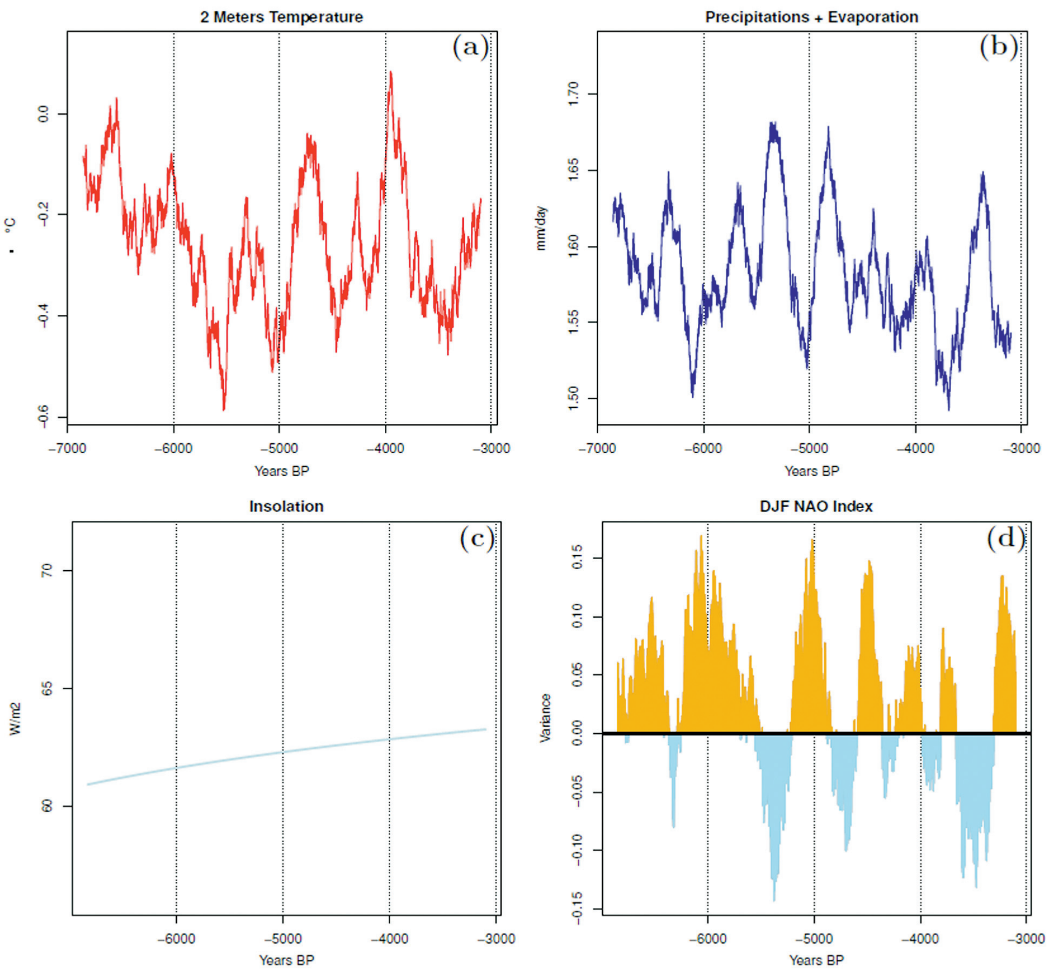


***Fig. 13. Graphs presenting:* a *winter temporal evolution of near-surface temperature regional mean computed over the area of study;* b *time series of winter precipitation + evapotranspiration calculated in mm/day;* c *insolation changes over the period of study;* d *DJF NAO index over the period of study. All the time series are smoothed using a 200-year running mean.***

does not permit a precise reproduction of such events. Additionally, even if evidence supporting them seems clear, their cyclic occurrence and causes are still highly debated, as well as the impact they had on a regional scale (*Wanner* et al. *2011*). This is one of the main reasons we focus our attention on long-term trends and the relevance of abrupt oscillations in the context of population adaptability.

Nonetheless, in our discussion, we take into consideration one particular example of RCC and the possible impact it had on the life of Eneolithic communities inhabiting the area. Although in the case of winter, no distinct trend is evident in our simulations, and the model results do not display the same level of correspondence with the other studies (as they do in the case of summer, particularly temperatures and moisture balance), the evident oscillations are physically plausible. Thus, acknowledging the possibility of the effects of RCCs during the simulated period does not contradict the model results at all. On the contrary, it means that if those events occurred, they only contributed to the evinced deterioration in climatic conditions.

## Discussion

The period between the mid-5th and the end of the 3rd millennium BC, in which the spread of both fleece-bearing sheep husbandry and new fibre flax in South East and Central Europe probably occurred, was characterised by profound social changes and has been studied so far in terms of intensified contacts and mobility (*Anthony 2007; Leary 2014*), environmental change (*Binford 1968; Barker 1985*) and economic transformation (*Sherratt 1981; 1997; 2006; Greenfield 1988; 2005*). This provided the entire contextual framework and theoretical background for the present investigation of textile production trends and their climate dependency in the aforementioned regions. Apart from the extensive research on textile production in Romania (*Mazare*

*2014*) and Bulgaria (*Petrova 2011*), which took into consideration indirect archaeological evidence from larger and confined geographical sections, the textile tools and production of the period have not yet been systematically approached in the Pannonian Plain contexts. Narrowing the focus on the particular region enabled us to raise specific questions regarding textile fibre raw materials and final product demand through their dependence on the changing climate. The declining summer trend in temperatures and the corresponding rising trend in moisture content might have caused the cultural-historically defined groups of the Post-Neolithic inhabiting the area to be more sensitive to possible climatic fluctuations like the simulated winter oscillations. Such events could have acted as a trigger for shifts in fibre procurement practices, resulting in a broadening of resources and, especially, in intensified selection in favour of their fitness.

Evidence has shown that the period between 6000 and 5000 BP, normally referred as a Rapid Climate Change event, was generally characterised by globally colder conditions (*Weninger* et al. *2009; 2011; Mayewski* et al. *2004*). In this case, the effects of the proposed scenario of a deterioration in climatic conditions would eventually have been amplified, and abrupt changes could have had even more drastic effects on the 'cultural groups' under consideration. Through a complex causal network, this could have led to substantial perturbations within human societies, as suggested by changes in the archaeological material in Central Europe (*Arbogast* et al. *1996; Berglund 2003; Magny 2004*). Weninger *et alii* (*2009*) found that at different times in the 6–5ka RCC period, there were abrupt abandonments of various settlements in Romania, Bulgaria, and Greece. During the same period in the Alpine region, abrupt oscillations on the scale of decades or a century seem to have caused changes in hunting and farming patterns (*Schibler 1997*).

The high-quality organic preservation at Sipplingen, an Alpine lakeshore settlement on the northern shore of Lake Constance in south-west Germany, enabled comprehensive dendroarchaeological, archaeobotanical and zooarchaeological investigations that revealed the adaptive character of the settlement and its subsistence strategies in response to changes in climate, environment and cultural influences over time (4000–2800 BC) (*Styring* et al. *2016.103*). Obvious economic changes that occurred during the 4th millennium BC, which have been attributed to climatic deterioration (*Schibler* et al. *1997*), reveal a dramatic cycle of establishment, expansion and reduction, or even abandonment of settlements around Lake Constance (*Billamboz, Köninger 2008*). A great deal of evidence of flax cultivation has been found from lake dwellings north of the Alps, (*Jacomet 2009*). In particular, the find densities of flax rise considerably during the second half of the 4th millennium BC (*Brombacher, Jacomet 1997.249*).

It is most likely that during the Middle Eneolithic period, which marked the turn and the first centuries of the 4th millennium BC, animal products, presumably including fibres, started to be more important as a result of deteriorating climate conditions. All the scarce textile evidence favours wild plant species, but the functional analysis of the Furchenstich and Lasinja spindle-whorls suggests that during this, apparently, intensive foraging period, animal fibres should not be disregarded. Faced with an environmental challenge due to the whimsical climate in the following centuries of the 4th millennium BC, in the context of intensified textile production, foraged plant material and possibly the old variety of flax might have been partially substituted with a new fibre fax in order to meet the growing demands of textile production. It is premature to conclude this, but the above-mentioned archaeobotanical research supports this idea.

The earliest direct evidence of wool, respectively woollen finds from Germany (*Rast-Eicher 2014.16*) and the North Caucasus (*Shishlina* et al. *2003*), when observed in the framework of changed herding strategies revealed in the contemporary contexts of South East and Central Europe[11], intensified sheep husbandry recorded at some sites[12] and the spin-

11 Regarding Central Europe, analysed faunal evidence from the Bronocice site in South Eastern Poland (*Pipes* et al. *2014*) suggest that sheep rearing intensified during the second half of the 4th millennium BC (Funnel Beaker horizon). Indeed, the increased herd sizes reported from the site revealed that the majority of animals were slaughtered as adults. In the case of South Eastern Europe, analysis of Late Eneolithic faunal samples from the Bubanj and Mokranjske Stene-potkapina sites in Serbia suggests the predominance of sheep husbandry (*Bulatović 2012; Bulatović, Milošević 2015*). Furthermore, analysis of the age profiles from the Mokranjske Stene-potkapina sample attributed to the Kostolac-Cotofeni horizon (late 4th to early 3rd millennium BC) revealed that the adult age group was the most represented.

12 Intensified sheep husbandry was recorded at the Middle Eneolithic Furchenstich site at Pod Kotom – jug pri Krogu I/II *(Šavel 2009*), at the Middle to Late Eneolithic Proto-Boleráz site at Abony (*Fábián 2008; 2012*), and at Late Eneolithic Boleráz/Baden sites at Balatonőszöd-Temetői dűlő (*Horváth 2010*) and Balatonkeresztúr-Réti-dűlő (*Fábián 2014*).

dle-whorl analysis results, push the presence of wool in the context of fibre production already into the 4th millennium BC.

Following the results of our analysis and according to the aforementioned studies, it is very likely that the middle of the 4th millennium BC (characterised by the appearance and spread of Baden culture in the Pannonian Plain) was a period of major climatic stress. Such pressure probably promoted further mastering of both fibre resources, thus influencing their specialisation. Intensified sheepherding is usually connected to this cultural group (*Maran 1998.514–516*), and many authors propose its acquaintance with wool (*Horvath 2010; Bondar 2012; Struhar* et al. *2014*). On the other hand, the level of flax pollen in samples from lake-shore settlements in Switzerland indicates intensive flax production, more recognisable in the frequent textile remains (*Capitani* et al. *2002. 115–120*). This allows us to speculate that, during the course of the second half of the 4th millennium BC, both fibre materials gained in importance.

By the beginning of the 3rd millennium BC, such strategies had already been mastered and spread, since textile production does not seem to have slowed down at this point. On the contrary, judging by the increase in the amount of spindle-whorls from the end of the Eneolithic period, it seems it even intensified. More organised fibre material resources had to have been acquired and established by that period. Both the changed environmental and cultural conditions resonated further in the new demands for specific types of textile products, which quite possibly corresponded to the intensified use of transport and traction. The predominance of very large tools, probably used for plying plant fibres or their filaments in order to make thick and strong threads and ropes which could have been used for harnessing animals, would support this scenario. Mobility and the transport of goods would also have promoted the trend. The increased variability of Late Eneolithic spindle-whorl assemblages in favour of a balanced distribution of moderate weight types between three main height categories is something that might reflect this kind of broadened fibre assortment, both in regard to the raw material resources and demand for end products, although the obvious predominance of heavy and very heavy types of tool, particularly in high and steep height categories, greatly accounts for longer plant fibre preferences. This trend is particularly pronounced at the turn of the millennium, and continues in the Vučedol and Somogyvár-Vinkovci phase. There is a possibility that this reflects the appearance of specialised fibre flax and its intensified use in the plying tradition of the late 4th and the following 3rd millennium BC. Impressed plied cord decoration (*Grömer, Kern 2010; Leghissa 2015*) representative of the Early Bronze Age Corded Wear complex (widespread in the Pannonian Plain) could attest to the growing importance of plied cordage in the course of the following centuries.

## Conclusions

Three main trends are evident in the spindle-whorl sample. First, the Middle Eneolithic assemblages suggest more intensive animal husbandry, which led to the first exploitation of animal fibres. Second, on the basis of the Late Eneolithic tools, continued use of wool may be argued, which was substantially accompanied by the intensified production of long plant fibre, presumably flax. And third, the results of the analysis of Early Bronze Age spindle-whorls reveal a specialisation of fibres, most probably due to the refinement of both textile fibre resources and demand for final products.

Despite the large textile tool sample on which this research is based and regardless of the climate conditions that support the outlined timeline for the introduction of both sheep wool and the new fibre flax, already during the Eneolithic in the Pannonian Plain, further zooarchaeological and archaeobotanical evidence is required to understand and explain the dynamics of these processes in finer detail. The exploration of the new fibre resources occurred simultaneously in remote contexts and could have been provoked by both cultural and environmental conditions.

Numerous interacting factors were probably responsible for the intensification of their exploitation and, to some degree, their further development, which might not have been as linear as we thought. Thus their evolutional character is contrary to the revolutionary scenario. They gradually developed from ordinary foraged fibres into occasional and then into common secondary products. Due to the intensification of their use, they finally became primary and specialised resources for developed textile production. It is plausible that, due to different factors in different areas and periods, similar reasons promoted fibre production as those that later contributed to their specialisations. Although the earliest direct evidence for wool in the studied region dates to the 2nd millennium BC (*Grömer* et al. *2013;*

*Rast-Eicher, Bender Jørgensen 2013*), its much earlier presence must be considered.

There are two possible reasons why in Europe the scant textile evidence sample from the 4th and 3rd millennium lacks woollen examples: first, its underrepresented use in comparison to flax and other plant fibres, and second, the fact that the European climate is not conducive to its preservation conditioning (*Ryder 1964*). Regarding resources for fibre production, the Middle Eneolithic could mark their initial exploitation phase, while the Late Eneolithic, with evident technological change which gradually resulted in greater tool standardisation in the Early Bronze Age, marks their second exploitation phase. The exploration phase for both resources might have already started in previous periods, and so future textile research of Early Eneolithic tools might clarify this dynamic. The results of the analysis suggest that in the studied region of South East and Central Europe, wool was probably already being exploited in the 4th and certainly the 3rd millennium BC, although on a smaller scale, first in comparison to flax, and also in comparison to the established wool economies of contemporary urban centres in the Near East.

The continuous deterioration in summer climatic conditions in the Pannonian Plain region during these two millennia would still have provided conditions congenial to fibre flax. Areas with less favourable conditions for cultivating it might have focused their developing textile production on other resources, causing them to specialise in alternatives. This is a question of difference in fibre specialisations, which so far have been interpreted as indications of use, creating an unacceptable dichotomy in the period of intensified mobility and contacts. A growing demand for raw materials, and metal in particular, resulted in intensified trade that could support this kind of fibre competition through division in specialisation during the 4th millennium, while textiles, and presumably fibres, may have been substantially involved in both short- and long-distance trade. Metal objects were certainly accountable for far-reaching cultural contacts, possibly facilitating breed mobility, which then accelerated the gene flow and the evolution of both fibres. Copper axes from burial mounds at Moravian TRB-Boleráz sites were wrapped in flax textiles, which could account for a combination of two luxury goods (*Baldia* et al. *2008.264–265*). Sherratt (*Sherratt 1997; 2006*) connected both the animal traction and wool with social stratification, explaining them as symbols of elites. Quite possibly, this connection should be to some extent related to inequalities between animals and plants reflected in the people who had privilege to select among them. Although wool's appearance and origin were for a long time considered within the textile economies of the urban revolution package in Bronze Age Mesopotamia (*McCorriston 1997; Kimbrough 2006*), the oldest finds, genetic evidence, and the analysis of the prehistoric textile tools pushed its early appearance on the fibre scene into a new and much wider framework regarding its theoretical (SPR), geographical (Fertile Crescent), chronological (Bronze Age) and social (stratified organised systems) context.

On the other hand, archaeobotanical research on the flax plant, taken in consideration with the processed textile evidence from circum-Alpine pile dwellings, place the fibre evolution in the same period of the thriving copper trade in the 4th millennium BC, suggesting that both resources were exploited in the production of Eneolithic textiles. Although both scenarios were connected to many cultural and environmental trends, climate change was certainly accountable, if not for their evolution, then for influencing the dynamics of their exploitation.

During the late 4th and early 3rd millennium BC, an interesting example of a technological shift occurred, one which accommodated to both new options of presumed raw material resources, and new demands for a seemingly greater variety of end products. The moderate weight types of spindle-whorls significantly represented in all height classes during this technological phase suggest that all of the fibres considered could have been used. This was evidently accomplished through a gradual change in tool properties, while assemblages were consecutively adjusted.

Although the boom in heavy and very heavy types of spindle-whorls is more obvious and easier to connect with long plant fibres, and the appearance of smaller sizes in the Early Bronze Age is something we search for when we expect wool use, the modest, ordinary, average, hard-to- interpret type of tool revealed the biggest evolution: craftsmens' slow and gradual accommodation to the world around them. Technology's potential to be modified is mainly reflected in the outlined tools' flexibility. Although its moderate and gradual transformation does not account for a high degree of specialisation, it does reveal our ability to combine tradition and innovation in altering and, more importantly, challenging circumstances.

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# Niti koje vežu elitu
# Lociranje eneolitičkih tekstilnih zanata

## Threads that bind the establishement
## Housing eneolithic textile craft

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### Uvod

#### Alatke i zanat

Tretiranje i obrada vlakana uvelike ovise o dostupnosti i prirodi izvora sirovine, kao i o željenim krajnjim proizvodima. Dakle, i početna i završna faza proizvodnje tekstila ocrtavaju se u dijelu procesa koji uključuje predenje. Posljedično, različiti načini eksploatacije vlaknastog materijala i njegovo pretvaranje u tekstilni proizvod mogu se promatrati kroz funkcionalni aspekt tekstilnih alatki, odnosno, preciznije, kroz pršljenove.

Pršljenovi su jednostavne alatke koje stvaraju napetost i rotaciju tijekom procesa predenja, dok se vretenom izvlači vlakna iz pripremljene sirovine i zavija ih se u uzicu ili nit. Pršljenovi su najbrojnija vrsta neizravnih dokaza za proizvodnju tekstila u eneolitičkim kontekstima, što doprinosi potencijalu za proučavanje tehnoloških trendova, osobito onih koji se odnose na dinamiku i promjene u obradi vlakana. Oni pružaju određene podatke o procesu predenja, a ujedno i o: prvo, svojstvima korištenih vlaknastih materijala (Grömer 2005; Verhecken 2010), i, drugo, tipu i kvaliteti proizvedene niti (Bohnsack 1981; Crewe 1998). Iako nisu ključni, pršljenovi su vrlo korisne alatke za proizvodnju niti (Barber 1991: 42) koje znatno ubrzavaju i poboljšavaju ovu, početnu, fazu u proizvodnji tekstila koja slijedi nakon pribavljanja i pripreme sirovih vlakana (Barber 1991: 51-53). Dok jedan pršljen označava proizvodnju jedne niti u pojedinom

### Introduction

#### Tools for the Craft

Fibre treatment and processing greatly depend on the availability and the nature of raw material resources, as well as on the desired end products. Thus, both the initial and the final phase of textile production are reflected in the spinning part of the process. Consequently, different modes of both, the fibre material exploitation and its fabrication into textile produce, can be studied through the functional aspect of textile tools, more precisely, the spindle whorls.

Spindle whorls are simple tools that impart both tension and rotation during the process of spinning, in which the spinner draws out strands of raw material and twists them together into a cordage or thread. They are the most numerous among indirect evidence for manufacture of textiles in Eneolithic contexts. This contributes to their potential for studying technological trends, particularly those related to fibre processing dynamics and change. They provide specific information about the spinning process, while offering information on: first, the used fibre material traits (Grömer 2005; Verhecken 2010) and second, the type and quality of the produced thread (Bohnsack 1981; Crewe 1998). Even though not essential, spindle whorls are highly beneficial tools for thread production (Barber 1991: 42) that make this initial stage in textile manufacture, which fallows the acquisition and preparatrenutku i tijekom procesa predenja ga može koristiti samo jedna osoba (prelja/predioc), veći broj i koncentracija nalaza mogu vrlo jasno ocrtavati grupne aktivnosti. Posljedično, arheološke strukture s visokom koncentracijom pršljenova mogu se smatrati indikatorom intenzivnih aktivnosti predenja.

Prostorni element proizvodnog procesa uključen je u analizu kako bi se ispitala složenost organizacije eneolitičke proizvodnje tekstila. Cilj ovog rada bio je istražiti u kolikoj su mjeri strategije nabavljanja, obrade i tretiranja vlakana bile društveno sprovođene. Preciznije, pokušalo se posvetiti raspravi o tome postoji li dovoljno dokaza koji sugeriraju da su obrada vlakana i proizvodnja niti bile, osim na razini kućanstva, koordinirane i u sklopu većih, moguće i specijaliziranih skupina ljudi unutar eneolitičkih zajednica.

Novi teorijski pristup (Joyce & Gillespie 2000; Robin & Rothschild 2002) naglašava ulogu posredovanja u stvaranju, transformaciji i doživljaju prostora i mjesta. Dakle, dublje razumijevanje određenih prozvodnih aktivnosti, a osobito njihova prostorna organizacija, ključni su čimbenici za istraživanje društvenog aspekta proizvodnje. Većina analiziranih i dokumentiranih neizravnih dokaza za proizvodnju tekstila u neolitiku spada u skupinu nalaza utega za tkalačke stanove otkrivenih *in situ*, a koji se na proučavanom prostoru najčešće pojavljuju u kontekstu kuća (Selmeczi 1969; Barber 1991; Jovanović 2011). S obzirom na činjenicu da se u nekim ruralnim područjima do današnjih dana većina poslova vezanih uz tekstil odvija u kućanstvu, proizvodnja tekstila na razini domaćinstva smatrana je standardnim objašnjenjem koje, nehotimično, negira mogućnost rane specijalizacije tog zanata. Nadalje, za razliku od tkanja, koje zahtijeva određeni prostor, predenje je prilično mobilna aktivnost koja se odvijala u nizu prostornih konteksta i nije ničime bila ograničena na prostor domaćinstva. Dakle, namjerno odbacivanje pršljenova često se nije moralo odvijati paralelno s odbacivanjem drugih vrsta predmeta iz domaćinstva. Etnografske su studije pokazale da se predenje često odvija prilikom obavljanja drugih radnji (Crowfoot 1931: 37). Elizabeth Barber (Barber 1991: 69) čak je zabilježila: „Jedan od razloga zbog kojih kotač nije bio popularan u Grčkoj jest to što je najprikladnije vrijeme za predenje bilo tijekom putovanja od jednog do drugog sela, ili prilikom čuvanja stada. Čini se da je navika predenja tijekom hodanja, ili jahanja na magarcu, na sjevernom

tion of raw fibres, much faster and more proficient (Barber 1991: 51–53). While a single spindle whorl counts for the production of one thread at a time and can be used by an individual spinner during the rendering process, their increased number and concentration can be highly reflective of group activities. Thus, archaeological features with high spindle-whorl concentration can be considered as an indication of intensified spinning practice.

In order to investigate the possibility and the complexity of organization of Eneolithic textile productions, the spatial element of the manufacturing process was addressed. The aim of this study was to examine to which extent were the fibre material procurement, handling and treatment strategies socially structured. More precisely, an attempt has been made to discuss if the initial phase of textile production was managed on the household level or is there enough evidence to suggest that the fibre processing and thread fabrication practice was also coordinated within larger, possibly specialized groups, during the studied periods.

New theoretical approach (Joyce & Gillespie 2000; Robin & Rothschild 2002) stresses the role of agency in the creation, transformation and experience of space and place. Hence, a deeper understanding of the specific manufacturing activities and in particular their spatial organization are the key factors for investigating the social aspects of the production. The majority of analysed and reported indirect evidence for the Neolithic textile productions falls into the group of *in situ* evidences of loom-weights, most often recovered from the house contexts across the studied region (Selmeczi 1969; Barber 1991; Jovanović 2011). Considering the fact that in some rural areas a big portion of textile work is still, until today, performed at home, the household level of textile production is regarded as a standard that rather unintentionally discriminates the possibility for early craft specialization. Further, unlike weaving that requires an activity area, spinning is a rather mobile practice that was practiced in a wider range of spatial contexts and is not at all limited to the domestic sphere. Thus, an intentional discard of spindle whorls often might not occure with other classes of domestic refuse. Etnographic studies show that spinning is often done while performing other tasks (Crowfoot 1931: 37). Elizabeth Barber (Barber 1991: 69) even reports: "One reason the wheel has not been popular in Greece is that one of the most convenient times there for spinning is while travelling about- from one village to the

Mediteranu prilično stara." Imajući navedeno na umu, visoka frekvencija pršljenova u jednom arheološkom kontekstu ukazuje na značajnu razinu proizvodnje pređe (specijaliziranu, organiziranu, ili oboje), bez obzira na prirodu depozita (primarnu ili sekundarnu).

S obzirom na to da morfološke odlike alatki znatno utječu na njihovu funkcionalnost (Gromer 2005; Martensson et al. 2006; Verhecken 2010), tehnička analiza pršljenova predstavlja temelj za istraživanje korištenih tehnika, metoda i materijala, te konačnih proizvoda predenja. Ipak, do koje mjere morfologija alatki uvjetuje sam proces proizvodnje i dalje se propitkuje i istražuje kroz eksperimentalne studije (Laurito et al. 2014; Kania 2015).

next, or while tending the flocks. The habit of spinning while walking, or riding a donkey, seems to be fairly old in the north Mediterranean". With all of this in mind, a high frequency of spindle whorls in a single archaeological context is suggestive of a significant level of yarn production (specialized, organized, or both), regardless of the nature of the deposit (primary or secondary).

Technical analysis of spindle whorls enables the investigation of techniques, materials, methods and products, since the morphological traits of the tools greatly impact their functionality (Grömer 2005; Mårtensson et al. 2006; Verhecken 2010). Nevertheless, the level on which the morphology influences and conditions the spinning process continues to be questioned and investigated through experimental studies (Laurito et al. 2014; Kania 2015).

## Zanat i specijalizacija

Promatranje razina procesa proizvodnje tekstila kroz vremenske i prostorne kategorije omogućava definiranje uzoraka zanatske proizvodnje. Mnoge studije bile su usmjerene na pojmove obrtništva i specijalizacije kroz proučavanje njihove uvjetovanosti društvenom organizacijom (Clark 1995; Chapman 2003). Već je Vere Gordon Child predložio svezu između pojave specijalizacije zanata i razvoja društvenih struktura (Childe 1930, 1950, 1951, 1958).

Veliki dio arheološke teorije odnosi se na specijalizaciju u poodmaklom, potpuno razvijenom obliku unutar društvenog konteksta profiliranih hijerarhija (Chapman 1996; Gilman 1996), iako postoje i studije koje propitkuju pretpostavke o razini društvene složenosti koja je potrebna za njezino rano uspostavljanje (Perlès & Vitelli 2000; Souvatzi 2008).

Cathy Lynne Costin predložila je model koji pokazuje najviše potencijala za za proučavanje prostornog aspekta specijalizacije (Costin 1991). Ona je specijalizaciju zanata definirala kao: „diferencirani, regulirani, trajni i, moguće, institucionalizirani sustav proizvodnje " (Costin 1991: 4), a predložila je i četiri kategorije za proučavanje njezine složenosti: *kontekst, koncentraciju, razmjer i intenzitet* (Costin 1991: 5-9). *Kontekst* se odnosi na političke i društveno-ekonomske uvjete proizvodnje, dok se *koncentracija* odnosi na njezinu prostornu organizaciju i distribuciju. *Razmjer* procjenjuje broj sudionika integriranih u proizvodni proces, do dok se

## Craft for the Specialization

Observation of the stages of textile manufacturing process in time and space categories allows for the definition of patterns of craft production. Many studies addressed the concepts of craftsmanship and specialisation through examining their dependence on social organization (Clark 1995; Chapman 2003). Already Vere Gordon Child proposed the relationship between the emergence of craft specialization and the development of class structures (Childe 1930, 1950, 1951, 1958).

A big portion of archaeological theory deals with specialisation already in its developed form within the social context of profiled hierarchies (Chapman 1996; Gilman 1996), although there are studies which challenged the assumptions about the level of social complexity essential for its early establishment (Perlès & Vitelli 2000; Souvatzi 2008).

Cathy Lynne Costin proposed a model, which probably holds the greatest potential for addressing the subject of specialization on a spatial level of investigation (Costin 1991). She defined the craft specialization as a "differentiated, regularized, permanent, and perhaps institutionalized production system" (Costin 1991: 4) and suggested four categories for addressing its complexity: context, concentration, scale and intensity (Costin 1991: 5–9). *Context* focuses on the political and socio-economic conditions of the production, while *concentration* examines its spatial organisation and distribution. *Scale* category assesses the amount of people involved and integrated in the process and finally, *intensity* ad-

*intenzitet* odnosi na količinu uloženog i utrošenog vremena (Costin 1991: 11-16).

U kontekstu arheologije tekstila, problemom specijalizacije zanata s teorijskog aspekta bavila se Eva Andersson-Strand, koja razlikuje četiri razine specijalizacije: *proizvodnju u kućanstvu, industriji u kućanstvu, zavisnu specijaliziranu proizvodnju* i *radioničku proizvodnju za trgovinu* (Andersson 2003: 47, fig.1.). Njezin se model odnosi na isti problem kao i onaj Cathy Lynne Costin, a sugerira da su stupanj organizacije rada (*koncentracija*), njezina raširenost (*razmjer*) i razina angažiranosti pojedinaca (*intenzitet*) u društveno-ekonomskom kontekstu (*kontekst*) glavni parametri za stupnjevanje ili procjenu specijalizacije zanata u sklopu proizvodnje tekstila (Andersson Strand 2011: 3). Iako utemeljen na proizvodnji tekstila iz doba Vikinga, njezin model može se smatrati prikladnim za proučavanje promjena u pretpovijesti (Grömer 2016: 246-61).

## Specijalizacija i složenost društva

U kontekstu proizvodnje tekstila, majstorstvo je neraskidivo povezano s nekoliko aspekata društvenog identiteta koji se ne odnose samo na status, već i na rod, dob i srodstvo (Dolfini 2013). Ipak, pri proučavanju nestratificiranih društava potrebno je prihvatiti pretpostavku da specijalizacija zanata nije nužno bila vezana uz složenost društvene strukture. U prilog tomu govore argumenti autorica Catherine Perlès i Karen Vitelli, koje smatraju da razine specijalizacije i društvene složenosti ne moraju nužno biti proporcionalne (Perlès & Vitelli 2000). Nadalje, Kenneth Sassaman kritizirao je pristranost modela koji se temelje na inkorporiranju i koncentriranju moći unutar političkih ekonomija, zbog toga što ne uzimaju u obzir nestratificirana društva, te time negiraju njihov potencijal za razvijanje specijaliziranih uloga u proizvodnji. (Sassaman 1998). John Cross predložio je novu definiciju specijalizacije koju bi se moglo implementirati pri proučavanju proizvodnje malih razmjera kakva se veže uz egalitarne zajednice (Cross 1993). Formiranje specijalizirane proizvodnje i njezina provedba mogle bi se, dakle, shvatiti kao kontinuum između *nezavisnih* (samostalnih i neustrojenih koji zadovoljavaju ekonomske potrebe društva) i *zavisnih* (unaprijeđenih i privrženih koji zadovoljavaju potrebe elita ili centraliziranih institucija) *specijalista* (Brumfiel & Earle 1987:5), dok bi se proces njihovog razvoja "trebalo proma-

dresses the amount of time spent and invested by individuals (Costin 1991: 11–16).

In the context of textile archaeology, the issue of craft specialization has been theoretically addressed by Eva Andersson-Strand, who distinguishes between four levels of specialisation: *household production*, *household industry*, *attached specialist production* and *workshop production for trade* (Andersson 2003: 47, fig.1.). Her model addresses the same issues as Cathy Lynne Costin's, suggesting that the degree of labour organisation (*concentration*), its spread (*scale*) and involvement (*intensity*) in the socio-economic context (*context*) are the main parameters for gradation or evaluation of craft specialisation within the frame of textile manufacture (Andersson Strand 2011: 3). Although established on the Viking age textile production, her model may be concerned as suitable for the study of prehistoric developments (Grömer 2016: 246–61).

## Specialization for the Social Complexity

In the context of textile production craftmenship is inseparably intertwined with several facets of social identity besides status, including gender, age and kin (Dolfini 2013). Whereas, the presumption that craft specialization is not necessarily related to the developed social complexity needs to be addressed for the study of non-stratified societies. Supporting this issue, Catherine Perlès and Karen Vitelli argued that levels of specialization and social complexity do not have to be necessarily proportional (Perlès & Vitelli 2000). Furthermore, Kenneth Sassaman criticized the bias towards models built on incorporation and concentration of power within political economies, with unranked societies being left unaddressed and excluded from having potential for specialized production roles (Sassaman 1998), while John Cross suggested a redefinition of specialization, so it could be implemented in the research of low-level production expected for the egalitarian communities (Cross 1993). Formation of specialized production and its enactment could thus be conceptualized as a continuum between *independent* (self-reliant, unregimented and providing for the economic demands of the society) and *attached* (promoted from, dependent of and providing for elites or centralized institutions) *specialists* (Brumfiel & Earle 1987:5), while the process of its development "should be viewed as additive, rather than the replacement of one mode trati kao pridodavanje novih segmenata načinu proizvodnje, a ne kao kao zamjenu jednog načina drugim" (Costin 2001: 274). Predložena dinamika vrlo se dobro uklapa u kontekst proizvodnje tekstila kroz pretpovijest, povijest, pa i moderno doba, osobito u ruralnim područjima i za vrijeme kada je proces proizvodnje na razini domaćinstva bio široko rasprostranjen i postojao usporedno s drugim oblicima koji su se razvijali s vremenom (Grömer 2016: 248).

Istraživanja obrade vlakana i proizvodnje tekstila u Mezopotamiji (McCorriston 1997) i Anatoliji (Sagona & Zimansky 2009) iznjedrila su dokaze o postojanju specijaliziranih zanata već u kasnom 4. i 3. tisućljeću prije Krista. Studije mezopotamske proizvodnje tekstila, koja se temelji na proizvodnji vune, bave se detaljima vezanim uz organizaciju i centralizaciju rane industrije kroz promatranje odnosa društvenih tokova, razvoja proizvodnje i procesa urbanizacije. (McCorriston 1997). Veliki broj očuvanih organskih dokaza iz naselja u močvarnim područjima oko Alpa doveo je do razvitka sličnih argumenata o istovremenoj organiziranoj i specijaliziranoj proizvodnji lana u zapadnoj i središnjoj Europi. U dobro očuvanim slojevima na lokalitetima Arbon-Bleiche 3 i Pfyn-Breitenloo otkrivene su važne informacije o pripremi i obradi lana,a koje sugeriraju da su pojedina sela bila fokusirana na uzgoj lana i obradu vlakana. (Schlichtherle 2009). Prostorna distribucija alatki za proizvodnju tekstila unutar naselja ukazuje na organiziranu i specijaliziranu proizvodnju (Maier 2001; Lauzinger & Rast-Eicher 2011: 539-540), dok arheološki i botanički nalazi ukazuju na podjelu rada i razvoj određenih društveno-ekonomskih razlika zbog kojih dobra i ekonomski faktori, uključujući lan, nisu u jednakoj mjeri bili dostupni svim stanovnicima (Schlichtherle et al. 2010). Za istovremenu proizvodnju tekstila u jugoistočnoj i središnjoj Europi dosad nisu doneseni isti zaključci. S obzirom na zatvorenost Panonske nizine, koja se proteže od Karpata i jugoistočnih Alpi na sjeveru i zapadu do sjevernih padina planina središnjeg Balkana na jugu i rijeke Dunav na istoku, ovo je područje izvjesno bilo vrlo otvoreno trgovačkim i prometnim putovima. Očekivano, istovremeno je moglo biti otvoreno i utjecajima vezanim uz proizvodnju tekstila koji su stizali preko Alpa i Karpata, kao i onima koji su stizali balkanskim i dunavskim putovima.

Čini se izglednim da srednje, a osobito kasnoeneolitička društva na prostoru velike Panonske nizine razvijaju nove izvore vlakana i načine proizvodnje

by another" (Costin 2001: 274). Proposed dynamics resonates very well within the context of textile production, mainly while its household level persists wide spread, from prehistoric times through the entire history, into the modern era, especially in rural areas, in addition to other forms that developed through time (Grömer 2016: 248).

Research on fibre processing and textile production in Mesopotamia (McCorriston 1997) and Anatolia (Sagona & Zimansky 2009) revealed evidence for craft specialization already in the late 4th and 3rd millennium BC. In particular, the study of Mesopotamian wool based textile production addressed the details of organization and centralization of the early industry, through its relation to the processes of urbanization and social flux (McCorriston 1997). Due to the abundance of preserved organic evidence from the wetland settlements of the circum alpine region, arguments for organized and specialized flax production were made for the contemporary western central Europe. Well preserved layers at Arbon-Bleiche 3 and Pfyn-Breitenloo revealed valuable information on its preparation and handling, suggesting that certain villages were focused on flax growing and fibre processing (Schlichtherle 2009). The spatial distribution of the textile tools within settlements proposes organized and specialized textile work (Maier 2001, Lauzinger & Rast-Eicher 2011: 539–540), while archaeological and botanical evidence pointed to the division of labor and the development of certain socioeconomic differences, where goods and economic factors, including flax, were not available in the same extent to all inhabitants (Schlichtherle et al. 2010). So far, no similar conclusions were made about the contemporary textile productions across the South East and Central Europe. With its enclosed Pannonian Plain, stretching from the foothills of the Carpathian Mountains and the South East Alps in the North and West, to the northern slopes of the Central Balkan Mountains in the South and the Danube River in the East, this area was presumably highly exposed to trade and traffic routes. Expectantly, it could have been simultaneously opened to the production influences that were crossing the Alps and Carpathians, as to those arriving through the Balkan and Danube routes.

It is not unlikely that during the period of the striving wool economies in the Near Eastern and East Mediterranean centres and the developing fibre flax productions in the western Central Europe, Middle and especially Late Eneolithic societies ocdok bliskoistočna i istočnomediteranska društva uzgajaju vunu, a upotreba lana raste u zapadnoj i središnjoj Europi. Najveći broj arheoloških dokaza o eneolitičkoj privredi potječe s prostora današnje Mađarske, dok zoološke, a osobito arheobotaničke, studije nisu toliko sustavno provođene u Hrvatskoj i Srbiji (Reed 2016). Osim toga, zbog manjka očuvanih nalaza tekstila, alatke korištene u proizvodnji ostaju jedini izvor informacija za istraživanje prijelaza na organiziranu proizvodnju koja se posljedično usmjeravala na kultivirane izvore vlakana.

Porast proizvodnje mogao je biti izazvan različitim faktorima. Primjerice, na taj su proces mogli utjecati tehnološki napredak, dostupnost sirovina, potražnja ili razmjena. Sukladno tomu, proizvodnja unutar domaćinstva zamijenjena je proizvodnim sustavom koji stvara viškove.

Specijalizaciju se u arheologiji često indirektno definira kroz proučavanje stupnja standardizacije u tehnologiji (Blackman et al. 1993; Costin & Hagstrum 1995; Eerkens & Bettinger 2001; Roux 2003). Uobičajen pristup za proučavanje standardizirane proizvodnje uključuje uočavanje uniformnosti sirovina i procjenu varijabilnosti metričkih atributa proučavanih predmeta.

## Analiza alatki

### Lociranje organizirane proizvodnje

Karakter i sastav eneolitičkih društava u različitim je regijama vjerojatno varirao ovisno o lokalnim geografskim značajkama, dostupnosti resursa te društvenim i ekonomskim sklonostima populacija. Prijelaz iz razdoblja kasnog neolitika objašnjava se zamjenom velikih telova manjim i kratkotrajnijim naseljima te promjenom strategije preživljavanja u smislu prijelaza sa zemljoradnje na intenzivnije stočarstvo (Parkinson 2006: 186; Gyulai 2010). Ipak, do kraja novog razdoblja, obrasci naseljavanja iznova su se promijenili. U Mađarskoj, badenska je kultura razvila gustu mrežu visinskih i nizinskih, kao i velikih i malih naselja i špilja (Horváth & Virág 2003:127). Iznova su formirani telovi koji su vjerojatno funkcionirali kao društvena i ekonomska središta kojima su gravitirala manja satelitska naselja koja su bila raspršena oko rijeka i potoka (Durman 1995; Tasić 2003-2004). Moguće je da ove promjene ocrtavaju pojačanu razmjenu koja se

cupying the vast Pannonian Plain were adapting new fibre resources and developing new modes of manufacture as well. The biggest portion of the archaeological evidence for Eneolithic husbandry comes from the region of modern day Hungary, while zooarchaeological and especially archaeobotanical studies have been not as systematically conducted in Croatia and Serbia (Reed 2016). Additionally, limited by the absence of preserved textile finds, textile tools remain the main source of information for investigating the transition to organized productions that consequently intensified the focus on cultivated fibre material resources.

The intensification of production might have been caused by different factors. For an example technological advance, resource availability, product demands or trade might have all fuelled the process. Consequently, the domestic mode of production gives way to a production system that produces surpluses.

In archaeology, the specialisation is often diagnosed indirectly by studying the degree of standardisation in technology (Blackman et al. 1993; Costin & Hagstrum 1995; Eerkens & Bettinger 2001; Roux 2003). The most common approach is to study standardisation by looking for the uniformity of raw materials or the variation in metric attributes of the studied objects.

## Tool Analysis

### Locating Organized Production

Character and constitution of Eneolithic societies most likely varied regionally, depending on local geography, accessibility of resources and socioeconomic inclinations. The transition from the late Neolithic period has been explained through the replacement of large tell sites with smaller shorter-term settlements and a transformation of subsistence strategies from crop agriculture to more intensified animal husbandry (Parkinson 2006: 186; Gyulai 2010). However, by the end of the period, settlement patterns are once again altering. In Hungary, the Baden culture developed a dense network of both upland and lowland large and small settlements and caves (Horváth & Virág 2003:127). Once again, the large tell sites were being established that most likely acted as the socioeconomic centres for the smaller satellite settlements dispersed around rivers and streams (Durman 1995; Tasić 2003–2004). These changes possibly reflect the in-dodatno objašnjava razvojem metalurških središta (Šljivar 2006; Jovanović 2009). U kontekstu pojačane trgovine i razvoja metalurgije intenzivirana proizvodnja čini se logičnom.

Istraživanje eneolitičke proizvodnje tekstila, s naglaskom na tehnologiju predenja, a koja je temelj ovog rada, oslanja se na opsežnu tehničku analizu tekstilnih alatki. Glavni cilj bio je proučiti ranu pojavu organizirane proizvodnje, s namjerom da se istraže sve mogućnosti pojave rane specijalizacije zanata među eneolitičkim zajednicama u Panonskoj nizini.

Temi je pristupljeno na dvije razine: prvo, kroz prostornu analizu distribucije alatki koje bi mogle upućivati na radioničke aktivnosti i napuštanje sfere proizvodnje u domaćinstvu te, drugo, kroz proučavanje standardizacije i funkcionalnosti radne opreme koje bi sugerirale upotrebu zajedničke sirovine ili ujednačenost tehnika i krajnjih proizvoda.

Proučavano razdoblje, počevši od srednjeg eneolitika (najranije alatke su pršljenovi lasinjske kulture), a završivši s ranim brončanim dobom (najmlađe alatke su pršljenovi kulture Somogyvár-Vinkovci), datirano je otprilike u vrijeme između sredine

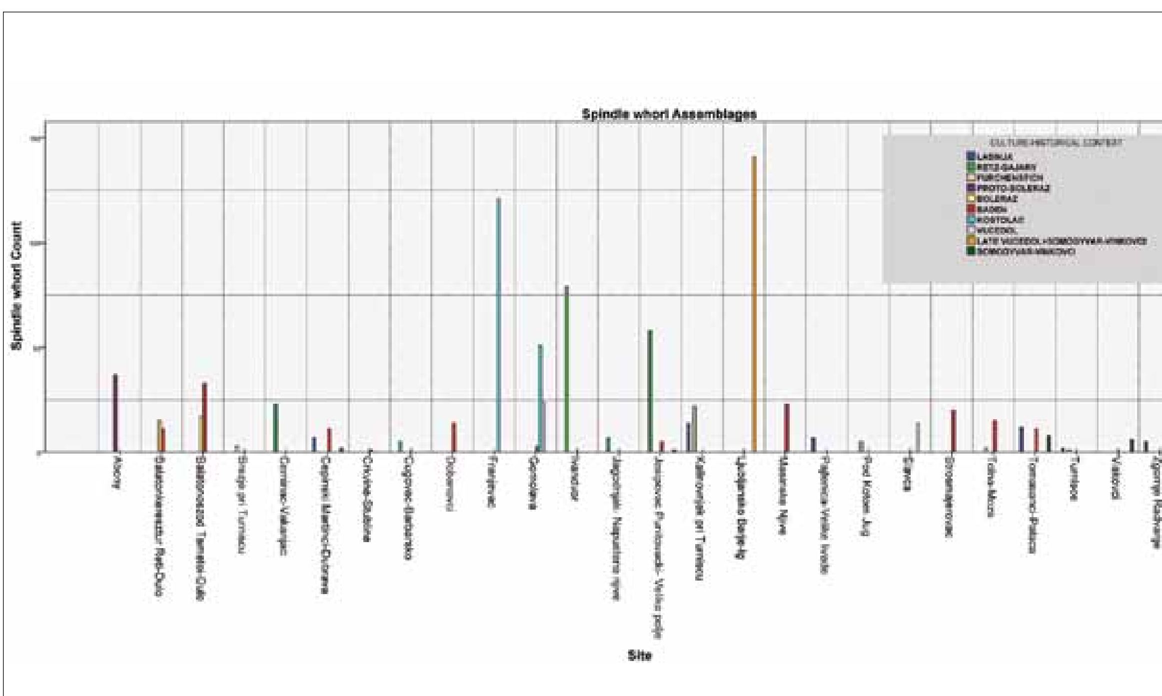
tensified exchange, further explained through the development of metallurgical centres (Šljivar 2006; Jovanović 2009). In the context of intensified trade and developing metallurgy, higher levels of production would be conceivable.

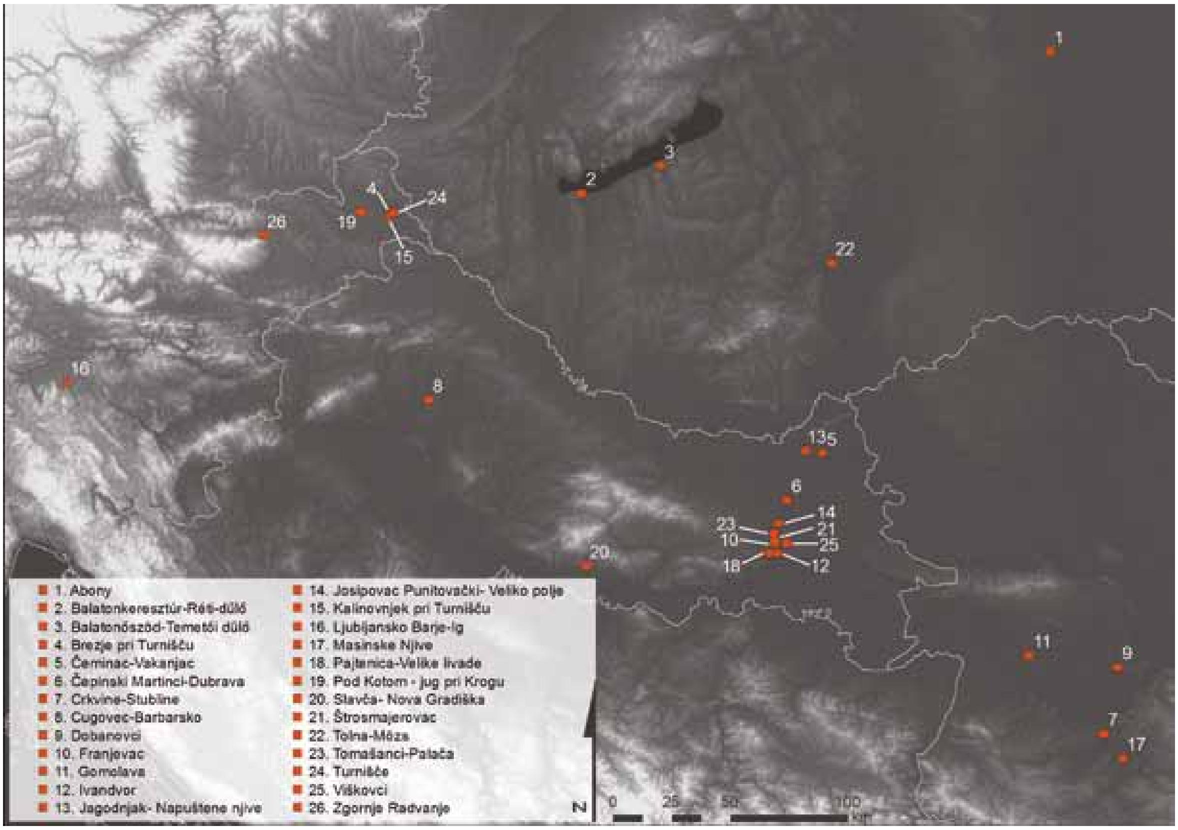
The research of the Eneolithic textile production with the emphasis on the spinning technology which represents the basis of this study, was performed through extensive technical analysis of textile tools. The main objective was to explore the early manifestation of organized production, with the aim to investigate any possibility for initial craft specialization among the Eneolithic communities of the Pannonian Plain region.

This subject was addressed on two levels: first, through the spatial distribution of tools that might indicate workshop activities and leaving of the domestic sphere of production, and second, through the inspection of standardization and functionality of the work equipment, that would propose communal fibre resources or uniformity of techniques and end products.

Studied period, beginning with the Middle Eneolithic (the earliest tools belonging to the Lasinja spindle whorl set) and ending with the Early Bronze

Slika / Figure 1. Skupovi nalaza pršljenova po lokalitetima s obzirom na kulturno-povijesnu atribuciju (N=836) / Spindle whorl assemblages with respect to their site distribution and culture-historical attribution (N=836).






Slika / Figure 2. Zemljopisni položaj lokaliteta s kojih potječu uzorci pršljenova / Geographical distribution of the sites represented in the spindle whorl sample.

5. i kraja 3. tisućljeća prije Krista.[1] Sve proučavane kulturno-povijesne skupine, izuzev protoboleráz grupe, u zadanom su uzorku zastupljene na dva ili više nalazišta (Sl. 1).

U skupini od 26 uzorkovanih lokaliteta (Sl. 2) s kojih potječe 836 pršljenova, na dva je ustanovljena značajna koncentracija alatki.[2] Oba nalazišta, Ivandvor i Franjevac kod Đakova, iskopavana su u zaštitnim istraživanjima na autocesti A5 koja je

1 Tijekom trogodišnjeg doktorskog istraživanja analizirano je 1152 pršljena koji su uneseni u bazu podataka alatki za proizvodnju tekstila. Studija je u početku obuhvaćala alatke s 34 arheološka lokaliteta, ali je konačna analiza provedena na ograničenom uzorku od 836 pršljenova: standard za uzorkovanje lokaliteta postavljen je na minimalno tri zabilježena pršljena s potpunim metričkim i kronološkim podacima. Skup nalaza pršljenova iz kasnog neolitika isključen je iz analize, prvenstveno zbog toga što baza podataka nije sadržavala pršljenove datirane u rani eneolitik, zbog čega nije bilo moguće temeljito istražiti kontinuitet ili promjene u organizaciji proizvodnje za ovu prijelaznu fazu.

2 Nije o svim pršljenovima postojala jednaka količina podataka stoga je za potrebe funkcionalne analize određen minimalni kriterij: pouzdano kronološko određenje, tipološko određenje i spomenuti standard izmjera. Nedostatak podataka o kontekstu pršljenova pronađenih na lokalitetu Ljubljansko Barje-Ig, a koji sačinjavaju veliki dio uzorka pripisanog ranom brončanom dobu, ne dopušta nikakvu podrobnu analizu prostorne distribucije, zbog čega je nemoguće donositi ikakve zaključke o dinamici i organizaciji zanata na prijelazu iz kasnog eneolitika u rano brončano doba, što je ograničilo analizu na razvojne procese tijekom srednjeg i kasno eneolitičkog perioda.

Age (the latest tools belonging to the Somogyvár-Vinkovci spindle whorl set), falls roughly between the middle of the 5th and the end of the 3rd millennium BC[1]. All investigated culture-historical groups in the sample were represented on two or more sites, except for the Proto-Boleráz group (Fig. 1).

In the cluster of 26 sampled sites (Fig. 2) that yielded 836 spindle whorls, two settlements displayed a significant level of concentration of tools[2]. Both

1 During a three-year doctoral research 1152 spindle whorls were recorded in the textile tools database. Initially, the study included tools from 34 archaeological sites, but consequently the final analysis was conducted on a restrained sample of 836 spindle whorls: the site sample standard was set at minimum three recorded spindle-whorls with the complete metric data and chronological placement. The Late Neolithic spindle whorl set was left out of the outlined analysis, mainly because Early Eneolithic spindle whorls were not at all recorded in the database. Thusly no continuity or change in manufacturing organization could be thoroughly investigated for the production of this transitional phase.

2 Not all spindle whorls provided equal amount of information and for the purpose of the functionality analysis a minimum criterion was applied: reliable chronological assignment, typological determination and the mentioned measurement standard. The lack of contextual data for the spindle whorls found at Ljubljansko Barje – Ig site, which account for the big portion of the Early Bronze Age sample unable any thorough spatial distribution examination. This left the conclusions regarding the dynamics of the craft organization during the Late Eneolithic to Early Bronze Age transitional period impossible, limiting the focus of the analysis on the developments that occurred in the Middle and Late Eneolithic.

dio europskog koridora C5, odnosno na trasi Osijek-Đakovo. Ostaci  naselja is srednjeg eneolitika koje se, prema još neobjavljenim analizama podataka, može pripisati kulturno-povijesnoj grupi Retz-Gajary, zabilježeni su na lokalitetu Ivandvor (Leleković 2007), dok je kasnoeneolitičko naselje pripisano kostolačkoj kulturi definirano na lokalitetu Đakovo-Franjevac (Balen 2011). Područje na kojem su lokaliteti dio je đakovačko-vinkovačkog ravnjaka, odnosno povišenog terena koji se pruža jugoistočno od Satnice Đakovačke. Eneolitička naselja ovog tipa osnivana su uz vodene tokove na prirodno povišenim mjestima. Oba su lokaliteta jednoslojna s horizontalnom stratigrafijom, a na njima, djelomično zbog intenzivne zemljoradnje, nije bilo očuvanih kulturnih slojeva (Leleković 2007; Balen 2011).

Pršljenovi uključeni u niže predstavljenu analizu dokumentirani su bilježenjem četiriju glavnih metričkih vrijednosti pršljena (promjer pršljena, promjer rupe za nasad vretena, visina pršljena i težina pršljena), te računanjem omjera težine i promjera pršljena i visine i promjera pršljena.[3]

## Lociranje prelja i predioca retzgajarske kulture

Naseljem retzgajarske kulture na Ivandvoru dominirala je velika višećelijska ukopana struktura, veličine otprilike 280 kvadratnih m (SJ 11861/11862) (Sl. 3), dok su na ostatku površine zabilježene manje strukture različitih oblika i veličina koje su bile raspršene na prostoru od 2 hektara. Ostaci nadzemnih konstrukcija ili nisu pronađeni, ili nisu prepoznati (Leleković 2007: 12-13).

Od 79 pršljenova pronađenih na lokalitetu koji su pripisani retzgajarskoj kulturi, njih 62 pronađena su u „glavnoj“ jami, u kojoj je pronađena i velika količina grube keramike, lomljenog kamena i životinjskih kostiju čije analize nisu završene i objav-

3 Analizirani uzorak alatki uključuje 328 potpuno očuvanih pršljenova, 163 polovično očuvana pršljena, 223 djelomično očuvana pršljena te 122 manjih ulomaka pršljenova (manje od 10% sačuvano). Vrijednosti težine pršljenova iz uzorka bilježene su u četiri različite kategorije vjerojatnosti, ovisno o stanju očuvanosti predmeta. Težina cjelovitih predmeta dokumentirana je u kategoriji cjelovita težina, težina gotovo cjelovitih predmeta kojima nedostaje tek manji dio u kategoriji procijenjena težina, težina polovično očuvanih predmeta dokumentirana je u kategoriji izračunata težina (izračunata težina = udvostručena izmjerena težina) i, naposljetku, težina djelomično očuvanih predmeta zabilježena je u kategoriji rekonstruirana težina (rekonstruirana težina = gustoća x volumen). Varijable volumena i gustoće dobivene su iz virtualnih (trodimenzionalnih) modela koji su napravljeni na temelju djelomično očuvanih pršljenova.

sites, Ivandvor and Franjevac near Đakovo, were excavated as a part of salvage archaeological investigations on the A5 highway route of the European C5 Corridor, more precisely on its Osijek-Đakovo section. The remains of a Middle Eneolithic settlement, which, according to the still unpublished data analysis, is attributed to the Retz-Gajary culture-historical group, were recorded on Ivandvor (Leleković 2007), while the Late Eneolithic settlement associated with the Kostolac culture-historical group was ascertained on Đakovo – Franjevac (Balen 2011). The area of the two localities belongs to the Đakovo-Vinkovci Plateau, namely the elevation extending southeast of Satnica Đakovačka. Eneolithic settlements of this type were founded near watercourses and on natural elevations. Both sites consist of a single layer with horizontal stratigraphy and had no cultural layer preserved, partly due to the intensive agricultural activity (Leleković 2007; Balen 2011).

Spindle whorls used for the following analysis were recorded by taking four main measurements (whorl's diameter, its perforation diameter, height and weight) and calculating their weight/diameter and height/diameter ratios[3].

## Housing Retz-Gajary Spinners

The Retz-Gajary settlement at Ivandvor was dominated by a large, multicellular, approximately 280 square meter big pit structure (SJ 11861/11862) (Fig. 3), while the rest of the smaller features of different shapes and sizes were sporadically scattered over an area of 2 hectares. The remains of the surface architecture were either not found, or were not recognized (Leleković 2007: 12–13).

Out of 79 spindle whorls excavated at the settlement and attributed to the Retz-Gajary culture, 62 were recovered from the 'main' pit structure that also yielded a large amount of coarse pottery, lithic material and animal bones that are still under anal-

3 Analysed tool sample includes 328 whorls which were completely preserved, 163 whorls preserved in half, 223 partially preserved whorls and 122 whorls that had small fragments (less than ten percent) missing. Weight values of the spindle whorls in the sample were documented in four different reliability categories, depending on their preservation status. Weights of complete samples was documented in the *complete weight* category, weights of almost complete samples with small fragments missing was documented in the *estimated weight* category (estimated weight ≈ weight if not complete), weights of samples preserved in half were documented in the *calculated weight* category (calculated weight= weight if not complete doubled) and finally weights of partially preserved samples were documented in the *reconstructed weight* category (reconstructed weight = density x volume). Volume and density variables were provided from virtual (three-dimensional) models created for the partially preserved spindle whorls.

Slika / Figure 3. Zračna fotografija velike strukture retzgajarske kulture (SJ 11861/11862) s lokaliteta Ivandvor / Aerial photo of the large Retz-Gajary structure (SJ 11861/11862) at Ivandvor (foto / photo: T. Leleković).

Slika / Figure 4. Pločasti pečat retzgajarske kulture s lokaliteta Ivandvor / Retz-Gajary tile stamp recovered at Ivandvor (foto / photo: T. Leleković).

ljene. Među važnijim nalazima iz tog konteksta svakako je bodež izrađen od tankog brončanog lima (dužine 12 cm) i plosnati keramički pečat, ili pintadera, koja je na obje strane ukrašena različitim simbolima (Sl. 4).

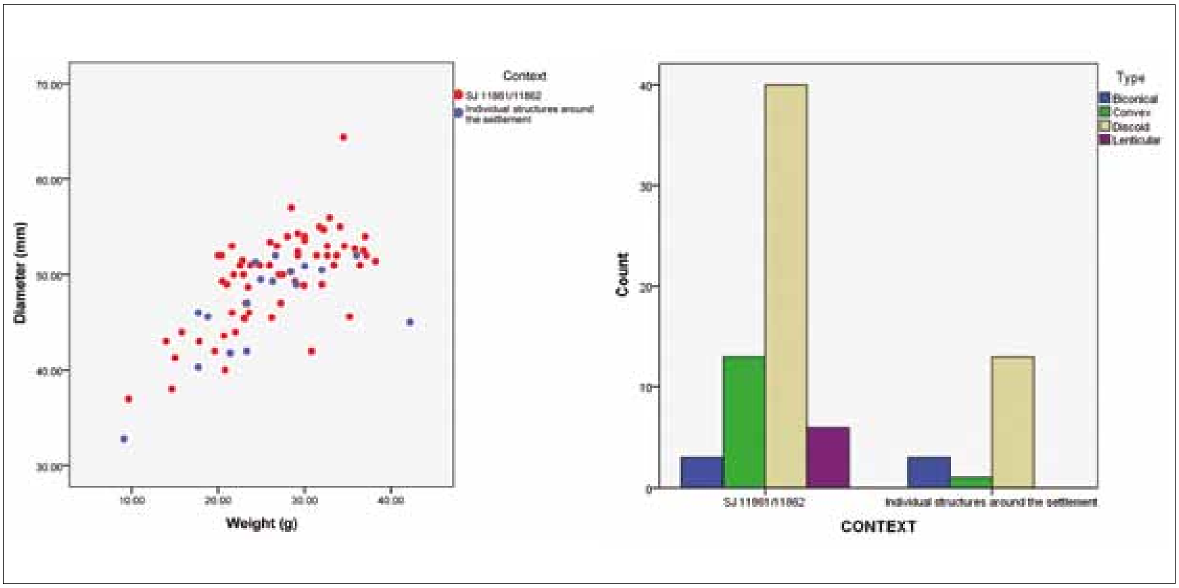
Preostalih 17 pršljenova s lokaliteta nalazilo se u 12 različitih struktura i s obzirom na njihov *in situ* kontekst, ne može ih se povezati s velikom grupom nalaza iz „glavne" strukture. Analiza alatki nije pokazala značajne razlike između glavne skupine pršljenova i onih koji su pronađeni u pojedinim strukturama drugdje u naselju.

Osnovne morfološke značajke koje ocrtavaju funkcionalna svojstva pršljena ne ukazuju na razlike u korištenim izvorima vlakana, niti debljinu dobivene niti, što sugerira da su se slični krajnji proizvodi mogli proizvoditi  na različitim lokacijama unutar naselja. Distribucija vrijednosti težine i promjera alatki ne varira u odnosu na prostorni kontekst, zbog čega je tehnološki standard moguće sagledati samo na razini lokaliteta, a ne u odnosu na određenu lokaciju ili proizvodni prostor unutar naselja (Sl. 5). Štoviše, neznatna devijacija promatranih parametara (Sl. 6) sugerira naizgled specijaliziranu tehnologiju koja može ocrtavati korištenje prilično uskog spektra izvora vlakana. Prilično lagani pršljenovi, težine između 20 i 30 grama, prevladavaju u uzorku s Ivandvora (56%), iako ima i nešto lakših (10-20 g) te nešto težih (30-40 g) primjeraka. Skupina srednjeg promjera (40-50 mm i 50-60 mm) sačinjava većinu, odnosno 94% uzorka. Skupina male visine uvjerljivo je najbrojnija na lokalitetu, što je dodatno naglašeno zbog ograničene tipološ-

ysis and remain unpublished.  Some of the more important findings allocated in the context include a dagger made of a thin bronze sheet (length 12 cm) and a ceramic tile stamp, or *pintadera*, decorated with different symbols on each side (Fig. 4).

The remaining 17 spindle whorls found at the site were distributed among 12 different structures and cannot be brought to connection with the large assemblage from the 'main' structure, at least as far as their *in situ* context is concerned. The tool analysis did not show a significant difference between the main spindle whorl set and the collection of spindle whorls discovered in individual structures around the settlement.

The main morphological traits, indicative of the spindle whorls' functional properties, do not propose distinction in either the fibre material that was used, nor in the thickness quality of the spun thread, thus suggesting similar end products may have been produced everywhere around the site. Distribution of the tools' weight and diameter values does not appear to vary depending on the spatial context, making the technological standard observable mainly on the site level, rather than conditioned by the specific location, or area of manufacture (Fig. 5). Nonetheless, low deviation of all the investigated parameters (Fig. 6) suggests a seemingly specialised technology that may be reflective of a rather narrow focus in terms of fibre resources. Relatively light whorls, ranging from 20 to 30 grams dominate in the Ivandvor sample (56 %), although slightly lighter (10-20 g) and slightly heavier (30-40 g) whorls are fairly represented as well. Middle di-




Slika / Figure 5. Omjer težine i promjera (lijevo) i distribucija tipova (desno) pršljenova iz pojedinačnih jamskih struktura s lokaliteta Ivandvor / Spindle whorls' weight-diameter (left) and type distributions (right) given for separate pit structures at Ivandvor.

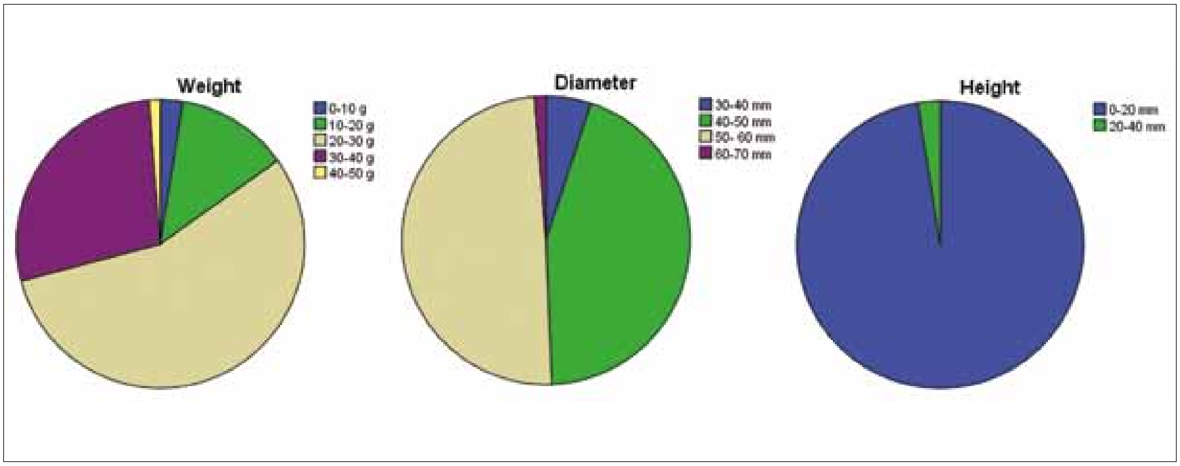
ke varijabilnosti u skupini pršljenova, a koja sadrži visoku frekvenciju diskoidnih primjeraka.

Jedine primjetne razlike između glavne skupine pršljenova i onih iz ostatka naselja vidljive su u distribuciji tipova (Sl. 5). Skupina nalaza iz velike ukopane strukture naizgled je tipološki raznolikija. Funkcionalno je nemoguće razlikovati lećaste i diskoidne pršljenove koji sačinjavaju većinu u obje skupine nalaza, ali zanimljivo je primijetiti da „glavni" skup nalaza iz najveće strukture sadrži prilično velik postotak pršljena lećastog tipa (7,6%) koji nije zabilježen drugdje na lokalitetu.

ameter classes (40-50 mm and 50-60 mm) represent the majority, making up for the 94 percent of the sample. Low height class is convincingly the main type represented at the site, which resonates further in the restricted typological variability within the spindle whorl set that revealed a very high frequency of discoid spindle whorls.

The only noticeable difference between the main spindle whorl set and the collection from the rest of the settlement can be observed in the distribution of the spindle whorl types (Fig. 5). The large assemblage recovered from the big pit structure appears typologically more diverse. Functionally

Slika / Figure 6. Frekvencija određene kategorije težine, promjera i visine pršljenova s lokaliteta Ivandvor / Frequency of the particular weight, diameter and height classes of spindle whorls at Ivandvor.



Slika / Figure 7. Velika jamska struktura retzgajarske kulture (SJ 194) s lokaliteta Josipovac Punitovački-Veliko polje I / Large Retz-Gajary pit structure (SJ 194) from Josipovac Punitovački – Veliko polje I site (prema / after: Čataj 2009: 34, Fig. 11.).

Sudeći prema velikoj količini lomljenog kamenog materijala, kako alatki tako i krhotina, s posebno velikim udjelom jezgri (>70 komada), lomljenih kamenih predmeta koji se ne mogu definirati kao alatke (Shott 1993), već kao mugući oblik pripremljene sirovine, „glavnu" ukopanu strukturu može se interpretirati kao zajednički radni prostor za obradu sirovina, a ne kao specijaliziranu radionicu za tekstil. Centralna pozicija te jame u naselju također se uklapa u ovaj scenarij, ako pretpostavimo da su najbitniji resursi mogli biti korišteni na razini zajednice. Centralizirana pozicija te jame u naselju također se uklapa u ovaj scenarij, ako pretpostavimo da su resursi korišteni na razini zajednice.

Iz spomenute velike ukopane strukture potječe 79% svih nalaza s lokaliteta (79 pršljenova) i 36% cijelog uzorka retzgajarske kulture (172 pršljena) zabilježenog u bazi podataka. Dakle, bez obzira na veličinu ovog, pretpostavljeno radnog prostora, koncentracija pršljenova ukazuje na prilično intenzivno i organizirano predenje. Ta činjenica postaje jasnija ako se primijeni model u kojem svaki pojedinac prede uz pomoć jedne alatke po pojedinom zadatku, što bi moglo sugerirati da je veća skupina prelja/predioca mogla koristiti prostor radionice.

Osim na Ivandvoru, uzorci pršljenova retzgajarske kulture zabilježeni su na lokalitetima Josipovac Punitovački-Veliko polje I (Čataj 2009), Cugovec-

the lenticular type cannot be separated from the discoid spindle whorls, which make the majority in both sets, but it is an interesting observation that the 'main' assemblage from the largest structure holds a relatively high percentage of the particular spindle whorl type (7.6 %) that hasn't been attested anywhere else on the site.

Judging by the vast amount of lithic material, tools and debitage, with particularly high frequency of cores (> 70 pieces), a non-tool category (Shott 1993) of chipped stone artefacts that might have only been used as sources of raw material, a joint work area for raw material processing, rather than a specialized textile workshop, presents a plausible interpretation for the 'main' pit structure. Its central position within the settlement also agrees with this scenario, if we consider the possibility that the most important resources were managed on a communal level.

The assemblage found in this large sunken structure at the site accounts for 79 percent of the entire settlement set (79 spindle whorls) and 36 percent of the entire Retz-Gajary sample (172 spindle whorls) recorded in the database. Thus, despite the size of this, presumably work-related space, the concentration of spindle whorls suggests a rather intensified and organized spinning activity. This becomes even more obvious if a tool per spinner scenario is applied, suggesting that a larger group of spinners may have been using the workshop area.

Slika / Figure 8. Replike retzgajarskih pečata pronađenih na lokalitetu Josipovac Punitovački-Veliko polje I i otisci kakve ostavljaju na lanenom platnu / Replicas of Retz-Gajary stamp seals found at Josipovac Punitovački-Veliko polje I and their impressions on a linen cloth (prema / after: Čataj 2009: 255, Fig. 6.).

Barbarsko (Balen & Drnić 2014), Jagodnjak-Napuštene njive i Čeminac-Vakanjac u istočnoj Hrvatskoj. Osim na Ivandvoru, samo je još na lokalitetu Josipovac Punitovački-Veliko polje I, također iskopavanom u zaštitnim istraživanjima na autocesti A5 na europskom koridoru C5, ustanovljena velika koncentracija pršljenova koja može sugerirati intenzivno korištenje prostora za predenje. I u ovom je slučaju najveći broj alatki pronađen u najvećoj ukopanoj strukturi na lokalitetu (19,5x12 m). Od 58 pronađenih pršljenova, ukupno njih 31 (53%) pronađen je u velikoj višećelijskoj ukopanoj strukturi (SJ 194) smještenoj na sasvim istočnom dijelu naselja (Sl. 7).[4] Osim velikog broja pršljenova, u ovom je kontekstu pronađeno i mnoštvo keramike (fine i grube fakture), životinjskih kostiju, lomljene litike i ulomaka lijepa. Samu strukturu autorica je interpretirala kao radni prostor (Čataj 2009: 34-35).

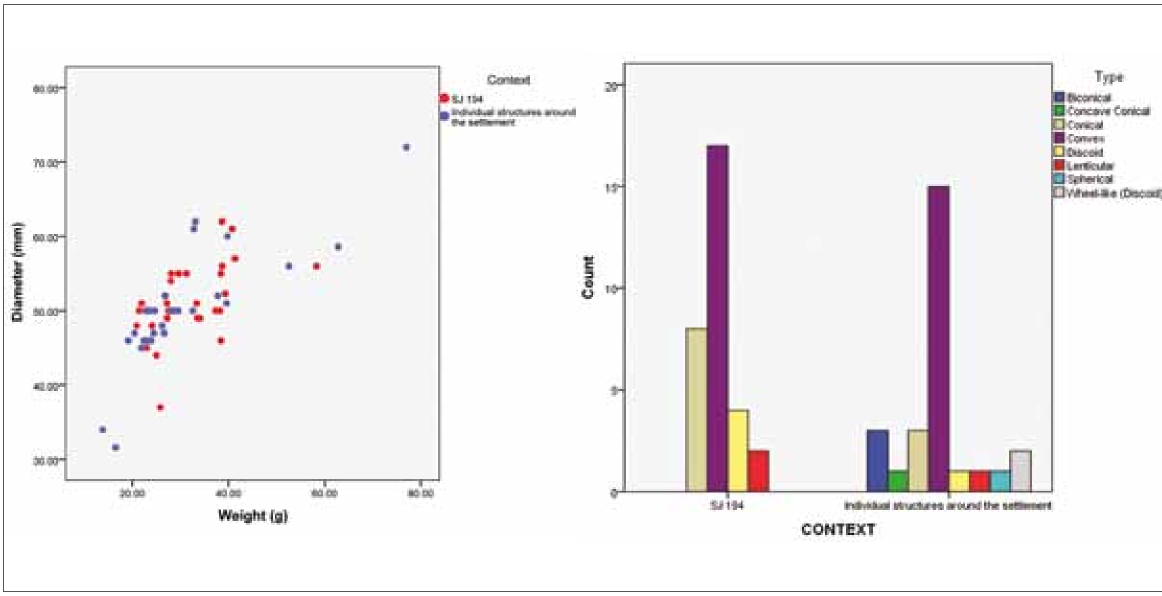
Već je i Lea Čataj (2009: 34) primijetila visoku frekvenciju pršljenova uz južni rub strukture, u blizini vatrišta, te interpretirala njihov *in situ* položaj kao oznaku dijela prostora u kojem se odvijala proizvodnja tekstila. Skupinu od 13 rupa od stupova i kolaca, koja je otkrivena u istom dijelu jame kao i pršljenovi, autorica smatra mogućim dokazima za postojanje strukture za tkanje (Čataj 2009: 34). Ako razmotrimo nekoliko mogućih načina tkanja (Barber 1991: 79-91), uključujući horizontalne varijante poput pojasnih i podnih tkalačkih stanova

4 SJ 194 je radiokarbonski datirana u vrijeme između 3790. i 3650. pr. Kr. (Čataj 2009: 50).

Besides at Ivandvor, spindle whorl samples attributed to the Retz-Gajary culture-historical group were recorded Josipovac Punitovački-Veliko polje I (Čataj 2009), Cugovec-Barbarsko (Balen and Drnić 2014), Jagodnjak-Napuštene njive and Čeminac-Vakanjac sites in eastern Croatia. Apart from Ivandvor, only at Josipovac Punitovački-Veliko polje I site, which was also excavated as a part of salvage archaeological investigations on the A5 highway route of the European C5 Corridor, a high concentration of spindle whorls that may propose an intensified use of space for spinning was attested. Here, again, the largest pit structure (19.5 x 12 meters) at the settlement yielded the highest number of tools. Out of 58 recovered spindle whorls, all together 31 (53 %) were found in a large multicellular sunken structure (SJ 194) located in the very eastern part of the settlement (Fig. 7)[4]. Besides the numerous spindle whorls, the context yielded a vast amount of ceramic finds (both fine and coarse ware), animal bones, lithic material and daub fragments. The structure itself was interpreted by the author as a working area space (Čataj 2009: 34–35).

Already Lea Čataj (2009: 34) notices a high concentration of spindle whorls located in the southern edge of the structure, close to the fireplace, and defines their *in situ* context as a textile production area within the working space. She refers to the group of 13 dowel and peg holes, discovered in the area

4 SJ 194 was C14 dated to the period between 3790 and 3650 BC (Čataj 2009: 50).




Slika / Figure 9. Omjer težine i promjera (lijevo) i distribucija tipova (desno) pršljenova iz pojedinačnih jamskih struktura s lokaliteta Josipovac Punitovački-Veliko polje I / Spindle whorls' weight-diameter (left) and type distributions (right) given for separate pit structures at Josipovac Punitovački-Veliko polje I.

pričvršćenih za tlo, ova situacija mogla bi predstavljati prihvatljivo objašnjenje za izostanak utega u dokumentiranim retzgajarskim kontekstima. Zanimljivo je spomenuti i dodatnih pet pršljenova iz male jamske strukture (3,5x3,5 m) sa sjevernog dijela iskopne površine (SJ 132), kao i dva pečata ili pintadere (Sl. 8).[5] Autorica je i taj prostor interpretirala kao radni, sugerirajući da je bio korišten za aktivnosti vezane uz proizvodnju tekstila (Čataj 2009: 33).

Slično distribuciji na Ivandvoru, analiza alatki ni u ovom slučaju nije otkrila razlike između „glavnog" skupa nalaza i pršljenova pronađenih u drugim strukturama u naselju. Glavne morfološke značajke koje ukazuju na funkcionalna svojstva alatki ne ukazuju na razlike u korištenim vlaknima ili kvaliteti debljine dobivene niti. S tim na umu, moguće je zamisliti da su konzistentni završni proizvodi bili proizvođeni unutar naselja. Distribucija težine i promjera pršljenova, kao i na Ivandvoru, ne varira s prostornim kontekstom. Iako pojedine lokacije pokazuju malo ili nimalo posebnosti s obzirom na promatrane parametre funkcionalnosti, veća koncentracija alatki iz glavnog proizvodnog prostora (SJ 194) pokazala je manju tipološku varijabilnost u usporedni s ostatkom pršljenova iz naselja (Sl.

5 SJ 132 je radiokarbonski datirana u vrijeme između 3950. i 3710. pr. Kr. (Čataj 2009: 50).

where spindle whorls were found, as a possible evidence of a weaving structure (Čataj 2009: 34). If we consider several weaving possibilities (Barber 1991: 79–91), including the use of horizontal variants, like the backstrap and the ground loom constructions, this could present a plausible explanation for the lack of loom weights in the documented Retz-Gajary context(s). Interestingly, another 5 spindle whorls were recorded in the smaller pit structure (3.5 x 3.5 meters) in the northern part of the investigated area (SJ 132), together with two stamp seals or *pintaderae* (Fig. 8)[5]. The author interpreted this feature as a work space as well, proposing it was used for textile related activities (Čataj 2009: 33).

Similar to the distribution at Ivandvor, the tool analysis did not show any difference between the 'main' assemblage and the set of spindle whorls found in different structures around the settlement. Again, the main morphological traits, indicative of tools' functional properties, do not suggest differences in fibre material use, or thickness quality of the spun thread. Having this in mind, it is conceivable that consistent end products were produced within the settlement. Distribution of the spindle whorls' weight and diameter values, again, like at Ivandvor, does not appear to vary depending on the spatial

5 SJ 132 was C14 dated to the period between 3950 and 3710 BC (Čataj 2009: 50).

9). Općenito niska devijacija svih promatranih metričkih vrijednosti sugerira prilično specijaliziranu proizvodnju koja je, moguće, odraz ograničenog izbora korištenih vlakana (Sl. 10). Glavni tehnološki standard, vidljiv isključivo na razini lokaliteta, sugerira da su ovdje, kao i na Ivandvoru, najčešće korišteni lakši pršljenovi. U uzorku prevladavaju pršljenovi težine od 20 do 30 g (53%), iako je uočena i znatna količina nešto težih primjeraka (30-40 g). Najčešći su oni srednjih vrijednosti promjera (40-50 mm i 50-60 mm) koji sačinjavaju 86% uzorka. Najzastupljeniji su primjerci nižeg razreda visine (<20 mm), iako to nije rezultiralo očekivanom dominacijom klasičnih spljoštenih tipova, poput diskoidnih i lećastih pršljenova. Suprotno tomu, i ono što je glavna razlika u odnosu na nalaze s Ivandvora, na ovom lokalitetu najčešće se javljaju konveksni i konični tipovi pršljenova (Sl. 9).

U usporedbi s drugim pršljenovima retzgajarske kulture, oni s lokaliteta Ivandvor i Josipovac Punitovački-Veliko polje I ne pokazuju značajna odstupanja koja bi ih izdvajala u tehnološkom smislu proizvodnje. Upravo suprotno, funkcionalna analiza alatki sugerira znatnu količinu dosljednosti koja može ukazivati na nepostojanje razlika u korištenim vlaknima, ali i na homogenost krajnjih proizvoda (Sl. 11).

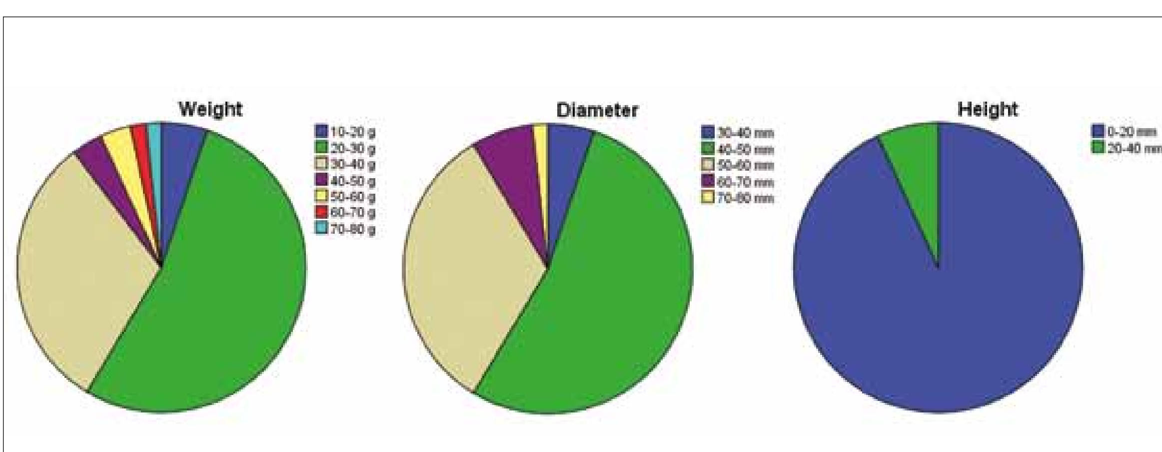
Uz povećanu frekvenciju pršljenova zabilježenu na oba lokaliteta, kada ih se promatra u kontekstu pojedinog nalazišta, njihovi tipološki profili ukazuju nekoliko stvari. Diskoidni pršljenovi, koji su naizgled najčešći tip u retzgajarskoj kulturi, prilično se rijetko javljaju na lokalitetu Josipovac Puni-

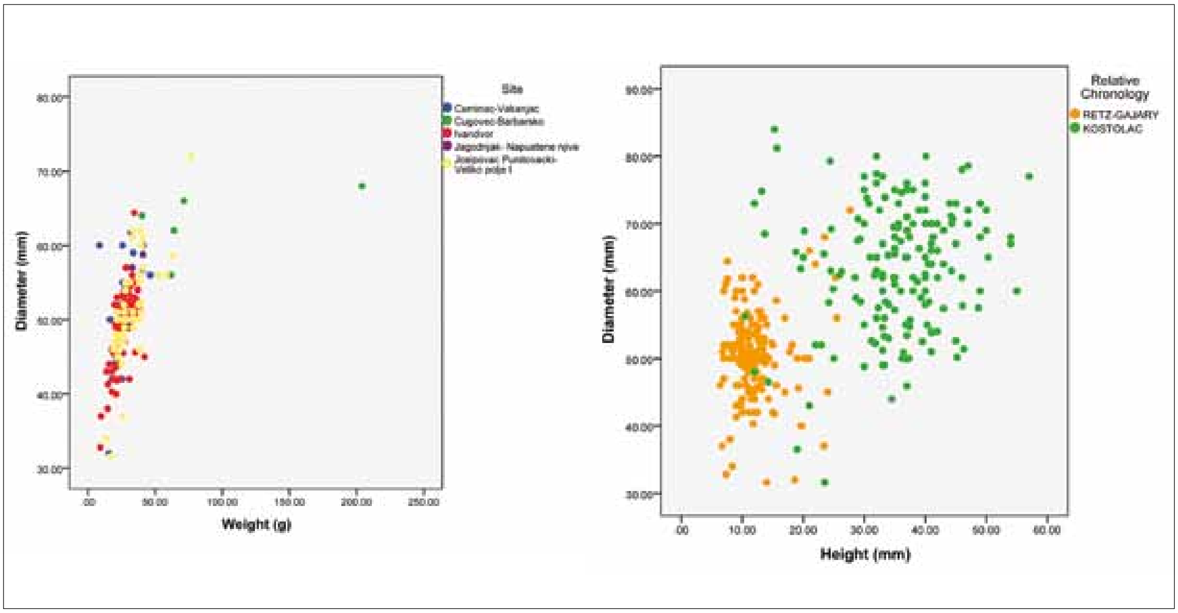
context. Although the specific locations, particularly the main area of the manufacture (SJ 194), display little to no peculiarity regarding the inspected functionality parameters, its higher tool concentration revealed a significantly lowered typological variability in comparison to the rest of the spindle whorl sample (Fig. 9).

The generally low deviation of all the considered metric values suggests a rather specialised production, possibly resonating limited fibre material options (Fig. 10). The main technological standard, observable only on the site level, suggests that here, again, like at Ivandvor, lighter spindle whorls were most commonly used. Spindle whorls ranging from 20 to 30 grams dominate in the sample (53 %), although slightly heavier (30-40 g) whorls are highly represented as well. Middle diameter classes (40-50 mm and 50-60 mm) are the most common, making up for the 86 percent of the sample. Low height class (< 20 mm) is the most represented at the site, although this is not reflected in the dominance of the typically flat types, like discoid and lenticular spindle whorls. On the contrary, and this is the main difference when compared to the Ivandvor set, the most frequent here is the convex and conical spindle whorl type (Fig. 9).

When compared to other Retz-Gajary spindle whorls, both the Ivandvor set and the set from Josipovac Punitovački-Veliko polje I are not revealing any significant deviation that would separate them in technological sense of production. On the contrary, functional analysis of the tools proposes a fair level of consistency, which may be further con-

Slika / Figure 10. Frekvencija određene kategorije težine, promjera i visine pršljenova s lokaliteta Josipovac Punitovački-Veliko polje I / Frequency of the particular weight, diameter and height classes of spindle whorls at Josipovac Punitovački-Veliko polje I.






Slika / Figure 11. Omjer težine i promjera (lijevo) i distribucija tipova (desno) pršljenova s lokaliteta retzgajarske kulture / Spindle whorls' weight-diameter (left) and type distributions (right) against sampled Retz-Gajary sites.

tovački-Veliko polje I, gdje prevladavaju konveksni pršljenovi, praćeni koničnima. Tip koničnih pršljenova, pak, u potpunosti izostaje u skupu nalaza s Ivandvora. Čini se da je bikonični tip, češći krajem 4. i tijekom 3. tisućljeća pr. Kr., korišten samo na ova dva lokaliteta, i nije zabilježen na preostala tri proučavana lokaliteta retzgajarske kulture. Cijeli skup nalaza pršljenova retzgajarske kulture karakterizira mala varijabilnost u visini (>80% nalaza je u kategoriji plosnatih predmeta čija visina ne prelazi 20 mm), kao i prilično standardizirana težina (>80% nalaza teži između 10 i 40 g) te maksimalna-vrijednost promjera (>80% nalaza varira od 40 do 60 mm).

## Lociranje prelja i predioca kostolačke kulture

Naselje kostolačke kulture na lokalitetu Đakovo-Franjevac jedno je od najvećih dokumentiranih lokaliteta te kulture u Hrvatskoj, a rezultate istraživanja detaljno je objavila Jacqueline Balen, koja je i vodila zaštitna istraživanja na nalazištu. Zabilježeni nepokretni arheološki nalazi uključuju višećelijske strukture ovalnog i izduženog oblika, plitke kružne ili ovalne jame, duge uske jarke te rupe od stupova.

Slično Ivandvoru, na lokalitetu nisu prepoznati ostaci nadzemne arhitekture, iako lijep pronađen u zapunama određenih jama ukazuje na postojanje konkretnih nadzemnih konstrukcija. Budući

sidered as an indication of both, the undifferentiated use of raw fibre materials and the homogeneity of end products (Fig. 11).

Along with the elevated frequency of spindle whorls attested at both sites, their typological profiles account for few peculiarities, when observed on an inter-site level. The discoid spindle whorl, which appears to be the most common Retz-Gajary type is fairly underrepresented at Josipovac Punitovački – Veliko polje I, where convex spindle whorls dominate and the conical type seems to be the second most common. The conical spindle whorl type, on the other hand, is completely missing in the Ivandvor set. The biconical type, more common for the later 4th and the succeeding 3rd millennium BC appears to be used only at these two settlements and has not been recorded at the other three investigated Retz-Gajary sites. The entire Retz-Gajary spindle-whorl sample is characterized by a low height value variability (> 80 % being in the flat tool class, not higher than 20 mm) and rather standardized weight (> 80 % ranging from 10 to 40 g) and maximum diameter values (> 80 % ranging from 40 to 60 mm).

## Housing Kostolac Spinners

The Kostolac settlement at Đakovo – Franjevac is one of the largest documented sites of this culture in Croatia and the results of its investigation were published in great detail by Jacqueline Balen, who led the rescue excavations. Multicellular structures of oval and elongated shape; shallow circular, or da u ukopanim strukturama na lokalitetu nisu *in situ* pronađeni ostaci peći ili ognjišta, kao ni popratnih stupova, autorica ove prostore interpretira kao radne, a ne stambene. Na Franjevcu je zabilježeno nekoliko vrsta dokaza koji podupiru ovakvu interpretaciju navedenih prostora. U tom smislu, interpretacija koju Jacqueline Balen nudi za istražene prostore pruža podatke o organizaciji aktivnosti na lokalitetu (Balen 2011: 86-88). Neke od struktura sadržavale su duboko ukopane manje jame, vjerojatno rupe od stupova koji su mogli nositi lakše nadzemne konstrukcije, a zbog čega je spomenute strukture moguće interpretirati kao radioničke prostore. Izduženi uski jarci smješteni u južnom dijelu istražene površine, mogli su biti dijelom samostojećih drvenih ograda korištenih u procesu štavljenja kože. Nepravilne jame ispunjene gotovo sterilnim sedimentom, u kojima nije bilo organskih sastavnica ni arheološkog materijala, vjerojatno su služile za miješanje gline, dok

Slika / Figure 12. Zračna fotografija lokaliteta Đakovo-Franjevac snimljena sa sjeverne strane. Žuta strelica pokazuje na južnu (SJ 160/161), a crvena na sjevernu (SJ 876/877) od dvaju velikih jamskih struktura u kojima je zabilježena velika koncentracija pršljenova / Aerial photo of the Đakovo-Franjevac site taken from the northern side. Yellow arrow is pointing to the southern (SJ 160/161) and the red arrow is pointing to the northern (SJ 876/877) of the two large pit structures with high concentration of spindle whorls (prema / after: Balen 2011: 12, Fig. 1. 1.).

oval pits; long, narrow trenches and postholes make up for the recovered immovable archaeological finds.

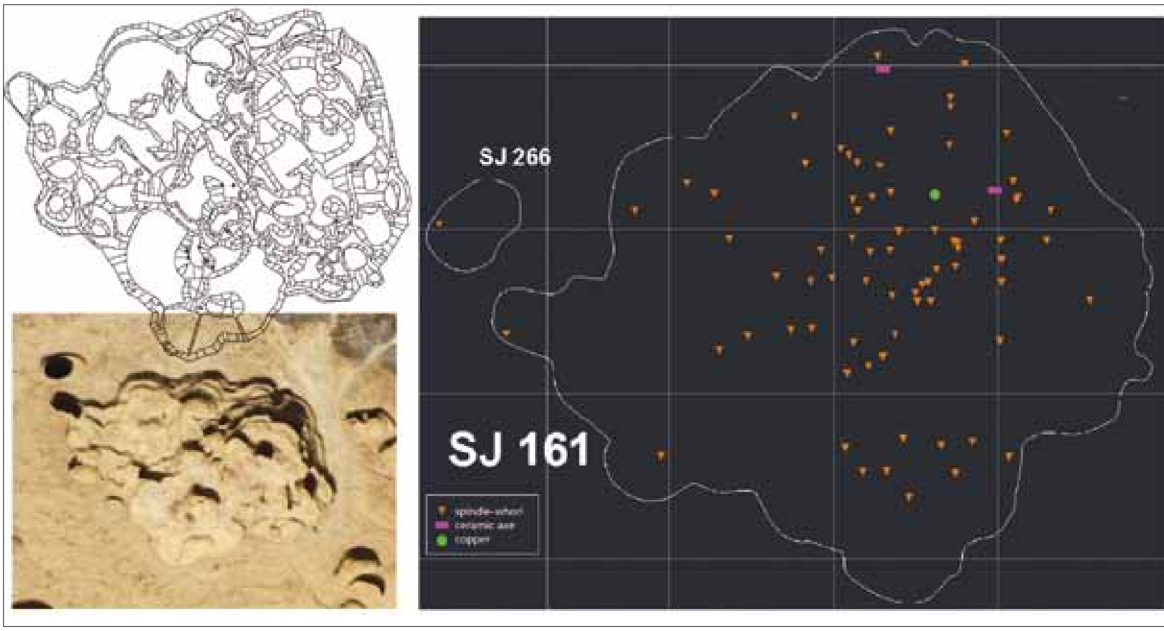
Similar to Ivandvor, no surface architecture was recognized with certainty at the site, although the recovery of daub in the fills of certain pits attests for the presence of solid above-ground structures. Since none of the sunken structures at the settlement contained *in situ* elements of ovens or hearts and no surrounding posts were traced, the author is closer to interpreting them as activity spaces, rather than ascribing them residential character. There are several different lines of evidence at Franjevac, which are in agreement with its work-related character. In this manner, Jacqueline Balen's interpretations of the investigated features inform about the organization of the activities at the site (Balen 2011: 86–88). Some structures were composed of deeply dug pits, most probably postholes, which could have supported light constructions, making these features interpretive as workshop spaces. Elongated narrow trenches, all located in the southern part of the investigated area may have been self-standing timber fences used in the process of tanning animal hides. Irregular pits that were filled with almost sterile sediment, lacking organic components and archaeological material, most likely served for mixing clay, while bell shaped pits that widen towards their dugout bottom, in which large concentrations of botanical remains were attested, were likely utilized for storage (Balen 2011: 86–88).

Interestingly, out of the 142 recorded features at Franjevac, which yielded Kostolac pottery, two structures (SJ 160/161 and SJ 876/877), the most dominating in size (20 x 17 meters), just like it was the case with Retz-Gajary sites, held the majority (62 %) of the recovered spindle whorls (Fig. 12).

Out of 121 spindle whorls excavated at the settlement and attributed to the Kostolac culture, 63 (more than 50 % of the entire Franjevac sample and 37 % of the entire Kostolac sample recorded in the database) were found in the southern large pit structure (SJ 160/161) that also yielded a substantial amount of other ceramic and lithic material (Fig. 13).

Other interesting findings allocated in the same context (SJ 160) include 8 polished stone tools, 5 grindstones, 3 small spools, 2 small ceramic axes, a small decorated ceramic tile and bone tools- spatulae and an awl (Balen 2011: 36–37, 135)[6]. This large sunken structure contained several pit features

6 SJ 160 (upper layer that yielded 56 spindle whorls) was C14 dated to the period between 3380 and 2880 BC (Balen 2011: 159).




Slika / Figure 13. Velika višećelijska ukopana struktura (SJ 160/161) s lokaliteta Đakovo-Franjevac. Lijevo: zračna fotografija i tehnički crtež (prema: Balen 2011: 37). Desno: tlocrt s prikazom prostorne distribucije nalaza preuzet iz objavljenog plana lokaliteta izrađenog u programu AutoCad (prema: Balen 2011) / Large multicellular sunken structure (SJ 160/161) from Đakovo-Franjevac. Left: aerial photo and the technical drawing (after: Balen 2011: 37). Right: plan with the spatial distribution of finds taken from the published AutoCad map of the site (after: Balen 2011).

su zvonolike jame, koje se šire prema dnu i koje su sadržavale velike koncentracije botaničkih ostataka, vjerojatno bile korištene za skladištenje (Balen 2011: 86-88). Zanimljivo, od 142 zabilježene strukture koje su na Franjevcu sadržavale kostolačku keramiku, dvije strukture (SJ 160/161 i SJ 876/877), najvećih dimenzija (20x17 m), kao što je bio slučaj i na retzgajarskim lokalitetima, sadržavale su većinu (62%) pronađenih pršljenova (Sl. 12).

Od 121 kostolačkog pršljena pronađenog na lokalitetu, 63 (više od 50% cijelog uzorka s Franjevca i 37% cijelog kostolačkog uzorka u bazi podataka) je pronađeno u velikoj ukopanoj strukturi (SJ 160/161), u kojoj je pronađena i znatna količina keramičkog i kamenog materijala (Sl. 13).

Iz istog konteksta (SJ 160) potječe još zanimljivih nalaza, uključujući osam glačanih kamenih alatki, pet žrvnjeva, tri mala kalema, dvije male keramičke sjekire, mala ukrašena keramička pločica i koštane alatke – spatule i šilo (Balen 2011: 36-37, 135).[6] Ova velika ukopana struktura sadržavala je nekoliko jamskih objekata različitih dubina i dimenzija, a autorica te činjenice uzima kao dodatni argument protiv moguće stambene funkcije objekta (Balen 2011: 87). Osim toga, Jacqueline Balen smatra da je

of uneven depth and dimensions, so the author interprets this fact as an extra argument against its possible residential function (Balen 2011: 87). In addition, Jacqueline Balen argues that the large structure from Franjevac might have been used for cult purposes: firstly, she suggests this on the account of the discovery of two buried skulls in the two separate smaller features within the pit itself (one belonging to a child and another to an adult female) and secondly, due to the position of another cylindrical feature next to it (SJ 265/266), which was initially probably used for storage, but secondarily served as a burial place (Balen 2011: 88). Interestingly, both the female skull burial pit from the large structure and the male burial pit next to it yielded a single spindle whorl, each. Female skull was found together with a fragment of a copper dagger (Balen 2011: 37), while a skeleton of an adult male was buried in the cylindrical pit together with two pigs (Balen 2011: 51).

Another 12 spindle whorls were recovered from the northern, of the two dominating structures (SJ 876/877) at Đakovo – Franjevac, which also contained several pit features of uneven depth and dimensions that lead the author's interpretation

6 SJ 160 (gornji sloj u kojem je pronađeno 56 pršljenova) je radiokarbonski datirana u vrijeme između 3380. i 2880. pr. Kr. (Balen 2011: 159).

velika struktura s Franjevca mogla biti korištena u kultne svrhe: prvo, autorica takvu funkciju pretpostavlja na temelju dvaju ukopanih lubanja koje su pronađene u dvije odvojene manje jame unutar strukture (jedna dječja i druga odrasle žene), i, drugo, zbog položaja dodatne cilindrične strukture koja je zabilježena pored ove (SJ 265/266), a koja je prvotno vjerojatno korištena za skladištenje, dok je sekundarno poslužila za ukop (Balen 2011: 88). Zanimljivo, i u ženskom grobu unutar jame, kao i u muškom iz jame pored, pronađen je po jedan pršljen. Uz lubanju žene pronađen je i ulomak bakrenog bodeža (Balen 2011: 37),dok je u cilindričnoj jami uz kostur muškarca otkriven i ukop dvije svinje (Balen 2011: 51).

Još je 12 pršljenova pronađeno u sjevernijoj od dvije najveće strukture (SJ 876/877) na lokalitetu Đakovo-Franjevac, koja je također bila sastavljena od nekoliko jama različitih dubina i dimenzija, što je autoricu navelo da niti ovu jamu ne interpretira kao stambenu. Izuzev pršljenova, u jami je pronađeno mnogo keramičkog i kamenog materijala. Neki od važnih nalaza iz ovog konteksta uključuju mali kalem i keramički žrtvenik (Balen 2011: 78).[7]

Preostalih 46 pršljenova kostolačke kulture s Franjevca pronađeno je u 18 različitih struktura širom lokaliteta i na temelju zabilježenog *in situ* konteksta, ne može ih se povezati s dva velika skupa nalaza.Veća koncentracija pršljenova (10) pronađena je u relativno velikoj jami (SJ 572/573) u kojoj je bila

7 SJ 876 je radiokarbonski datirana u vrijeme između 3100. i 2960. pr. Kr. (Balen 2011: 159).

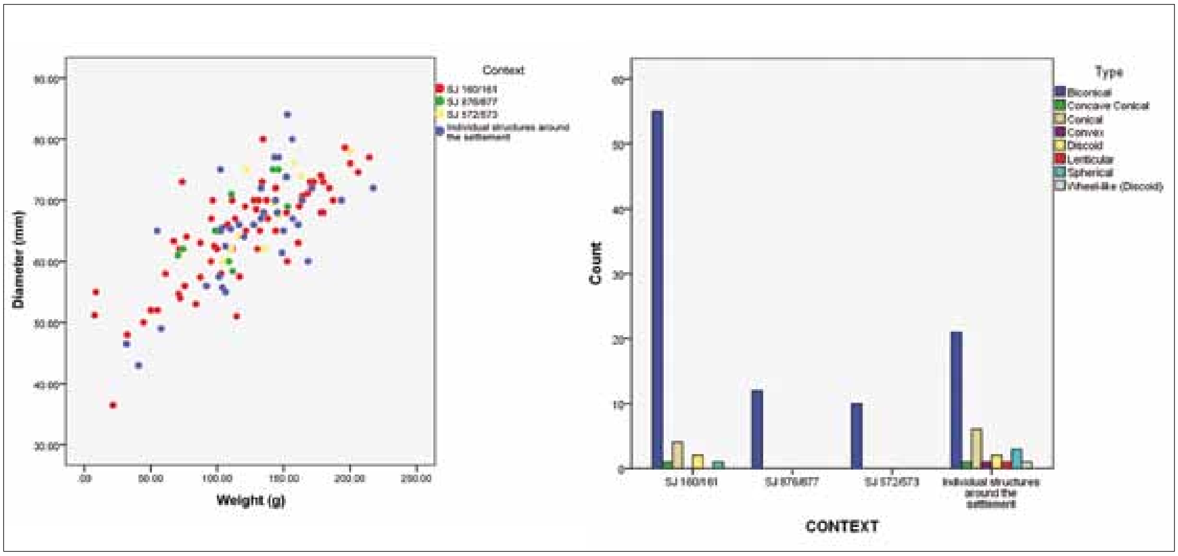
away from defining it as a living area. Besides the spindle whorls, the pit yielded a huge amount of ceramic and lithic material. Some of the more important findings allocated in the context include a small spool and a ceramic altar (Balen 2011: 78)[7].

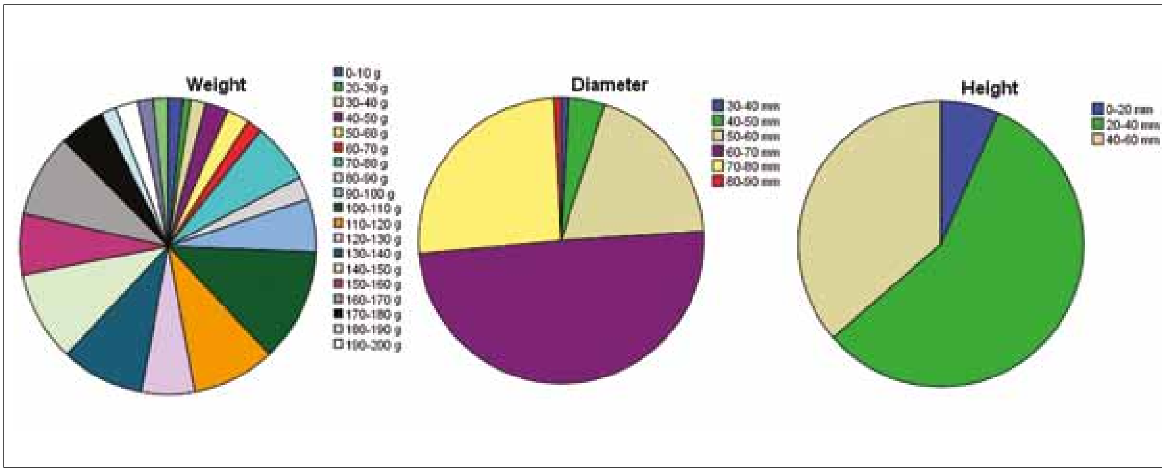
Remaining 46 Kostolac spindle whorls found at Franjevac were distributed among 18 different features and cannot be brought to the connection with the two large assemblages as far as their *in situ* context is concerned. Higher concentration of spindle whorls (10) was recovered in another relatively large pit (SJ 572/573) which also yielded a fair amount of ceramic material and a stone axe. Even though fireplaces were documented in this particular structure, Balen is still inclined to consider it as a working space rather than ascribing it residential character (Balen 2011: 67, 88).

The results of the tool analysis reveal some specifics among the three 'main' assemblages from the largeest pit structures. Although only minor differences were observed, which would functionally or typologically separate these sets from the rest of the spindle whorls recovered around the settlement, they are significant for the investigation of tool standardisation and thus potentially indicative of higher levels of specialisation attestable for the particular locations at the site.

7 SJ 876 was C14 dated to the period between 3100 and 2960 BC (Balen 2011: 159).

Slika / Figure 14. Omjer težine i promjera (lijevo) i distribucija tipova (desno) pršljenova iz pojedinačnih jamskih struktura s lokaliteta Đakovo-Franjevac / Spindle whorls' weight-diameter (left) and type distributions (right) given for separate pit structures at Đakovo-Franjevac.






Slika / Figure 15. Frekvencija određene kategorije težine, promjera i visine pršljenova s lokaliteta Đakovo-Franjevac / Frequency of the particular weight, diameter and height classes of spindle whorls at Đakovo-Franjevac.

i znatna količina keramike te kamena sjekira. Iako su u ovom dijelu strukture zabilježena ognjišta, Balen i ove strukture smatra radnim, a ne stambenih prostorima (Balen 2011: 67, 88).

Rezultati analize alatki otkrivaju neke osobitosti u tri „glavna" skupa nalaza iz najvećih jamskih struktura.Iako su među njima primijećene samo manje razlike koje bi ove skupove nalaza mogle funkcionalno i tipološki razlikovati od ostalih pršljenova sa nalazišta, dovoljno su značajne za istraživanje standardizacije alatki i stoga potencijalno ukazuju na višu razinu specijalizacije na određenim lokacijama na lokalitetu.

Usporedba morfoloških značajki prisutnih u trima skupovima nalaza ne ukazuje na znatne razlike u korištenim vlaknima ili kvaliteti krajnjih proizvoda, iako je među analiziranim pršljenovima uočena zanimljiva varijabilnost u pogledu veličine i tipa, a koja bi mogla ukazivati na eventualna ograničenja u pogledu funkcionalnosti alatki (Sl. 14). Najveće su razlike zabilježene između dvaju manjih skupova nalaza iz velikih struktura (SJ 876/877 i SJ 572/573). U oba skupa vidljiva je slaba zastupljenost manjih vrijednosti težina i promjera pršljenova, pošto su prisutne isključivo velike (>50 mm u promjeru) i teške (teže od 70 g) alatke.

Najveći skup nalaza iz južne ukopane strukture nije pokazao značajne razlike u distribuciji vrijednosti težina i promjera pršljenova u usporedbi s ostalim skupovima alatki koje su pronađene na različitim mjestima u naselju. Suprotno dvama manjim skupovima, u „glavnom" skupu nalaza pršljenova iz 'južne' strukture (SJ 160/161) zabilježena je

Morphological traits represented in the three assemblages, when compared, do not propose a major distinction in fibre material use, or different quality end products, although few interesting observations regarding the level of both size and type variability within the analysed sets of spindle whorls can be drawn, pointing to possible limitations regarding their functionality (Fig. 14). The biggest difference can be noticed in the case of two smaller assemblages coming from the two large structures (SJ 876/877 and SJ 572/573). They are both showing restriction in the distribution of smaller weight and diameter values, holding exclusively large (> 50 mm diameter classes) and heavy (heavier than 70 r g weight classes) tools.

The largest assemblage from the southern pit structure does not reveal much difference regarding the distribution of spindle whorls' weight and diameter values, when compared to the rest of the tool set recovered at different locations around the settlement. Opposite to the two smaller assemblages, a slightly higher frequency of smaller weight (10 % < 50 g) values can be detected for the 'main' spindle whorl set recovered from the 'southern' structure (SJ 160/161). Although there is no big difference observable in the distribution of higher values between the studied sets, since the massive tools appear to dominate in all of them, it should be mentioned that both the very large (> 80 % > 60 mm) and especially the very heavy tools (> 60 % > 100 g) are convincingly the most represented classes in the 'main' (SJ 160/161) assemblage.

The general tendency of all the considered metric values to cluster around the higher end of the nešto viša frekvencija nalaza manje težine (10% <50 g). Iako u proučavanim skupovima nije uočena značajna razlika kod distribucije većih vrijednosti, s obzirom na to da masivnije alatke prevladavaju u svima, valja istaknuti da izuzetno velike (>80% je >60 mm), a osobito izuzetno teške (>60% je >100 g) alatke uvjerljivo sačinjavaju najveće razrede u „glavnom" skupu nalaza (SJ 160/161).

Opća tendencija grupiranja svih promatranih metričkih vrijednosti oko višeg kraja spektra ukazuje na prilično specijaliziranu proizvodnju koja, gotovo sigurno, odražava i ciljani odabir vlakana i korištenje određenih tehnika. Glavni tehnološki standard, gledano na razini lokaliteta, pokazuje da su najčešće korišteni teški, a posebno vrlo teški pršljenovi. Pršljenovi teži od 100 g prevladavaju u uzorku (>70%), iako su zabilježeni i nešto lakši primjerci (>20% je 40-100 g). Prevladavaju nalazi velikih promjera (>60 mm) koji sačinjavaju više od 70% uzorka, iako su prisutni (>20%) i oni umjerenih veličina, od 40 do 60 mm (Sl. 15). Ova prilično velika varijabilnost u težini pršljenova nije se odrazila kroz varijabilnost tipova. Bikonični pršljenovi uvjerljivo su glavni tip na Franjevcu (>80%), i jedini korišteni tip (100%) na dvije određene lokacije (SJ 876/877 i SJ 572/573), na kojima je već ustanovljena viša razina standardizacije alatki.

Unatoč ljudskim ukopima otkrivenim u južnoj strukturi (SJ 160/161), koji bi mogli objasniti kontekst kroz posebno odlaganje, u višim slojevima strukture nisu uočene indikacije sekundarnog depozita glavnog skupa nalaza pršljenova.

Najveća koncentracija pršljenova na Franjevcu, ako se uzme u obzir model po kojem svaki pojedinac za vrijeme predenja koristi po jedan pršljen, sugerira da je znatan broj prelja/predioca mogao koristiti „glavni" radionički prostor u južnoj jamskoj strukturi (SJ 160/161), što ujedno ukazuje na intenzivne, i, najizglednije, specijalizirane aktivnosti koje su se odvijale u naselju, i to upravo u središnjim i najvećim strukturama, barem na istraženoj površini.

Osim na lokalitetu Đakovo-Franjevac, pršljenovi kostolačke kulture pronađeni su na Gomolavi, lokalitetu tel tipa u Srbiji. Na Gomolavi, za razliku od Đakovo-Franjevca, njihova prostorna distribucija ukazuje na proizvodnju u domaćinstvu (Sl. 16). Sloj kostolačke kulture na lokalitetu izvrsno je očuvan, a arheološki nalazi koji dokazuju postojanje nadzemnih konstrukcija pružili su vrijedne podatke o naseljavanju: tri horizonta naseljavanja koji su

spectrum suggests a rather specialised production, almost certainly reflecting both the focused fibre material use and the particular technique practice. The main technological standard, when observed on the site level, suggests that heavy and especially very heavy spindle whorls were most commonly used. Whorls heavier than 100 grams dominate in the sample (> 70 %), although slightly lighter (40-100 g) whorls are represented as well (> 20 %). Larger diameters (> 60 mm) seem to prevail, making up for more than 70 percent of the sample, although moderate sizes, ranging from 40 to 60 mm appear to be represented (> 20 %) as well (Fig. 15). This relatively high weight value variability is not at all reflected in the deviation of types. A biconical whorl is convincingly the main type used at Franjevac (> 80 %), and the only type used (100 %) at the two specific locations (SJ 876/877 and SJ 572/573), which already displayed a higher level of tool standardisation.

Despite the human burials recovered in the southern structure (SJ 160/161), that may suggest a special deposition as a plausible explanation for the context, no indications for a secondary refuse of the main spindle whorl assemblage, found in the upper layers of the investigated feature, were attested.

The highest recorded concentration of spindle whorls at Franjevac, if a tool per spinner scenario is concerned, would suggest that a substantial number of spinners could have been using the 'main' workshop space in the southern pit structure (SJ 160/161). Thus, this large concentration of tools proposes that intensified and, most likely, specialized spinning practice took place at the settlement, precisely in its most central and largest structures, as far as the investigated area is concerned.

Besides at Đakovo – Franjevac, spindle whorls attributed to the Kostolac culture-historical group were recorded at Gomolava, a tell site in Serbia. At Gomolava, as opposed to Đakovo – Franjevac, their spatial distribution agrees with the household production (Fig. 16). Kostolac cultural layer was substantially preserved at the site and the archaeological evidence, attesting above ground constructions, provided some valuable information on housing: three habitation horizons comprised of houses and accompanying features revealed intensive occupancy, displaying parallel rows of buildings, overlapping of certain house plans, continuous architectural renovations, use of partition walls, use of in-house hearts and ovens and double-

Slika / Figure 16. Kuća 6 (IIIb1) s lokaliteta Gomolava – pršljenovi u kućnom lijepu / House 6 (IIIb1) at Gomolava – Spindle whorls in daub. (prema / after: Petrović & Jovanović 2002: 100).

sadržavali kuće i popratne strukture ukazuju na intenzivnu okupaciju, a vidljivi su paralelni redovi građevina, preklapanje planova nekih kuća, kontinuirano arhitektonsko obnavljanje, korištenje pregradnih zidova, vatrišta i peći unutar objekata te dvostruka krovišta na pravokutnim građevinama (Petrović & Jovanović 2002: 299).[8]

Pršljenovi iz kostolačkog sloja naseljavanja često su pronalaženi u kućama, jamama i popratnim prostorima na telu kroz sve tri faze naselja (Petrović & Jovanović 2002). Visoka frekvencija alatki koja je zabilježena na Gomolavi (51 pršljen) čini ovaj uzorak važnom referentnom točkom za usporedbe sa drugim lokalitetima, iako nije bilo moguće izdvojiti pojedinačne lokacije s većom koncentracijom alatki koje bi sugerirale da su se aktivnosti vezane uz predenje ikada odvijale na za to predodređenoj lokaciji.

Tehnološki standard na Gomolavi karakterizira najveća zastupljenost velikih (>40% je 50-60 mm) i teških (>75% je 40-100 g) pršljenova, za razliku od Franjevca gdje je zabilježena znatno viša frekvencija ekstremnih vrijednosti. I jako veliki (>60 mm) i jako teški (>100 g) pršljenovi, kakvi prevladavaju na Franjevcu, znatno se rjeđe pojavljuju u uzorku s Gomolave (Sl. 17).

8 C14 datumi s Gomolave padaju u raspon između 3038. i 2903. pr. Kr. te 3108 i 2877 pr. Kr. (Petrović & Jovanović 2002: 303), što znači da je faza naseljavanja tela istovremena naselju s lokaliteta Đakovo-Franjevac.

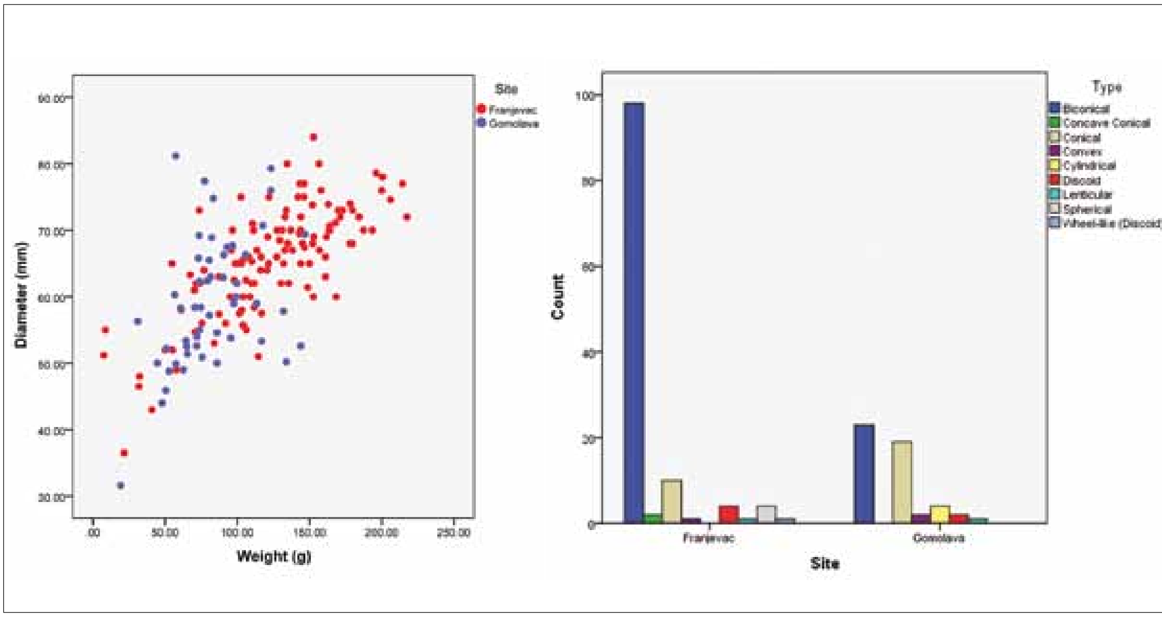
pitched roofing of rectangular buildings (Petrović and Jovanović 2002: 299)[8].

Spindle whorls from the Kostolac level of occupation at the tell were commonly found in houses, pits and their surrounding areas belonging to all three habitation horizons (Petrović & Jovanović 2002). A high frequency of tools recorded at Gomolava (51 spindle whorls) makes this sample a valuable point of reference for the inter-site comparison, although no specific location with a higher concentration of tools could be recognized, which would suggest that a designated area for spinning activities ever existed at the site.

The technological standard at Gomolava is characterized by the highest distribution of the large (> 40 % 50-60 mm) and heavy (> 75 % 40-100 g) spindle whorl classes. As oposed to the Franjevac sample, which revealed a much higher frequency of extreme values. Both, very large (> 60 mm) and very heavy (> 100 g) spindle whorls, which dominate at Franjevac are significantly less represented in the Gomolava sample (Fig. 17).

In terms of typological variability, the situation at Gomolava appears more dynamic. Although

8 C14 dates from Gomolava cover the span 3038-2903 BC and 3108-2877 BC (Petrović & Jovanović 2002: 303), making the Kostolac occupational phase at the tell contemporary to the Đakovo – Franjevac settlement.

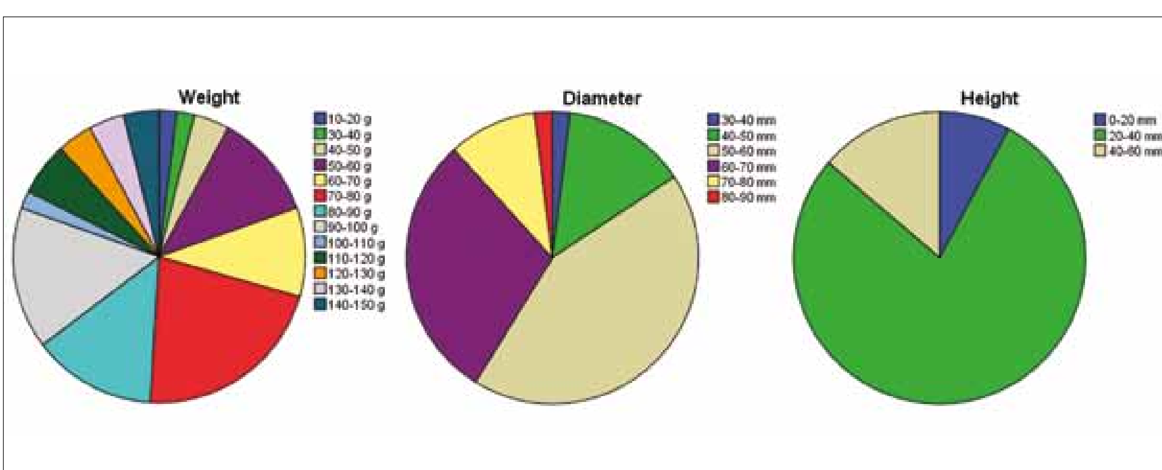



Slika / Figure 17. Omjer težine i promjera (lijevo) i distribucija tipova (desno) pršljenova s lokaliteta kostolačke kulture / Spindle whorls' weight-diameter (left) and type distributions (right) against sampled Kostolac sites.

U pogledu tipološke varijabilnosti, situacija na Gomolavi čini se dinamičnijom. Iako je u uzorku s Franjevca zabilježeno osam različitih tipova, zbog potpune prevlasti bikoničnih pršljenova taj se skup nalaza čini izrazito standardiziranim. S druge strane, na Gomolavi je zabilježeno šest različitih tipova pršljenova, a dva glavna tipa (>80%) prilično su jednakomjerno zastupljena (bikonični >45%, a zatim konični tip >35%).

the sample from Franjevac yielded eight different types, the absolute dominance of biconical spindle whorls makes this set appear as highly standardized. On the other hand, at Gomolava six different types of spindle whorls were recorded, but the two main types (> 80 %) seem to be more equally distributed within the sample (biconical > 45 %, followed by conical type > 35 %).

Slika / Figure 18. Frekvencija određene kategorije težine, promjera i visine pršljenova kostolačke kulture s lokaliteta Gomolava / Frequency of the particular weight, diameter and height classes of Kostolac spindle whorls at Gomolava.



Glavno ograničenje varijabilnosti u uzorku s Gomolave, za razliku od tehnološkog standarda kostolačke kulture, vidljivo je u distribuciji vrijednosti visine (Sl. 18). Ovdje uvjerljivo prevladavaju pršljenovi srednje visine (20-40 mm), što se znatno odražava na smanjenu varijabilnost vrijednosti težina (u usporedbi s distribucijom težina u uzorku s Franjevca). Osim toga, distribucija vrijednosti promjera na Gomolavi također pokazuje manju zastupljenost velikih alatki (60-70 mm i 70-80 mm).

In the Gomolava sample, the main variability restriction, in comparison to the Kostolac technological standard, can be observed in the height class distribution (Fig. 18). Here, the convincing dominance of the medium height class spindle whorls (20-40 mm), is substantially resonating the lowered deviation of the weight value (in comparison to the weight value distribution in the Franjevac sample). Additionaly, the diameter value distribution at Gomolava displays a decreased frequency of large tools (60-70 mm and 70-80 mm) as well.

## Trendovi ili tradicije

Kako bi se istražili glavni čimbenici koji su mogli utjecati na tehnološki razvoj, rane faze te dinamiku procesa specijalizacije tijekom srednjeg i kasnog eneolitika, uspoređena su dva uzorka pripisana retzgajarskoj i kostolačkoj kulturno-povijesnoj skupini (Sl. 19).

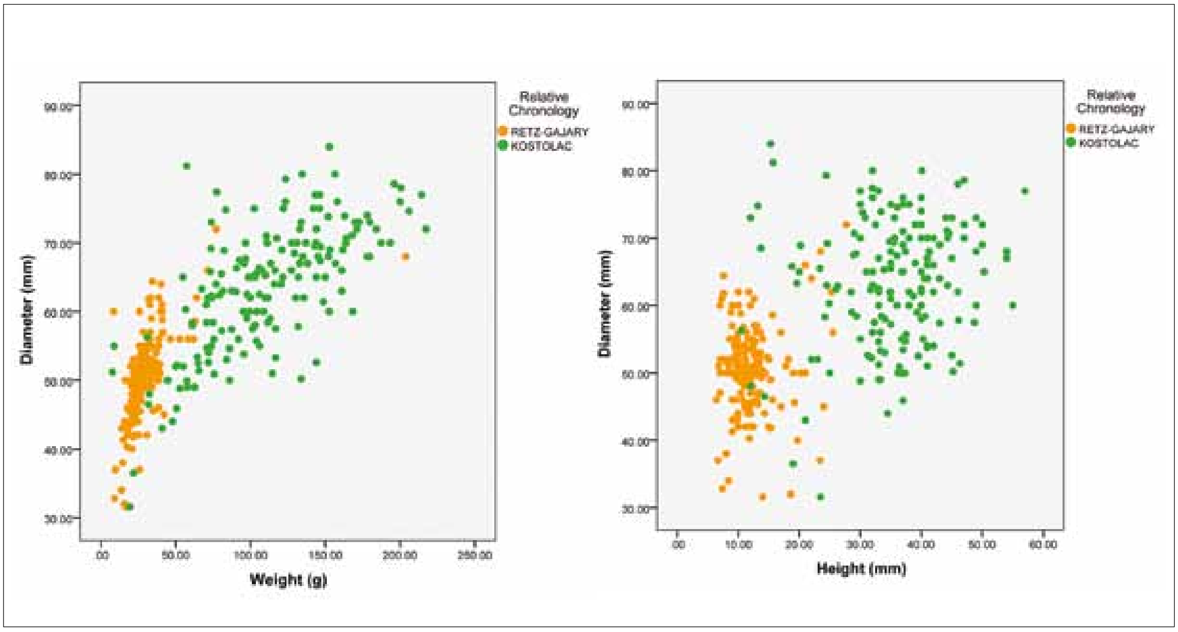
Zanimljivu posebnost u oba skupa nalaza kostolačke kulture čini distribucija vrijednosti težina pršljenova, odnosno očita smanjena zastupljenost lakših alatki (<30 g), unatoč njihovoj brojnosti i generalno visokoj varijabilnosti u vrijednosti težina primjećenoj u uzorcima. Ovaj razred težine pršljenova je, pak, uvjerljivo najučestaliji u proučavanim retzgajarskim skupovima nalaza.Kao što pokazuju

## Trends or Traditions

In order to explore the main factors which might have influenced the technological developments, the early stages and the dynamics of the specialisation process during the Middle and Late Eneolithic, two samples belonging to Retz-Gajary and Kostolac culture-historical groups were compared (Fig. 19).

An interesting peculiarity regarding both of the investigated Kostolac assemblages is that their spindle whorl weight value distribution, or their spindle whorl weight class variability is highly restricted in the case of light tools weighing (<30 g), despite the high frequency of spindle whorls and the high weight value deviation apparent in the samples. This particular weight class of spindle whorls is, on

Slika / Figure 19. Distribucija omjera težina-promjer (a) i visina-promjer (b) za uzorke pršljenova retzgajarske i kostolačke kulture / Weight-diameter (a) and height-diameter (b) distributions given together for Retz-Gajary and Kostolac spindle whorl samples.



rezultati analiza, pršljenovi retzgajarske kulture grupiraju se oko nižeg kraja spektra vrijednosti varijable težine: u istraženim je skupovima nalaza ustanovljen samo mali postotak teških, i još neznatniji broj izuzetno teških alatki.

Ograničena zastupljenost pršljenova manje visine u kostolačkom uzorku također odražava prevladavanje, prvo, bikoničnog, i, zatim, koničnog tipa pršljena. Suprotno tomu, zanimljivo je primijetiti stabilne vrijednosti težine retzgajarskih pršljenova: tehnološki standard koji je jasno postignut kroz dominaciju nižih pršljenova i ograničenje maksimalne vrijednosti promjera (Sl. 20). U kostolačkim skupovima uvelike prevladavaju teški i vrlo teški pršljenovi. Kao što je spomenuto, vrlo teški pršljenovi posebno su zastupljeni na lokalitetu Đakovo-Franjevac, gdje su razredi vrlo velike težine pronađeni u dvije strukture koje pokazuju najveću lokaliziranu standardizaciju. Te, izuzetno velike, vrijednosti tipične su za kostolačke skupove nalaza i mogu se povezati sa značajno dugim (pretpostavljeno biljnim) vlaknima i/ili predenjem (Hochberg 1979: 21; Barber 1991: 52) teže i deblje pređe ili užadi (Vakirtzi 2014: 53). Izuzev uplitanjem (uvijanje dvaju ili više niti zajedno), visoku frekvenciju vrlo teških pršljenova moguće je objasniti korištenjem određene tehnike predenja.

Poznate su dvije tehnike predenja ručnim vretenom: uz pomoć visećeg vretena koje samostalno visi na niti, i uz pomoć poduprtog vretena koje je oslonjeno i okreće se na tlu ili u posudi. Pri predenju s oslonjenim vretenom gravitacija ne utječe na proces, zbog čega je parametar težine manje važan. Glavni nedostatak ove tehnike jest to što pojedinac mora stajati na istom mjestu, za razliku od korištenja visećeg vretena koje omogućava da se sjedi, stoji, hoda, jaše, itd. dok se prede. (Grömer 2005: 109). Lokalizirane koncentracije vrlo teških pršljenova pronadene u najvećim jamskim strukturama na lokalitetu Đakovo-Franjevac mogle bi ukazivati na odredenu logiku koja stoji iza „sedentarnog“ karaktera korištenja oslonjenog vretena. Karina Grömer je u pokusima predenja dokazala kako je pomoću poduprtog vretena (oslonjene na tlu ili u posudi) s vrlo teškim pršljenom (iznad 100 g) moguće ispresti čak i fine niti promjera 0.3 mm, jer gravitacija ne utječe na proces, te ne dovodi do pucanja niti (Grömer 2005: 110).

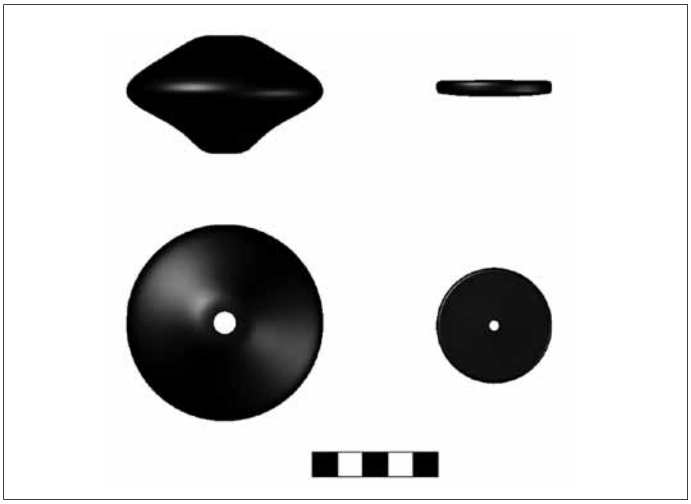
Razmotri li se odnos težine pršljena i tipa vlakna koje se prede korištenjem visećeg vretena, postaje jasno da bi za predenje tankih i kratkih vlakana

the other hand convincingly the most dominating one in the studied Retz-Gajary sets. As shown by the results of the analysis, Retz-Gajary whorls cluster in the lower spectrum of the weight variable distribution: only a low percentage of heavy and even lower percentage of very heavy tools appear in the investigated assemblages.

Restricted distribution of the low height class in Kostolac sample is also resonating a dominance of firstly, the biconical and secondly, the conical type of whorls. In contrast, it is interesting to observe the fixed weight values of the Retz-Gajary spindle whorls: a technological standard that is evidently established through the dominance of lower height classes of whorls and the restriction of the maximum diameter value (Fig. 20). Kostolac sets are greatly dominated by heavy and very heavy spindle whorls. As mentioned, very heavy whorls are particularly represented at Đakovo – Franjevac, where two structures that showed the highest localized standardization held mainly very heavy classes. These extremely high weight values, typical for Kostolac assemblages, may be brought to connection with substantially long (presumably plant) fibres and/or plying (Hochberg 1979: 21; Barber 1991: 52) heavier thick yarns or ropes (Vakirtzi 2014: 53). Besides plying (twisting two or more threads together) the use of a specific spinning technique could explain a high frequency of very heavy whorls.

Two different techniques of spinning with a hand spindle are known: using a drop spindle that hangs freely on the lengthening thread and using a supported spindle that turns on the ground or in a vessel. In supported spinning gravity does not influence the process, making the weight parameter less crucial. The main disadvantage is that the spinner has to stay in one place, in contrast to the use of drop spindle, which allows the spinner to sit, stand, walk, ride etc. (Grömer 2005: 109). Localized concentrations of very heavy whorls found in the largest pit structures at Đakovo – Franjevac may resonate a certain logic behind the ‘sedentary’ character of practicing the supported technique. Karina Grömer's spinning experiments proved that when spinning supported (on the ground or in a bowl) even fine threads of 0.3 mm diameter can be spun with heavy whorls (more than 100 g), while gravity does not affect the spinning process or break the thread. (Grömer 2005: 110).

If we consider the relationship between the weight of a whorl and the type of fibre being spun when



Slika / Figure 20. Veliki bikonični pršljen kostolačke kulture s lokaliteta Đakovo-Franjevac i diskoidni pršljen retzgajarske kulture s lokaliteta Ivandvor / A large Kostolac spindle whorl of a biconcal type from Đakovo-Franjevac and a Retz-Gajary spindle whorl of a discoid type found at Ivandvor (crtež / drawing: A. Grabundžija).

bilo prikladnije koristiti lakše pršljenove te da bi odabir težih pršljenova bio prikladniji za predenje debljih i dužih vlakna ili za uplitanje niti (Liu 1978: 99). U proučavanim skupovima nalaza, razlike između dominacije lakših pršljenova u retzgajarskoj i dominacije težih pršljenova u kostolačkoj kulturi ukazuju na znakovite prilagodbe u tehnologiji.

Michael Ryder (1968: 81) i Elizabeth Barber slažu se u tvrdnji da su pršljenovi težine oko 33 g prikladni za predenje dugih niti vune srednje težine (Barber 1991: 52). Osim toga, objavljeni rezultati tehnološke analize skupova nalaza datiranih u 4. i rano 3. tisućljeće pr. Kr. s lokaliteta Arslantepe u Turskoj (Laurito et al. 2014) govore u prilog navedenoj tezi. Zanimljivo, jedini koštani pršljen iz cijelog uzorka (836 pršljenova u bazi podataka) koji je pronađen na lokalitetu Josipovac Punitovački-Veliko polje I[9] vrlo je sličan (oblikom, načinom izrade te zabilježenim vrijednostima veličine i težine) spomenutim koštanim alatkama 4. tisućljeća s lokaliteta Arslantepe koje su, pretpostavlja se, korištene za predenju vune.

Valja spomenuti rezultate još jedne analize (Vakirtzi 2014) koja je provedena na brončanodobnim alatkama iz Tasosa u sjevernoj Egeidi, a koja također sugerira da je ovaj težinski razred pršljenova korišten za predenju vune. Nasuprot tomu, kako bi se moglo presti punu dužinu lanenih vlakana, najpogodnije je koristiti teške pršljenove, težine između 100 i 150 g (Gleba & Mannering 2012: 10).

9 Koštani pršljenovi izuzetno su rijetki u Panonskoj nizini tijekom ovog razdoblja, a ovaj nalaz prvotno je objavljen kao koštani privjesak (Čataj 2009: 31).

using a drop spindle, a light whorl would be suitable for spinning fine, short fibres and heavy whorls would be chosen for coarser and longer fibres or for plying (Liu 1978: 99). In the examined assemblages, the difference between the dominance of light weighted spindle whorls in the Retz-Gajary sets and the dominance of heavy weighted spindle whorls in the Kostolac sets, accounts for a significant technological adjustment.

Both Michael Ryder (1968: 81) and Elizabeth Barber argued that whorls around 33 grams are suitable for long staple medium-heavy wool (Barber 1991: 52). Additionally, reported results of the technological analysis on the 4$^{th}$ and early 3$^{rd}$ millennium BC assemblages from Arslantepe, Turkey (Laurito et al. 2014) support this conclusion. Interestingly, a single bone spindle whorl in the entire (836 spindle whorls in the database) sample, which was recovered at Josipovac Punitovački – Veliko polje[9] highly resembles (in shape, production, and recorded size and weight values) the mentioned 4$^{th}$ millennium bone tools from Arslantepe, suggested for spinning wool.

It should be mentioned that results of another analysis (Vakirtzi 2014), of the North Aegean Early Bronze Age tools from Thasos, also propose that this particular spindle whorl weight class was used for spinning wool. Quite the opposite, in order to spin a full-length flax, it is ideal to use a heavy whorl, weighing between 100 and 150 grams (Gleba & Mannering 2012: 10).

9 Bone spindle whorls are very rare in the Pannonian Plain during this period and the particular find was initially published as a bone pendant (Čataj 2009: 31).

Iako vještina pojedinca do određene mjere može biti važnija od težine alatke (Kania 2015), znakovitu razliku u vučnoj snazi između kratkih životinjskih i dugih biljnih vlakana trebalo bi se moći prepoznati, ako ne u distribuciji alatki umjerenih/srednjih vrijednosti, onda svakako kroz zastupljenost ekstremno različitih kategorija pršljenova. Prve su vunene tkanine izuzetno rijetke i javljaju se tek od 4. tisućljeća pr. Kr. (Shishlina et al. 2003; Rast-Eicher 2014). S druge strane, količina peludi lana u uzorcima iz priobalnih naselja na švicarskim jezerima sugerira intenzivnu proizvodnju lana na prijelazu tisućljeća, a koja postaje još jasnije vidljiva zahvaljujući konkretnim ostacima tekstila pronađenim na ovim, izuzetno dobro očuvanim, lokalitetima (De Capitani et al. 2002: 115-120).

Bilo da je ona vezana uz ciljano korištenje određenih izvora vlakana, ili pak da ovisi o primjeni određenih tehnika, u usporedbi uzoraka retzgajarske i kostolačke kulture može se govoriti o određenoj razini standardizacije alatki. S druge strane, ako uzmemo kvalitetu predene niti kao parametar za usporedbu ove dvije proizvodne tradicije, također možemo objasniti razlike između ciljanih krajnjih proizvoda.

S obzirom na to da je u proučavanom razdoblju dokazano korištenje životinja za vuču (Fabiš 2005; Johannsen 2005; Isaakidou 2006), uprezanje životinja, povećana zemljoradnja te mobilnost i transport mogli su utjecati na pojačano korištenje tehnike uplitanja niti (vjerojatno za izradu teških konopa i užadi), kao što sugerira masivnost alatki kostolačke kulture.

Keramički pečati predstavljaju posebnu kategoriju nalaza koje se može povezati sa standardizacijom. Mnogi autori predlažu da su ti predmeti korišteni u proizvodnji tekstila (Mellart 1967: 220; Makkay 1984: 91; Barber 1991: 175; Budja 2003: 119), dok se o njihovom simboličkom aspektu nagađa kroz prizmu razvoja indeksa društvenih odnosa između različitih naselja na razini regije (Prijatelj 2007: 252). Hodder ih interpretira kao osobne predmete (Hodder 2006: 231), prvenstveno na temelju dva pečata pronađena u grobovima iz slojeva IV i VI na lokalitetu Çatalhöyük.

Pitanja o osobnom identitetu i statusu, koja su objašnjiva kroz pojam osobnog vlasništva ili iznimne umješnosti individue, moguće je postaviti i za kontekst ljudskih ukopa iz velike strukture kostolačke kulture na lokalitetu Đakovo-Franjevac. Iako na analiziranim lokalitetima retzgajarske kulture

Although the influence of tool's weight can be to a certain degree surpassed by a spinner's skill (Kania 2015), the substantial difference in tensile strength between the short animal and long plant fibres should be distinguishable, if not in the distribution of the moderate spindle whorl types, then in the distribution of the extremely different tool categories. First woolen textiles are exceptionally rare and appear only from the 4th millennium BC (Shishlina et al. 2003; Rast-Eicher 2014). On the other hand, level of flax pollen in the samples taken from the lake-shore settlements in Switzerland indicated an intensive flax production at the turn of the millennia, even more obvious thanks to the actual textile-remains recovered at these exceptionally preserved sites (De Capitani et al. 2002. 115–120).

Whether being connected to the more focused use of certain fibre materials or dependent on the application of specific techniques, when compared, a certain level of tool standardization may be argued for the Retz-Gajary and Kostolac samples. In addition, if we would use the spun thread quality as a parameter for distinction it might explain how substantially different end products were aimed for by these two production traditions.

Since animal traction has been attested for the period (Fabiš 2005; Johannsen 2005; Isaakidou 2006), harnessing of animals, increased agriculture, mobility and transport may all have promoted the intensified plying technique (maybe for heavy cords and ropes), as suggested by the massiveness of the Kostolac tools.

Ceramic stamps are a perculiar category of finds that might be connected to the standardization. Many authors proposed their use in textile production (Mellart 1967: 220; Makkay 1984: 91; Barber 1991: 175; Budja 2003: 119), while their symbolic aspect has been hypothesised through the development of indexes for social relationships between various settlements at the regional level (Prijatelj 2007: 252). Hodder interprets them as personal items (Hodder 2006: 231), mainly on the account of the two stamps found in burials at Çatalhöyük in levels IV and VI.

Questions regarding personal identity and status, explainable whether through ownership or craftsmanship, may be raised also on the account of human burials from the large Kostolac structure at Đakovo – Franjevac. Although no human burials were found at the analysed Retz-Gajari settlements, a large Furhenstich cemetery from Slovenia (Pod Kotom-jug pri Krugu), where spindle whorls nisu ustanovljeni ljudski ukopi, veliko groblje s keramikom ukrašenom brazdastim urezivanjem iz Slovenije (Pod Kotom-jug pri Krugu), gdje su pršljenovi zabilježeni u nekoliko grobova (Šavel 2009), dokazuje važnost obrade vlakana već u 4. tisućljeću pr. Krista. Zanimljivo je istaknuti da su zooarheološke analize ostataka faune s te nekropole pokazale da su ovce/koze najčešće prisutne životinje (66,7%) pronađene u ukopima (Šavel 2009: 137). Pretpostavka da bi to moglo ukazivati na rano korištenje ovčje vune za proizvodnju tekstila mogla bi objasniti dominaciju pršljenova male težine u retzgajarskom uzorku.

Izuzev činjenice da su središnji i najveći prostori uvijek bili korišteni za predenje, rijetki metalni nalazi, otkriveni u istim kontekstima s pršljenovima, mogli bi dodatno naglašavati važnost barem jednog aspekta obrade vlakana. Sherratt (Sherratt 1997; 2006) je povezao vuču i vunu s društvenom stratifikacijom, objašnjavajući ih kao simbole elite, iako bi brončane sjekire pronađene u grobnim humcima moravske kulture ljevkastih pehara (njem. Trichterbecherkultur, eng. Funnel Beaker Culture), pronađene zamotane u lanenu tkaninu, mogle sugerirati da nisu samo vunene tkanine bile vezane uz prestiž (Baldia et al. 2008: 264-265). Drugi oblici specijalizacije pojedinih naselja tijekom kasnog eneolitika zabilježeni su u Srbiji, gdje je na nizu lokaliteta utvrđeno ciljano vađenje bakrene rudače, dok je na drugima i dalje vidljivo kontinuirano bavljenje stočarstvom (Kapuran & Milošević 2013: 24-26). Ukoliko su proizvodnja/nabavljanje i obrada vlakana pratile sličan uzorak upravljanja izvorima sirovine, kakav povezujemo s gospodarenjem izvorima bakra i metalurgijom. Čini se izglednim da je i u proizvodnji tekstila donekle moguće zamisliti neki oblik rane organizacije, specijalizacije, centralizacije i kontrole proizvodnog procesa.

Izostanak razreda lakih pršljenova (<30 g) povezanih s korištenjem kraćih životinjskih vlakana, i na Đakovo-Franjevcu i na Gomolavi, a koji može odražavati opću usmjerenost na predenje (i uplitanje) dugih biljnih vlakana (i niti), ukazuje na razvijenu specijalizaciju u tom razdoblju. Ne samo rezultati analize pršljenova, već i rijetki konkretni dokazi iz regije (nalazi pređe iz Ljubljanskog barja u Sloveniji)[10] te botanički ostaci (Reed 2016; Tolar et al. 2016), govore u prilog ideji o intenziviranju korištenja biljnih vlakana krajem 4. tisućljeća pr.

10 Očuvana vlakna iz Ljubljanskog Barja izrađena su od divljih biljnih vlakana iz porodice trava (*Poaceae*) (Pajagič-Bregar et al. 2009) i vlakana lišća rogoza (*Typha angustifolia*) (Greif 1997: 41).

were recorded in several graves (Šavel 2009), attest the importance of fibre processing already in the 4th millennium BC. Interestingly, zooarchaeological analysis of the faunal remains from the cemetery revealed that the sheep/goats were the most commonly (66.7 %) found animals in the burials (Šavel 2009: 137). If we consider that this might point to the early use of sheep wool for textiles, it could explain the dominance of the low weight values of spindle whorls in the Retz-Gajary sample.

Besides the fact that always the most central and the biggest spaces were allocated for spinning activities, rare metal objects recovered in the same contexts together with spindle whorls may further emphasise the relevance of at least one aspect of the fibre processing practice. Sherratt (Sherratt 1997; 2006) connected both the traction and the wool with social-stratification, explaining them as symbols of the elites, but copper axes from the burial mounds of the Moravian Trichterbecherkultur-Boleráz (Trichterbecherkultur or Funnel Beaker Culture) sites that were wrapped in flax-textiles, may propose not only woollen fibres had a high value (Baldia et al. 2008: 264–265). Other forms of settlement specialisation during the late Eneolithic were documented in eastern Serbia, where a number of sites exhibit a focused copper ore extraction, while others present a continued focus on animal husbandry (Kapuran and Milošević 2013: 24–26). It is plausible that early organisation, specialization, centralization and control associated with copper resources and metal work might be, to some extent, traced in the textile manufacture as well, if the fiber production/procurement and processing followed a similar pattern of the raw material management.

The absence of the light class spindle whorls (< 30 g), connected to shorter animal fibres, both at Đakovo – Franjevac and Gomolava, which may be reflecting a general focus on spinning (and plying) long plant fibres (and filaments), suggests a developed specialisation for the period. Not only the results of the spindle whorl analysis, but also the rare actual evidence from the region (yarn finds from Ljubljansko barje in Slovenia)[10] and the botanical remains (Reed 2016; Tolar et al. 2016) support the idea of intensified plant fibre use at the end of the 4th millennium BC. Expanding the Kostolac spindle whorl sample should provide some arguments for the

10 Preserved fibres from Ljubljansko Barje were made of wild plant fibre belonging to the family of grasses (*Poaceae*) (Pajagič-Bregar et al. 2009) and leaf-fibres of lesser bulrush (*Typha angustifolia*) (Greif 1997: 41).

Krista. Proširivanje uzorka tekstilnih alatki kostolačke kulture trebalo bi rezultirati dodatnim argumentima za hipotezu o specijalizaciji pojedinih naselja, u slučaju kada bi na proširenom uzorku lokaliteta bile zabilježene više frekvencije lakših pršljenova. Ako se to ne ostvari, drugo objašnjenje za izostanak razreda lakših pršljenova moglo bi biti to da su prelje i predioci koristili drugačije tehnike predenja, s obzirom na činjenicu da bi korištenje oslonjenih vretena omogućilo obradu kraćih životinjskih vlakana i finijih niti. Naposljetku, najuži zaključak bio bi taj da je proizvodnja tekstila, ako ne u potpunosti, onda u znatnoj mjeri ovisila o izvorima dugih biljnih vlakana. To bi značilo da je, u kontekstu intenzivne i organizirane proizvodnje, fokus bio stavljan na uzgajanje određenih vlakana, pri čemu je lan najizgledniji kandidat.

Prema iznesenim rezultatima analize tekstilnih alatki čini se da nije bilo prijelaza na masovnu produkciju tijekom dva proučavana tisućljeća. Niti jedan od analiziranih lokaliteta iz Panonske nizine nije pružio dokaze koji bi govorili u prilog industrijalizacije procesa, barem ne na razini koja je postignuta u istovremenoj proizvodnji tekstila na Bliskom Istoku (McCorriston 1997; Sagona & Zimansky 2009). Ipak, indikacije za postojanje rane specijalizacije, barem na razini radionice, dovoljno su jake i sugeriraju da se prvu pojavu organizirane proizvodnje može pratiti od vremena retzgajarskih i kostolačkih društava (4. tisućljeće pr. Kr.).

Razvojni procesi na pojedinim lokalitetima nisu bili predmetom ove analize. Pretpostavljeno je da prostorni raspored alatki u određenim jamskim strukturama izravno ocrtava primarni kontekst njihovog korištenja i/ili odbacivanja. Takva pretpostavka do određene mjere negira razlike između sistemskog i arheološkog konteksta (Schiffer 1976; 1985). Ovaj se pristup smatra valjanim zbog toga što rezultati analiziranih skupova nalaza pokazuju značajnu razinu standardizacije. Nadalje, neobično visoka frekvencija alatki u pojedinim kontekstima, koje su mogle biti korištene u raznim situacijama, te stoga nisu ograničene na pojavljivanje isključivo u okviru naselja, sugerira da se uvjerljivo intenzivna proizvodnja odvijala u i oko određenih struktura, zbog čega analizirane skupove nalaza ne treba odbaciti kao dokaze organiziranih i specijaliziranih proizvodnji na proučavanim lokalitetima, čak ni u slučaju da se radi o sekundarno odbačenim predmetima.

settlement specialization hypothesis, in the case that higher frequencies of lighter spindle whorls would be recorded on other sites. If that does not appear to be the case, another explanation for the absence of the lighter classes of whorls would suggest that a different spinning technique was used by Kostolac spinners, since the supported spinning would allow the use of heavy spindle whorls even for shorter animal fibres and finer threads. Finally, the most restrictive conclusion would be that their textile production was highly, if not exclusively dependable on long plant fibre resources. This could mean, that in the context of intensified and organized production, emense focus was placed on a particular fibre cultivation, with flax plant being the main candidate.

The results of the presented textile tool analysis propose that there was no transition to the mass production during the two studied millennia. None of the investigated sites of the Pannonian Plain region displayed evidence for industrialization of the process, at least not on the level achieved by the contemporary textile productions in the Near East (McCorriston 1997; Sagona and Zimansky 2009). Nonetheless, indications for an early specialisation, possibly on the workshop level are convincing enough to argue that the first manifestations of organized productions are traceable all the way to the Retz-Gajary and Kostolac societies ($4^{th}$ millennium BC).

This analysis did not take into account formation processes. It is assumed that the spatial layout of tools in the particular pit structures directly reflects their primary context of use and/or deposition. Such an assumption neglects to some extent the difference between the systemic and archaeological contexts (Schiffer 1976; 1985). It is held to be a valid approach, given the fact it was demonstrated by the results of the analysis that the investigated assemblages revealed a significant level of standardisation. Further, an unusually high frequency of tools, which can be used in a wide range of situations and are not at all limited to the settlement context for that matter, is suggestive of convincingly intensified manufacture in or around the particular features. Thus, even in the case that the analysed assemblages represent a secondary refuse, they should not be disregarded as a valid evidence of organized and specialized productions at the investigated localities.

Kako bi se moglo baviti određenim elementima tehnološkog kontinuiteta i njegovog odnosa s glavnim kulturološkim, društvenim i ekonomskim promjenama, potrebno je napraviti detaljnu analizu proizvodnje tekstila vučedolske kulture. Takva bi analiza mogla pružiti vrijedne podatke o daljnjem razvoju procesa specijalizacije koji je, kako se čini, već započeo u društvima srednjeg te se nastavio razvijati u razdoblju kasnog eneolitika.

In order to address the specific elements of the technological continuity and its connection with the major cultural, social and economic changes, a detailed analysis of the succeeding Vučedol textile production is necessary. It could provide valuable information on further developments of the specialization process that, as it appears, already started in the Middle Eneolithic and continues to shape its form in the Late Eneolithic period.

## Zaključci

Izostanak pršljenova među arheološkim nalazima može se objasniti nekolicinom faktora kao što su slaba očuvanost, ručno uplitane niti te obrasci naselja. Osim toga, praktičnost korištenja slobodnog pršljena za viseće vreteno dopušta obavljanje više zadataka istovremeno (Levy & Gilead 2013: 38). Dakle, ručno predenje je aktivnost koja se često odvija izvan sfere domaćinstva. Ipak, visoka frekvencija očuvanih pršljenova u proučavanim kontekstima ukazuje na porast proizvodnje pređe, što prelazi razinu proizvodnje u domaćinstvu.

Neizravni dokazi za eneolitičku proizvodnju predstavljeni u ovom radu ukazuju na intenzivnije prakse predenja u zajednicama koje su nastanjivale Panonsku nizinu. Očite tehnološke promjene u proizvodnom procesu koje su se odvijale tijekom 4. tisućljeća pr. Kr. zahtijevaju novu i prilagođenu perspektivu. Prvo, pojavu novih izvora sirovina treba sagledavati u širem kontekstu. Proizvodnja tekstila jedna je od najstarijih ljudskih tehnologija, što znači da su vlakna morala biti glavni dio strategija preživljavanja, ekonomije, pa čak i trgovine. Korištenje i vune i vlakana novog tipa lana (prilagođenog za tekstil, a ne ishranu) objašnjava ključne inovacije koje ne samo da su promijenile tehnološke aspekte proizvodnje, već su utjecale i na njezinu društvenu i ekonomsku važnost. Niti u jednoj od proučavanih ukopanih struktura u kojima je pronađen velik broj alatki nisu ustanovljeni dokazi na temelju kojih bi ih se moglo okarakterizirati kao stambene strukture. Nadalje, na Ivandvoru i Đakovo-Franjevcu, dvaju od lokaliteta s najvećom ustanovljenom koncentracijom pršljenova, nisu utvrđene nikakve karakteristike stambenih prostora. Vrlo je izgledno da su tijekom razdoblja kada je uvođena nova sirovina/e neke zajednice razvile organizirane sustave proizvodnje i obrade istih. Ovi prvi izvori kultiviranih vlakana vjerojatno su utjecali na specijalizaciju zanata i organizaciju rada, tako da se neke aktivnosti više

## Conclusions

Spindle whorl deficiency in the archaeological record may be explained by several different factors, such as poor archaeological preservation, finger twined products and settlement patterns. Additionily, the practicality of the spindle whorl when used for drop-spinning allows multi-tasking (Levy & Gilead 2013: 38). Thus, hand spinning is an activity quite often dislocated from the domestic sphere. However, a high frequency of efficient spindle whorls from the investigated contexts suggests a degree of yarn production intensification, which exceeds the household level.

Indirect evidence for the Eneolithic production presented in this study reveal an intensified spinning practice among the communities inhabiting the Pannonian Plain region. Obvious technological changes that occurred in the manufacturing process during the 4th millennium BC call for a new and modified perspective. First of all, the appearance of new raw materials is something that should be observed in a wider context. The manufacture of textiles is one of the oldest human craft technologies, which makes fibres an elementary part of subsistence and economy, even trade. Both wool and fibre flax (a new type of plant, selected for its fibre instead of nutritional traits) account for a crucial innovation, which noth only changed the technological aspects of the production, but also impacted its social and economical importance. None of the investigated pit structures that yielded a high number of tools revealed any evidence that would characterize them as residential dwellings. Furthermore, both Ivandvor and Đakovo–Franjevac, two of the sites that showed the higest concentration of spindle whorls are lacking the residential characteristics whatsoever. It is highly possible that during the period of the new raw material(s) introduction some communities developed organized systems for their production and processing. These first cultivated fibre resources most probably in-nisu odvijale u domaćinstvima, već u radionicama. Iako spekulativno, izgledno je da se upravljanje ovim sirovinama moglo konsolidirati na razini naselja, kao što je to bio slučaj s drugim sirovinama u tom razdoblju. Lokaliteti Ivandvor i Đakovo-Franjevac mogli bi biti jedni od lokaliteta koji su bili korišteni u te svrhe. Janet Levy i Isaac Gilead, koji su istraživali tekstilnu proizvodnju 5. tisućljeća pr. Kr. na južnom Levantu, predložili su model koji sugerira da su se lanena vlakna proizvodila u određenim zonama, odakle su bila distribuirana u naselja i područja sa manje pogodnim okolišnim uvjetima. (Levy & Gilead 2012: 137).

Veliki skupovi nalaza pršljenova zabilježeni na lokalitetima Ivandvor i Đakovo-Franjevac ukazuju na visoku razinu proizvodnje pređe. Čak i ako ih se promatra kao sekundarne depozite, uzevši u obzir izostanak struktura stambenog karaktera, te dokaze koji upućuju na druge specijalizirane aktivnosti na dvaju istraživanim lokalitetima, obrađene je tekstilne alatke moguće interpretirati kao pokazatelje razvijenog zanata.

Predložena organizacija dijela procesa proizvodnje tekstila koja se odnosi na predenje sugerira da je eneolitička proizvodnja tekstila sudjelovala u društveno-ekonomskom razvoju, iako je, zbog izostanka izravnih dokaza, odnosno očuvanih tekstila, niti i užadi, teško odrediti da li su na to više utjecale strategije nabavljanja vlakana, važnost krajnjih proizvoda, ili pak oboje. Kako bi se moglo bolje razlučiti regionalnu razinu spomenutih procesa specijalizacije i organizacije zanata, predloženi pristup trebalo bi dodatno ispitati na većem broju susjednih lokaliteta iz istog vremenskog okvira te iste kulturno-povijesne asocijacije. Izložena prostorna analiza, koja bi obuhvaćala veći broj lokaliteta, mogla bi pružiti više podataka o ekonomskim vezama i savezima između eneolitičkih kulturnih skupina. Predloženo je da društvena složenost nekog društva sasvim korelira s demografskim varijablama poput veličine populacije (Feinman & Neitzel 1984; Feinman 2011). Nažalost, društva srednjeg i kasnog eneolitika su, zbog svog načina života i udaljenosti između naselja, posebno zahtjevna pri provođenju ovakvih analiza.

Na trenutnoj razini istraživanja, rezultati funkcionalne analize sugeriraju da glavni tehnološki aspekti proizvodnje tekstila ispoljavaju visoku razinu ovisnosti o kulturi. Kako bi se otkrilo jesu li uzroci ove tehnološke podudarnosti bili dijelom integralnih ekonomija ili su pak bili povezani s fluenced the craft specialisation and organization, both of which possibly influenced certain activities to leave the household and enter a workshop. It is highly speculative, but managing these resources might have been consolidated on an inter-settlement level, like it was the case with other raw materials at the time. Both Ivandvor and Đakovo – Franjevac might be among localities that served this function. Janet Levy and Isaac Gilead who investigated the 5th Millennium BC textile production in the Southern Levant proposed that flax fibers were produced in the particular zones and then distributed among settlements situated in the areas with unsuitable environmental conditions (Levy & Gilead 2012: 137).

Large assemblages of spindle whorls recorded in particular deposits at Ivandvor and Đakovo – Franjevac are suggestive of a significant level of yarn production. Even if they were to be seen as secondary deposits, considering the lack of residential structures and the evidence that is supporting other specialised activities at both of the investigated sites, these tool concentrations can be interpreted as an indication of a developed spinning craft.

Proposed organization of the spinning part of the fabrication process indicated that the Eneolithic textile productions participated in the socioeconomic transition of the period, although, due to the absence of direct evidence of the textile craft, more precisely, preserved textiles, thread and cordage, it is hard to determine whether this is connected to the fibre procurement strategies or to the final produce importance, or possibly both. In order to gain a higher resolution for the regional perspective of the outlined processes of craft specialization and organization, the proposed approach should be further tested against a greater number of neighbouring sites belonging to the same temporal frame and culture-historical attribution. Proposed spatial analysis, which would cover a greater number of sites could provide more information on economic interconnection and alliance within Eneolithic cultural groups. It is suggested that the organisational complexity of a society positively correlates with demographic variables such as population size (Feinman & Neitzel 1984; Feinman 2011). Unfortunatelly, Middle and Late Eneolithic societies, due to their way of life and the dispersity of their settlements, are particularly challenging for this type of analysis.

drugim aspektima stvaranja „kulturnog" identiteta, potrebne su daljnje analize na razini većeg broja lokaliteta.

Iako se potvrđene aktivnosti predenja izvan domaćinstva mogu smatrati dokazom intenzivne proizvodnje, ili čak specijalizacije zanata, čini se da to nije bila široko rasprostiranjena i ustaljena praksa tijekom eneolitičkog razdoblja. U Panonskoj nizini moglo je doći do razvoja elita, iako je u proučavanom razdoblju teško odrediti tragove političke centralizacije, institucionalizirane hijerarhije ili pak privilegiranog pristupa izvorima sirovina. Osim toga, dokazi zanatske proizvodnje znatno variraju od lokaliteta do lokaliteta, stoga je povećanje uzorka alatki korištenih u proizvodnji tekstila nužna stavka u proučavanju ovih pitanja.

Unatoč činjenici da dokazi za specijalizaciju i složenost društva znatno variraju među ovdje proučavanim pojedinačnim lokalitetima, moguće je ustanoviti neke trendove. Otkrivene koncentracije alatki sugeriraju da je proizvodnja tekstila u proučavanom razdoblju bila na granici specijalizacije. Tehnički izvještaj i rezultati analize alatki pokazali su da alatke, koje odražavaju tehnološki razvoj, imaju potencijal da prošire razumijevanje pojedinih društveno-ekonomskih čimbenika. Nadalje, dobiveni rezultati otkrili su određene trendove i razvoje u smislu standardizacije alatki. Naposlijetku, prostorna distribucija nalaza ukazuje na organizaciju rada i intenzitet uključenosti aktera. Izuzev parametara *koncentracije*, *razmjera* i *intenziteta*, definirani su i određeni pokazatelji *konteksta* specijalizacije zanata. Iako ih je teško pripisati *zavisnoj specijalizaciji*, rijetki metalni predmeti i ljudski ukopi koji su kontekstualno vezani uz skupove nalaza pršljenova ukazuju na važnost i ulogu proizvodnje tekstila koja je bila utkana u svakodnevni život retzgajarskih i kostolačkih zajednica.

At this point of the research the results of the functional analysis suggest that main technological aspect of the textile manufacturing tends to display a high level of cultural dependency. Further inter-site investigations are needed to reveal if the reasons for this technological concordance lie in the integral aspects of their economies or they are connected to other aspects of the 'cultural' identity amassment.

Although attested extra-domestic spinning may be accepted as evidence of intensified production, or even craft specialization, it does not appear to be a widespread and established practice during the Eneolithic period. Nascent elites may be developing in the Pannonian Plain, even though traces of political centralization, institutionalized hierarchy or privileged access to raw material resources are hard to determine for the investigated period. In addition, the evidence of craft production is highly variable both from site to site, so the enlargement of the textile tool sample is necessary for addressing this specific questions.

Despite the fact that the evidence for craft production and social complexity varies greatly between the separate sites included in this study, some trends are observable. Detected tool concentrations suggest that textile productions of the period bordered with specialization. The technical report and the results of the tool analysis outlined that textile tools, reflective of the technological developments, hold the potential for broadening our understanding of the advancement of particular socioeconomic factors. Furthermore, the obtained results revealed certain trends and developments regarding the tool standardization and, finally, the spatial distribution of the finds suggested, besides the organization of labour, also the intensity of investment. Besides *concentration*, *scale* and *intensity* parameters, some indications for the craft specialization *context* were also detected. Although it is difficult to assign them to the *attached specialization*, rare metal objects and human burials, which were contextually associated with the whorl assemblages, attest to the importance and the role of textile production in the fabric of everyday life for Retz-Gajary and Kostolac communities.

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# Kosti za tkalački stan. Eksperiment tkanja s astragalima

## *Bones for the Loom. Weaving Experiment with Astragali Weights*

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*Kratki eksperiment tkanja održao se u Arheološkom muzeju u Zagrebu ne bi li se istražila funkcionalnost objavljenih astragala s Gomolave te raspravila njihova moguća upotreba kao utega za tkalački stan. Autorice su uspjele posuditi set od 15 astragala iz komparativne zbirke Zavoda za paleontologiju i geologiju kvartara HAZU u Zagrebu. Za napinjanje niti osnova tkanja iskorišteno je 14 astragala koji su postavljeni umjesto utega na vertikalni tkalački stan, konstruiran od strane Centra za eksperimentalnu arheologiju – CEKSA, u svrhu predstavljanja tehnika tkanja sudionicima i posjetiteljima radionice. Osnovna svrha pokusa bilo je testiranje moguće uporabe astragala, dok je dokumentiranje tkanja bilo stjecanje iskustva, s ciljem postavljanja određenih pitanja koja se odnose na proučavanje astragala. S obzirom na ograničenost vremenom, tijekom pokusa tkan je samo jedan komad tekstila. Petnaesti astragal poslužio je za jednostavan eksperiment namotavanja pređe.*

*Ključne riječi: eksperiment, astragali, tekstilna arheologija, vinčanska kultura, Gomolava, utezi za tkalački stan, obrađene kosti, funkcionalnost, upotreba, posredni dokazi, tekstilne alatke, kalemi (špule)*

*A short weaving experiment took place at the Archaeological Museum in Zagreb in order to test the functional nature of the published astragali from Gomolava site as well as to determine and discuss their potential for use as loom-weights. Authors managed to borrow a set of 15 astragali from the Institute for Quaternary Paleontology and Geology in Zagreb. They warped 14 of them on a vertical loom, built by the Centre for Experimental Archaeology – CEKSA, in order to demonstrate weaving techniques to the participants and visitors of the workshop. The main purpose of the experiment was to test their potential functionality, while recording the weaving experience, in order to raise some particular questions that should be addressed in the prospective research on the astragali bones. Being limited by time, during the experiment only a single piece of textile was woven. The fifteenth astragalus bone was used for a simple spooling experiment.*

*Key Words: Experiment, astragali, textile archaeology, the Vinča culture, Gomolava, loom-weights, worked bones, functionality, use, indirect evidence, textile tools, spools*

## UVOD

Tri neuobičajena seta obrađenih astragala s Gomolave, poznatoga vinčanskog nalazišta u Srbiji, objavljena su kao mogući setovi utega za tkalački stan. Navedeni primjerci kostiju izloženi su u Muzeju Vojvodine i dio su stalnoga postava nalazišta. Glavni razlozi zašto su ih autori interpretirali (Blažić, Radmanović 2011) i izložili (Jovanović 2011: Gospodari gline i žita) kao utege za napinjanje niti osnove tkanja proizlaze iz konteksta njihova pronalaska te tragova obrade i korištenja koji su utvrđeni na kostima.

Prilikom iskopavanja vinčanske kuće 3 1972. godine, pronađeno je 18 astragalnih kostiju. Ukupno 12 primjeraka domaćeg goveda (*Bos taurus*) i 6 jelena (*Cervus elaphus*) pronađeno je na podnici kuće 3, uz sjeveroistočni zid građevine. Nadalje, 50 astragala s iskopavanja 1956. godine, među kojima su evidentirani i perforirani primjerci, pronađeno je u vinčanskoj kući 8, neposredno uz ognjšte – mjesto u kući na kojem su često pronalaženi keramički utezi za tkalački stan. Čak 40 primjeraka iz te grupe pripadalo je domaćem govedu, a deset jelenu. Prilikom istraživanja 1972. godine (faze Ib na Gomolavi), u neposrednoj blizini vinčanske kuće 1, pronađena je i treća grupa kostiju koja je brojila 24 astragala: 19 primjeraka pripadalo je domaćem govedu, a pet jelenu. Utvrđeni tragovi obrade na pojedinim primjercima, u vidu poliranja i perforacije, upućuju na to da su kosti mogle biti korištene prilikom tekstilne proizvodnje (Jovanović 2011: 44).

U neolitičkim slojevima na Gomolavi sveukupno je pronađeno oko 200 obrađenih primjeraka astragala (gležanjskih kostiju) domaćeg (*Bos taurus*) i divljeg (*Bos primigenius*) goveda, te jelena (*Cervus elaphus*). No, samo su tri zasebne gomile, pronađene u kućama 1 i 3, istraživanim 1972. godine, te kući 8, istraživanoj 1956. godine, analizirane kao dio kolekcije utega za tkalački stan (Blažić, Radmanović 2011: 129–143).

U kontekstu suvremene arheologije, ponosne na razvoj kritičke misli i usvojene znanstvene metode analize, umjerenost i opreznost postale su poželjne kvalitete, barem kada je riječ o interpretaciji karaktera arheoloških nalaza, bez obzira na to je li riječ o razjašnjavanju njihove simboličke ili funkcionalne naravi. Arheolozi koji se bave istraživanjem tekstilne tehnologije zbog tendencije da vide tekstil i tekstilnu produkciju u arheološkim nalazima i situacijama češće nego što to podupiru gole činjenice, nemilosrdno oskudne zbog neočuvanosti i nevidljivosti izravnih dokaza, tj. tekstilnih artefakata, često su izloženi većoj količini zdrave kritike. No, upravo zahvaljujući njihovoj rijetkosti, arheološki tekstili bude kuriozitet. Oslanjajući se primarno na posredne dokaze proizvodnje, kao što su alatke, izbjegavanje klopke kurioziteta u tekstilnoj arheologiji često je zahtjevno.

Jedan od najjednostavnijih načina da se izbjegne upadanje u klopku kurioziteta prilikom istraživanja jest provođenje eksperimenata. To, dakako, podrazumijeva kontrolirane uvjete i evidenciju protokola tijekom testiranja hipoteze ne bi li se eksperiment mogao ponoviti s jednakim rezultatima. Sami rezultati eksperimenta, osim što osiguravaju dokaze za početnu argumentaciju, također predstavljaju i analogije koje često nisu prisutne u evidenciji arheoloških nalaza.

## INTRODUCTION

Three peculiar sets of finds involving worked astragali bones from Gomolava, the famous Vinča Culture site in Serbia, were published as probable collections of loom-weights. The astragali in question are displayed in the Museum of Vojvodina as part of a permanent exhibition of the Gomolava site. The main reasons why the authors interpreted (Blažić, Radmanović 2011) and displayed (Jovanović 2011: Masters of Clay and Wheat) these finds in such a functional and pragmatic manner derive from both the contexts in which they were found, as well as the marks of use and working recorded on the bone tools.

In the 1972 excavation of the Vinča house 3, 18 astragali were found: 12 specimens of cattle (*Bos Taurus*) and six specimens of deer (*Cervus elaphaus*) astragali were recovered on the floor, next to the northeastern wall of the house. Further, 50 astragali, some of which were singed, were discovered next to the hearth in the Vinča house 8, excavated in 1956. This has in fact been the place where ceramic weights are usually found. In this group of bones, 40 specimens were cattle and ten were deer. The third group of astragali, which consisted of 24 specimens, was discovered in the immediate vicinity of the Vinča house 1, investigated in 1972 (the Gomolava Ib phase). This group consisted of 19 cattle and 5 deer specimens. Traces of deliberate working, such as polishing and perforations, were recorded on some of the bones, which indicate that they might have been used in the production of textiles (Jovanović 2011: 44).

There were altogether around 200 *Bos Taurus* (cattle), *Bos primigenius* (aurochs) and *Cervus elaphus* (red deer) worked astragali bones found in the Neolithic layers at Gomolava. However, these three separate heaps, found in houses 1 and 3, excavated in the 1972, and the house 8, excavated in 1956, were analysed in detail as loom weight collections (Blažić, Radmanović 2011: 129–143).

In contemporary archaeology, proud of its developed critical thought and adopted scientific methods of analysis, temperance and carefulness become desirable qualities, at least when it comes to interpreting the character of the finds regardless of whether the concerns lie in their symbolical or functional nature. When dealing with textile production and technology in their research, textile archaeologists are often subjected to a fair amount of healthy criticism for trying to see textiles and textile work in the find records more often than is supported by the naked facts, which are so cruelly stingy in regards to their perishable and invisible artefact of interest. Thanks to their rareness, archaeological textiles appear to be a curiosity. With only indirect evidence such as tools to rely on, avoiding the curiosity trap in textile archaeology often seems to be quite challenging.

One of the easiest ways to feed the curiosity without falling into its trap is to conduct an experiment. This implies a controlled environment for testing one's hypothesis while recording a protocol, so it is reproducible. Results themselves are not only considered to be valuable arguments, but also at the same time provide analogies, which are often absent in the record.

## TKANJE NA VERTIKALNOM TKALAČKOM STANU

Postoje dvije varijante vertikalnih tkalačkih stanova za koje se smatra da su bile u široj upotrebi tijekom prapovijesti. Prva je vertikalni dvogredni tkalački stan kod kojeg se za napinjanje niti osnove tkanja koristi donja greda. Upravo je zbog toga ovaj oblik ograničen u pogledu dužine tkanine za razliku od druge varijante, tj. vertikalnoga tkalačkog stana s osnovom nategnutom utezima, koja se smatra primjerenijom za tkanje dužih tkanina (Andersson 2003: 29; Barber 1991; Broudy 1979). U usporedbi s dvogrednim tkalačkim stanom (ili drugim tipovima razboja, kao npr. horizontalnim tkalačkim stanom, koji su također mogli biti ustaljeni u upotrebi), prepoznavanje vertikalnoga tkalačkog stana s utezima u arheološkoj evidenciji donekle je jednostavnije jer su utezi, potrebni za napinjanje niti osnove, najčešće su bili rađeni od neorganskih materijala.

Najstariji nalaz okomitoga tkalačkog stana s osnovom nategnutom utezima, koji je datiran u 6. ili čak kasno 7. tisućljeće pr. Kr., pronađen je u neolitičkoj kući na Tiszajenu, poznatom nalazištu Körös kulture u Mađarskoj (Barber 1991: 93). U otprilike isto razdoblje datira i primjer sa Zadubravlja, starčevačkog lokaliteta u Hrvatskoj (Minichreiter 2001: 208).

Pripadnici vinčanske kulture također su se nedvojbeno oslanjali na jednaki način tkanja u proizvodnji tekstila, barem pri izradi nekih od svojih tkanina. Sudeći samo po mnogobrojnim zabilježenim nalazima keramičkih utega za tkalački stan s vinčanskih lokaliteta koji su u novijim istraživanjima evidentirani unutar pouzdanih konteksta (Spasić, Crnobrnja 2014: 192; Orton 2012: 19; Tripković, 2011: 16–18), čini se da su pripadnici vinčanske kulture bili dobro upoznati s određenom tehnologijom što je očigledno u svim fazama i na čitavom prostoru rasprostiranja kulture (Mazare 2012: 31–33; Ninčić 2011: 186–191; Jovanović 2011: 13–45).

Tehnologiju tkanja moguće je utvrditi i na osnovi nekih drugih posrednih dokaza, kao npr. otisaka tkanine. Otisci tekstila mogu ostati sačuvani na različitim materijalima i u raznim okolnostima, no najčešće se pronalaze na keramici. Naime, pošto su tekstili često bili korišteni prilikom proizvodnje keramike, njihovi su tragovi, u obliku otisaka, ostali zapečeni neposredno na keramičke predmete (Cybulska, Maik 2007: 188).

Otisci tkanina relativno su često sačuvani na nalazima vinčanske keramike. Najčešće su konzervirani na donjoj strani posuda (Mazare 2012: 23–26; Ninčić 2011: 181–184) iako ih je moguće pronaći i na drugim keramičkim oblicima (Crnornja et al. 2009: 17; Vasić 1936: 44–45, T. 34). Osim što sugeriraju koje su tehnike i metode bile korištene pri izradi tekstila, također pružaju informacije o proizvodnji keramike i proširuju naš uvid pri istraživanju tradicija obrađivanja gline.

## ASTRAGALI KAO UTEZI

Astragal ili gležanjska kost jedna je od zastopalnih kostiju koja čini skočni zglob između donjeg dijela noge i stopala. Neka njezina svojstva, poput gustoće, kompaktnost i izdržljivosti, čine je neprimjernom za izradu pojedinih alatki

## WEAVING ON A WARP-WEIGHTED LOOM

There are two types of vertical looms, both considered to have been widely used during prehistory. One is called 'tubular', or the two-beam vertical loom, where a lower beam is used for the tension of the warp threads. For this reason it is more limiting in terms of the length of the woven fabric than the other, called the warp-weighted vertical loom, where loom-weights provide the tension, which makes it more suitable for weaving longer fabrics (Andersson 2003: 29; Barber 1991; Broudy 1979). Compared to the two-beamed vertical loom (or other types of looms for this matter, such as the horizontal, that might have been used just as frequently), the warp-weighted vertical loom is relatively easy to recognise in the archaeological record. Loom-weights, which are in this case only needed for warping, were fortunately often made from non-organic materials.

The earliest evidence of the warp-weighted loom is found at a Neolithic house at Tiszajeno, a Körös culture site in Hungary, calibrated to the 6th or even late 7th millennium BC (Barber 1991: 93). There is another Neolithic loom of approximately the same age from Zadubravlje, a Starčevo culture site in Croatia (Minichreiter 2001: 208).

In their textile production, Vinča people undoubtedly also relied on this type of weaving, at least with some of their fabrics. Judging only by the frequently reported loom weight finds from Vinča sites, which are in recent research analysed within stable and recorded contexts (Spasić, Crnobrnja 2014: 192; Orton 2012: 19; Tripković 2011: 16–18), it is apparent that they were well acquainted with this particular type of loom in all phases of the culture and throughout the area of its dispersal (Mazare 2012: 31–33; Ninčić 2011: 186–191; Jovanović 2011: 13–45).

Weaving technology can be confirmed by another form of indirect evidence – that of the imprint. Imprints can be preserved on different materials and in different circumstances, but are most frequently found on ceramics. Textiles were often used in production of pottery, and their traces, which are left on the clay surface, were baked directly onto the objects (Cybulska, Maik 2007: 188).

Sl. 1 Niti osnove napete astragalima i pričvršćene jednostavnim čvorom „na omču"

*Fig. 1 Warp threads wound up around the astragali and secured with a slip knot* (npr. igli, šila, spatula), no istodobno i prikladnom za druge namjene. Uzorci većih životinja, kao oni pronađeni na Gomolavi, te korišteni u eksperimentu, iznimno dobro pristaju u ljudsku šaku. Astragali većih papkara zabilježeni su i na nekoliko drugih vinčanskih lokaliteta, kao što je Selevac (Russell 1900: 38–39), Divostin (Lyneis 1988: 313) te Drenovac. Drenovac iskače kao posebno interesantan zato što su na nalazištu, uz astragale, pronađeni i koštani štapovi, moguće korišteni za vretena i preslice, što može dodatno upućivati na obrađivanje vlakana na lokalitetu (Vitezović 2011: 129–130). Nedavno su, tijekom zaštitnih arheoloških istraživanja na nalazištu Pavlovac–Kovačke Njive u blizini Vranja, pronađena dva goveđa, dva jelenja te dva ovčja astragala, od kojih su neki bili perforirani (Vitezović 2015). Među još nekoliko zanimljivijih primjeraka jesu i tri goveđa astragala, pronađena kod Motela Slatine, od kojih su na dva perforirana uzorka utvrđeni i tragovi dotrajavanja perforacije što upućuje na korištenje tekstilnih vlakana, odnosno niti koje su ostavile tragove korištenja u obliku uskih brazdi (Vitezović 2007: 98–99). Slični tragovi korištenja, zbog urezivanja niti u površinu kosti, zabilježeni su i na dva primjerka svinjskih astragala pronađenih na nalazištu Belovode (Jacanović, Šljivar 2001: 31–32).

Tri specifične kvalitete astragala trebaju se uzeti u obzir prije analize njihove funkcionalnosti u ulozi utega za napinjanje niti osnove tkanine na vertikalnom tkalačkom stanu:

(1) Oblik – jedinstven i prepoznatljiv, iznimno prikladan za upotrebu u vidu konkretnih alatki, uz malo (ili bez) dodatne obrade i oblikovanja.

(2) Niska hranjiva vrijednost – osim kao potencijalni izvor masti, koja se dobiva drobljenjem i mljevenjem kostiju, nemaju medularnu šupljinu, pa ni koštanu srž, dakle nije postojala potreba za njihovim razbijanjem. Nadalje, astragali su relativno male kosti čiji oblik olakšava rezanje kamenim ili metalnim sječivom kroz gležanjski zglob, pri čemu je moguće odvojiti donji dio noge bilo koje životinje, bez potrebe da se siječe kroz kost. Također, zastopalne kosti i kosti stopala (astragali i falange) najčešće ostaju čitave prilikom deranja kože životinja, nakon čega se ostatak trupla najčešće raskomada (Foster 1986), dok one ostaju očuvane za naknadnu upotrebu.

Različiti načini korištenja pojedinih dijelova životinja uvjetovani su kulturom, i nije neuobičajeno da se čak i gležanjske kosti nastoje smanjiti na više manjih fragmenata prilikom naknadnog komadanja, odnosno u kasnijoj fazi mesarenja. Naime, jedno od obrazloženja predlaže da su astragali ipak mogli biti i namjerno lomljeni i usitnjavani u svrhu pripremanja juhe (Mensch 1974).

(3) Pojavljuju se u odgovarajućim parovima – izuzev lubanje i kralježnice, svi ostali dijelovi kostura dolaze u paru, dakle u tom smislu astragali nisu nimalo jedinstveni što ujedno ne objašnjava njihovu širu upotrebu, ali svakako treba uzeti u obzir kao prednost u pogledu praktičnosti pri analizi njihove funkcionalnosti kao utega za tkalački stan.

„Naročito je teško prepoznati prirodne artefakte, organske i mineralne, s minimalnim ili neprimjetnim promjenama i tragovima korištenja koji su mogli biti prikupljani i čuvani

The imprints of woven fabrics are relatively common evidence found on numerous Vinča ceramic finds. They were most frequently preserved on the very bottom of the vessel (Mazare 2012: 23–26; Ninčić 2011: 181–184), but some were found on other ceramic features as well (Crnobrnja et al. 2009: 17; Vasić 1936: 44–45, Pl. 34). They not only tell us more about the weaving techniques, but also provide information on ceramic production and give insight into clay working traditions.

## ASTRAGALI LOOM-WEIGHTS

Astragalus is one of the tarsal bones that form the ankle joint between the lower leg and the foot. It is dense, compact and durable, which makes it unsuitable for some tool types (e.g. needles, awls, spades), but at the same time convenient for other very specific purposes. Specimens from larger animals, like the ones found at Gomolava and used in the experiment, fit particularly well into the human hand. Large ungulate astragali have been reported at several other Vinča sites like Selevac (Russell 1990: 38–39), Divostin (Lyneis 1988: 313), and particularly interestingly, Drenovac. There, bone rods, probably spindles or distaffs that also point to fibre processing, were found alongside astragali (Vitezović 2011: 129–130). More recently, two cattle, two red deer and two ovicaprine specimens (some perforated) were found during the rescue excavations at Pavlovac–Kovačke Njive, in the vicinity of Vranje (Vitezović 2015). Three cattle astragali from Motel Slatina are also among the more peculiar specimens, since two of the perforated bones additionally have a groove running out of the perforation, suggesting textile fibre/thread use (Vitezović 2007: 98–99). Similar cord marks were also recorded on the two pig specimens found at the Belovode site (Jacanović, Šljivar 2001: 31–32).

One should consider three specific qualities of these bones before analysing their possible loom weight function:

(1) Their shape – They are unique and recognisable, very convenient for use as specific tools without much (or any) additional re-shaping.

(2) Their low nutritional value – Except as a potential source of grease, obtained by crashing and grinding them, they have no bone cavity and therefore no bone marrow, so there is no need to break them. Furthermore, they are relatively small-sized and their shape makes it easy to cut through the ankle joint with a (stone or metal) blade, thereby disarticulating the lower leg of any animal without the need to cut through the bone. Also, tarsal bones (astragali, phalanges) are often preserved on an animal in the skinning process, after which the rest of the carcass is butchered (Foster 1986). That of course preserves them perfectly for any additional use.

The different ways of using animal body parts are culturally-specific. Sometimes even astragali bones tend to get reduced to multiple small fragments during tertiary butchery. A suggestion has been put forward that the purpose of this particular practice was for making soup (Mensch 1974).

(3) Their occurrence in matching pairs – Excluding cra-

zbog određenih razloga u prošlosti. To je, dakako, problematično i u slučaju s astragalima koji su u arheološkoj literaturi najčešće evidentirani samo u situacijama u kojima su njihov broj, kontekst pronalaska ili vidljivi tragovi obrade i/ili upotrebe jasno pokazivali da je bila riječ o objektima od posebnog značenja. Razumljivo je očekivati da u arheološkoj dokumentaciji mnogi astragali nisu evidentirani kao predmeti, odnosno alati, nego jednostavno kao kosti, koje su ostale nezabilježene ili neanalizirane. Upravo je to glavni razlog zbog kojeg je pristup podacima o astragalima u arheološkoj dokumentaciji ograničen i nepotpun" (Affanni 2008: 7).

Funkcionalnost, upotreba i simboličko značenje astragala već su naširoko raspravljeni. Doduše, najveća pozornost dosad je bila posvećena ovčjim i kozjim primjercima koji su podrobnije proučavani u različitim kontekstima. Dandoy (2006: 131–137) je analizirao njihovu učestalu pojavu u širem prostornom i vremenskom kontekstu te činjenicu da su pronađene i replike astragala, napravljene od nekoštanih materijala, što je pripisao vjerojatnoj upotrebi u kontekstu igara i proricanja. Sasson (2007: 171–181) je interpretirao astragale iz Tel Beershebe kao moguće žetone, dok je Holmgren (2004: 212–220) predložio da su mogli biti korišteni kao oblik valute. Affanni (2006: 77–92) je sličnim pristupom došao do pretpostavke da su primjerci pronađeni u slojevitom nalazištu Tell Afisa imali zavjetno ili sakralno značenje prilikom konstrukcije građevina. S druge strane, Meier (2013: 166–173) se u svojoj interpretaciji više fokusirala na ispitivanje njihove funkcionalnosti i upotrebe, prije svega kao alatki korištenih pri obradi kože i gline, nego na njihovo simboličko značenje. Popis studija koje se bave ovčjim primjercima je značajna, za razliku od astragala većih domaćih životinja i divljači, koji dosad nisu bili proučavani u jednakoj mjeri.

Prije nego što istražimo prikladnost njihove upotrebe za napinjanje niti osnove na vertikalnom tkalačkom stanu, valja uzeti u obzir različita opažanja drugih eksperimenata s keramičkim utezima. Kao rezultat eksperimenata provedenih u Centru za tekstilna istraživanja Danske nacionalne istraživačke zaklade, moguće je definirati sljedeći odnos između parametra utega tkalačkog stana i tkanine: testovi tkanja s različitim tipovima utega za tkalački stan pokazali su da su za proizvodnju otvorenije (prozračnije) tkanine s debljom pređom potrebni teži i deblji utezi, dok je za tkanje grube, zbijenije tkanine potrebno koristiti teške, ali tanje utege. S druge strane, za proizvodnju otvorene tkanine s tanjim nitima pređe nužni su lakši i deblji utezi, dok tkanje guste tkanine s tankom pređom i više niti po cm$^2$ zahtijeva laganije i tanje utege. Nadalje, obilježja koja također utječu na proces tkanja i kvalitetu tekstila uključuju ravnomjeran položaj utega na tkalačkom stanu te ujednačen raspored i broj niti opterećenih pojedinim utegom (*cf.* Mårtensson et al. 2005/06; 2007a; 2007b; 2009).

Astragali korišteni u eksperimentu (sl. 2 i 3) različitih su težina i debljina te se u njihovu postavljanju nisu mogla slijediti sva pravila preporučena za napinjanje niti osnove na vertikalnom tkalačkom stanu. Zbog različitih je težina

nium and vertebral column, all other skeletal elements come in pairs – hence astragali are not unique in this way and even though that cannot provide an argument for their widespread use, it should certainly be considered as an advantage for their functionality as loom-weights.

"It is particularly problematic to distinguish natural items, organic and mineral, with little if any modification or apparent marks of use, possibly collected and kept for some reasons in the past. This is the case of knucklebones, which in the archaeological literature are generally documented only in the cases in which the number, the particular context or evident signs of modifications indicate clearly that they are to be regarded not as simple ecofacts, i.e. bones, but as objects of particular meaning. In the archaeological documentation it has probably not been duly recorded that many astragali could have had such meaning; probably they were not regarded as objects but simply as bones, as such not interesting and therefore not properly treated. For this reason the access to archaeological documentation on knucklebones is unfortunately limited and partial" (Affanni 2008: 7).

Both the functional use and the symbolical meaning of these bones have been widely discussed. Sheep and goat astragali in particular have been given the most attention and appear more widely researched. Dandoy (2006: 131–137) explored continuous occurrences of astragali bones over a wide spatial and temporal continuum and discussed their use in games and divination, as some of their representations were made of non-bone materials. Sasson (2007: 171–181) interpreted Tel Beersheba astragali as possible tokens, Holmgren (2004: 212–220) also argued that they might have been used as a form of currency and Affanni (2006: 77–92) proposed Tell Afis astragali from foundation deposits had a votive or sacrificial meaning in building. On the other hand, Meier (2013: 166–173), less focused on their symbolical meanings, experimentally tested their function as tools for working hide and clay. The list of research on ovicaprid astragali goes on, but knucklebones that come from large domesticates or game did not receive that much attention so far.

Before exploring their possible function as loom-weights we took into consideration several observations from other weaving experiments on the warp-weighted loom. As a result of experimental research carried out in the Danish National Research Foundation's Centre for Textile Research, the following relationship between the parameters of loom-weights and fabrics may be defined: weaving tests with different types of loom-weights showed that to produce an open fabric with thick yarn, one should choose heavy, thick loom-weights and for weaving a coarse, dense fabric, one should choose heavy but thin loom-weights. On the other hand, to produce an open fabric with thin threads, one should choose light, thick loom-weights and for weaving a dense fabric with thin yarn and many threads per cm$^2$, one should choose light, thin loom-weights. Moreover, the loom-weights set-up: their levelled position, even distri-

| VRSTA/ SPECIES | BROJ UZORKA/ SAMPLE NUMBER | TEŽINA/ WEIGHT | VISINA/ HEIGHT | DEBLJINA/ THICKNESS | ŠIRINA/ WIDTH |
|---|---|---|---|---|---|
| Divlje govedo/Wild cattle *Bos primigenius* | 1 | 176.75 | 87.74 | 51.59 | 64.12 |
| Divlje govedo/Wild cattle *Bos primigenius* | 2 | 148.85 | 87.32 | 52.09 | 61.53 |
| Domaće govedo/Domestic cattle *Bos primigenius* | 3 | 76.40 | 75.37 | 43.40 | 51.18 |
| Domaće govedo/Domestic cattle *Bos primigenius* | 4 | 116.30 | 81.27 | 48.19 | 56.26 |
| Domaće govedo/Domestic cattle *Bos primigenius* | 5 | 58.20 | 63.09 | 37.98 | 44.88 |
| Domaće govedo/Domestic cattle *Bos primigenius* | 6 | 67.80 | 64.58 | 36.72 | 45.03 |
| Jelen/Deer *Cervus elaphus* | 7 | 49.45 | 54.2 | 33.53 | 38.74 |
| Jelen/Deer *Cervus elaphus* | 8 | 53.3 | 54.11 | 32.43 | 38.97 |
| Jelen/Deer *Cervus elaphus* | 9 | 43.20 | 53.44 | 30.44 | 34.69 |
| Jelen/Deer *Cervus elaphus* | 10 | 44.10 | 53.38 | 31.15 | 35.56 |
| Jelen/Deer *Cervus elaphus* | 11 | 57.90 | 56.97 | 34.38 | 38.20 |
| Jelen/Deer *Cervus elaphus* | 12 | 55.5 | 56.94 | 33.09 | 39.27 |
| Jelen/Deer *Cervus elaphus* | 13 | 36.15 | 56.05 | 28.89 | 36.63 |
| Jelen/Deer *Cervus elaphus* | 14 | 37.35 | 55.81 | 29.87 | 37.27 |
| Jelen/Deer *Cervus elaphus* | 15 | 35.55 | 51.38 | 82.32 | 34.22 |

Sl. 2 Težine i dimenzije astragala korištenih u eksperimentu (za detalje mjerenja debljine i širine vidjeti sl. 3)
*Fig. 2 Astragali bones weights and measurements (for measuring thickness and width see Fig. 3)*

bilo nužno rasporediti neujednačen broj niti po pojedinom astragalu. Također, uslijed različitih oblika korištenih primjeraka, kosti je bilo nemoguće postaviti na jednaku visinu. Unatoč tomu, specifična forma astragala je, uz malo dodatne pozornosti, dopustila da se kosti razmjeste usporedno, jedna uz drugu, nalik glinenim utezima ili kalemima/špulama.

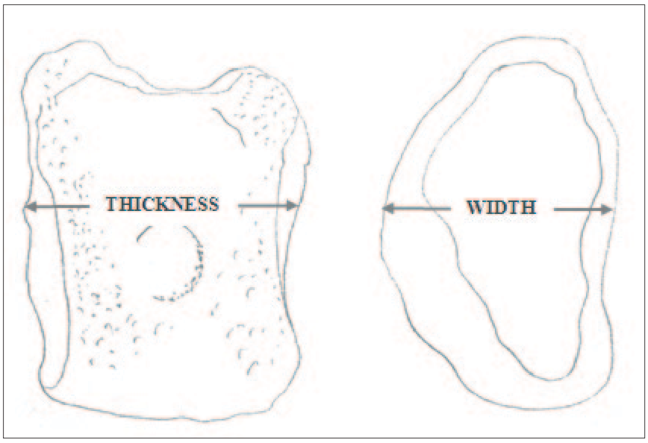
Zahvaljujući obliku i teksturi, korišteni primjerci kostiju pokazali su se podobnim, kako prilikom tkanja tako i tijekom namotavanja niti. Štoviše, glatka površina koštanog materijala omogućuje znatno manje trenja među takvim, koštanim utezima, nasuprot keramičkim primjercima. Nadalje, njihova anatomska obilježja dopuštaju nekoliko različitih metoda privezivanja, uz mogućnost namotavanja dodatne dužine niti (sl. 1).

Među objavljenim primjercima iz kuće 1/1972 (24 primjerka: 3 astragala divljeg goveda, 16 astragala domaćeg goveda i 5 astragala jelena), kuće 3/1972 (18 primjeraka: 12

bution and the number of warp threads attached to a single implement, have been recognized as features that further influence the weaving process and the quality of a textile (cf. Mårtensson et al. 2005/06; 2007a; 2007b; 2009).

The astragali used in the experiment (Fig. 2 and 3) differed in weight and thickness and, therefore, their set up could not follow all the rules suggested for man-made loom-weights. Warp threads needed to be redistributed in varying amounts over each astragali weight and, since they were not homogenous in shape, it was impossible to place them at the same level. However, due to their shape, astragali may be positioned with some care side by side, analogously to clay loom-weights or spools.

Astragali, due to their shape and texture, appeal as very well suited for both weaving and warping. The smooth surface of the material itself suggests less friction between weights than when using ceramic tools. Their anatomical features enable several warping methods with the facility of storing the extra warp length in order (Fig. 1).




Sl. 3 Mjerenje debljine i širine astragala
*Fig. 3 Measuring astragalus thickness and width*

domaćeg goveda i 6 jelena) te kuće VIII/1956 s Gomlove (50 primjeraka: 2 astragala divljeg goveda, 38 astragala domaćeg goveda i 10 astragala jelena) zabilježeno je više parova gotovo identične veličine i težine (Blažić, Radmanović 2011: 132–140).

Kako je pri provedbi eksperimenta na raspolaganju bilo samo 15 primjeraka astragala, posuđenih iz Zavoda za paleontologiju i geologiju kvartara u Zagrebu, nije postojala mogućnost testiranja jedne od potencijalnih postavki astragalnih utega na tkalačkom stanu s Gomolave. Glavni cilj testiranja tkanja s astragalima bila je procjena njihove podobnosti i funkcionalnost u ulozi utega za napinjanje niti osnove te bilježenje i sumiranje iskustva tkanja, s namjerom postavljanja novih i konkretnih pitanja koja će, nadajmo se, biti naslovljena u budućim istraživanjima dotičnih kostiju. Čak i uz samo 15 primjeraka na raspolaganju, postojala je mogućnost odabira između nekoliko varijanti postavljanja osnove tkanja i raspoređivanja utega. Međutim, ograničenost vremenom, dostupnim pređama i samo jednim tkalačkim stanom, uvjetovala je našu odluku da istkamo samo jedan komad tekstila, ali s tri dijela različito postavljenih niti osnove.

Prije objašnjenja rasporeda astragala na tkalačkom stanu, odnosno distribucije opterećenja u svrhu napinjanja niti osnove tkanine, valja napomenuti nekoliko opaski o težini dotičnih kostiju. Svježe kosti koje sadrže znatnu količinu masti su, naravno, osjetno teže od suhih kostiju, poput komparativnih primjeraka korištenih u eksperimentu. Također, zbog mineralizacije i raznih dijagenetskih procesa u tlu, koštani materijal može tijekom vremena (ponovno) dobiti na masi, što je moguće u slučaju iskopanih kostiju. Dakle, glavna rasprava vodi se oko pitanja kakve su kosti mogle biti korištene te kojoj su vrsti pripreme bile podvrgnute prije eventualne upotrebe na tkalačkom stanu. Naime, neki etnografski primjerci strugala za obradu životinjske kože napravljeni od metapodijalnih kostiju (kostiju stopala) imaju ostavljene ligamente kao dio baze/osnove, te su tako korišteni (Steinbring 1966). Uzimajući u obzir specifičnu upotrebu pri izradi tekstila u vidu, za pretpostaviti je da su pri-

Among Gomolava astragali collections from house 1/1972 (24 astragali: three specimens of aurochs, 16 of cattle and five of red deer), house 3/1972 (18 astragali: 12 of cattle and six of red deer) and house VIII/1956 (50 astragali: two specimens of aurochs, 38 of cattle and 10 of red deer) several pairs of almost identical weight and size were identified (Blažić, Radmanović 2011: 132–140).

In the weaving experiment we did not attempt to replicate one of the possible warp or loom setups from Gomolava site, since we were limited to only 15 specimens borrowed from the Institute for Quaternary Paleontology and Geology in Zagreb. Our aim was to test their potential functionality, to record our observations, our weaving experience and to raise some new questions that can hopefully be addressed in prospective research on these peculiar bones. Even with only 15 astragali at our disposition we were able to choose from several possibilities. Being limited by time, available yarns and only one loom, we decided to weave a single piece of textile, albeit with three different warp setups.

Few remarks on the weight of the astragali bones have to be made. Fresh bones, which consist of substantial amount of fat, are naturally heavier than dry bones, such as those that come from the comparative material used in the experiment. Over time, due to the mineralization and various diagenetic processes in the soil, bone can (re)gain mass. This of course takes time and pertains only to excavated bones. The main question is what kind of bones were used and to what kind of preparation they were subjected before their proposed warping function. Even though some ethnographic examples of hide scrapers made on metapodials retain the ligaments and carpals or tarsals as a part of their base (Steinbring 1966), with the specific textile use in mind, one would expect that the astragali bones were somehow prepared in order to remove the grease and obtain a smoother surface. Some of the astragali from Gomolava were burnt (Blažić, Radmanović 2011: 141). It is hard to say whether they were burnt before use, in the process of cleaning and/or working and reworking the bones, or after they were discarded, but it is something that definitely decreased their initial weight.

## WEAVING EXPERIMENT – WARP AND LOOM SETUP

The workshop loom (Fig. 4) used for the experiment was built from roughly shaped and debarked wooden posts and beams with a rather thick cloth beam (ca. 10 cm in diameter) and rods of smaller diameter for the heddle bar and the shed bar (both ca. 5 cm in diameter).

Of the 15 available astragali bones of different weight and size derived from deer, aurochs and cattle, 14 were tested as loom-weights, although only 12 were used for weaving (for detailed information see Fig. 2).

All used yarns were industrially spun. The linen thread we used, its thickness of about 56 wpi (wraps per inch) with tensile strength quite high, was a very fine z-spun single thread (16 Nm, eqv. 62.5 Tex) obtained from Textile Factory

Sl. 4 Vertikalni tkalački stan
*Fig. 4 The workshop loom*

mjerci koji su bili korišteni pri tkanju bili obrađivani u svrhu uklanjanja masti te dobivanja što je moguće glađe površine. Štoviše, neki su od primjeraka s Gomlove bili spaljeni (Blažić, Radmanović 2011: 141). Teško je procijeniti jesu li kosti bile izložene vatri prije upotrebe, tijekom procesa čišćenja i/ili obrade, ili pak nakon što su namjerno odbačene, no gorenje im je svakako smanjilo prvobitnu težinu.

## EKSPERIMENT TKANJA – POSTAVLJANJE OSNOVE TKANINE I RASPOREĐIVANJE UTEGA

Tkalački stan korišten u eksperimentu (sl. 4) bio je izrađen od grubo oblikovanih i od kore oguljenih stativa i klinova okvira, s poprilično debelom gornjom poprečnom gredom za pričvršćivanje tkanine (promjera oko 10 cm). Slični štapovi, samo manjeg promjera (oko 5 cm), iskorišteni su za gornju prečku s nićanicama te donju prečku za razdvajanje (prednjih od stražnjih) niti osnove.

Od 15 astragala različitih težina i veličina koji su nam bili na raspolaganju, podrijetlom od jelena, divljeg i domaćeg goveda, prvotno je 14 kostiju poslužilo za utege za napinjanje niti osnove tkanine. No, samo je 12 primjeraka iskorišteno prilikom tkanja, na konačnoj postavci tkalačkog stana (za detaljnije informacije, vidi sl. 2).

Sve tekstilne niti korištene u eksperimentu bile su industrijski predene, uključujući jednostruki laneni konac vrlo

Trgovišće LCC. It was chosen for the starting border and the warps of the fabric, and partially for its weft. Additionally, two different coloured sheep wool yarns of the same type (Shepherd's Own 100% All Natural Undyed Wool by Fybra-Natura) were used as weft threads. Both were made of three z-spun singles of undyed wool, thickness of 15 wpi (wraps per inch) that were s-plied (2.3 Nm eqv. 434.7 Tex). One was made of three woollen white singles, and the other of one white and two brown singles. The selection of yarns for the experiment was restricted to what was available within the short preparation time. Hand-spun yarns would be advisable for a repetition of a similar experiment. In addition, the decision to combine a linen warp with a woollen weft is not based on actual textile finds, which are usually made from either plant or animal fibres.

The setup of the warp was woven as a starting border with the rigid heddle horizontally tensioned and stretched between two poles for the first few centimetres. Then, a third pole was positioned in approximately 3 m distance orthogonal to the starting border and used for the textile warping (Fig. 5). A modern rigid heddle was chosen because of its high usefulness for an effective weaving of a starting border, without any analogies to an array of textile tools in the Vinča culture.

The starting border warp threads, the same as the warp for the textile, were of the same linen thread. For the star-

Sl. 5 Tkanje početne bordure tekstila i postavljanje niti osnove tkanine („snovanje")
*Fig. 5 The setup of the warp using the starting border*

fine z-pređe (lanena su vlakna uvijana u smjeru kazaljke na satu u jednostruku lanenu nit), debljine oko 56 wpi (*waps per inch* / namota po inču), te visoke vlačne čvrstoće, kojim nas je opskrbila Tvornica tekstila Trgovišće d. o. o. i koja se u komercijalne svrhe prodaje za uvez knjiga. Lanena pređa iskorištena je ponajprije za početnu borduru ili pasicu (rubnu granicu ili porub tekstila) i niti osnove, te dijelom i za niti potke tkanja. Nadalje, dvije pređe ovčje vune istog tipa, ali različite prirodne nijanse (Shepherd's Own 100% All Natural Undyed Wool by FybraNatur) upotrebljene su isključivo za niti potke. Obje vunene pređe bile su tvornički s-prepredene, odnosno uvijene u smjeru kazaljke na satu iz tri jednostruke, z-predene niti (2,3 Nm eqv 434,7 tex i debljine 15 wpi). Jedna od pređa sastoji se od tri jednostruke bijele, a druga od jedne jednostruke bijele i dvije jednostruke smeđe vunene niti. Valja istaknuti da je, prije svega zbog kratkog vremena pripreme eksperimenta, odabir pređi bio znatno ograničen. Naime, u svrhu provođenja sličnih eksperimenata ili u slučaju ponavljanja istog, bilo bi uputno koristiti ručno predene niti. Također, valja napomenuti kako odluka za korištenja lanene osnove i vunenih potki nije utemeljena na stvarnim tekstilnim pronalascima, koji su najčešće bili rađeni ili od biljnih ili od životinjskih vlakana. Iako se ta pretpostavka uvelike temelji na činjenici da su za očuvanje dva različita tipa vlakana nužni bitno različiti i međusobno nekompatibilni uvjeti.

ting border warp, 29 threads were double-warped for strength, but unplied. For the warp of the textile, three different setups were chosen to compare the outcome of different techniques. Each setup was applied for roughly 8 cm of width.

For the first setup only every other weft was used as a textile warp and the weaving in between was used to stabilize the starting border. This setup created a more open warp with a wider space between every other warp thread (3 warps per cm, Fig. 15). It contained in total 18 warp threads for the textile. After a centimeter of weaving back and forth on the starting border the second setup was woven with every weft, resulting in a warp for the textile. This setup resulted in a denser warp (4 warps per cm, Fig. 15) and left the bottom side of the starting border open, since no securing was done through back weaving. A total of 28 central warp threads for the textile were executed in this second setup. Finally, for the third and last part of the textile the same mode of warping of the first setup was used but with a doubled thread, resulting in an even wider warp spacing (2 warps per cm, Fig. 15). Every other weft was back woven into the starting border and every other was used to produce a textile warp. This last part of the textile setup consisted of a total of 14 doubled warps. At the end, the starting border was continued for a few more centimeters in order to secure the set-up. Altogether 60 warp threads

Snovanje, tj. postavljanje niti osnove tkanine, započeto je tkanjem kanice, odnosno početne bordure ili pasice budućeg tekstila. Uz pomoć tkalačke daščice, s horizontalno napetim nitima osnove između dva stupa, istkano je prvih nekoliko centimetara kanice. Zatim je postavljen i treći stup, udaljen 3 m ortogonalno u odnosu na početnu borduru i iskorišten za namatanje niti potke kanice, koje će poslije poslužiti kao niti osnove za testno tkanje (sl. 5). Tkalačku daščicu smo izabrale za tkanje kanice isključivo zbog njezine jednostavne primjene i prikladnosti za izradu početnih bordura tekstila, bez poznatih analogija u okviru širokog raspona tekstilnih alatki vinčanske kulture.

Za niti osnove kanice, odnosno početne bordure tekstila, iskorišteno je 29 dvostrukih, ali neuvijenih niti lanene pređe. Niti su udvostručene u svrhu osiguravanja izdržljivosti i čvrstoće početne bordure. U svrhu postavljanja niti osnove budućeg tkanja, primijenjene su tri različite kombinacije snovanja, prije svega radi mogućnosti usporedbe konačnih rezultata, dobivenih zbog korištenja različitih tehnika. Svaka od tri različite i primijenjene varijante bila je raspoređena na otprilike 8 cm širine tkanine.

Kod prve varijante svaka je druga potka odvojena za nit osnove buduće tkanine, dok je tkanje (provlačenjem svake druge potke neiskorištene za buduću nit osnove tkanja) između njih stabiliziralo tkanje, odnosno kanicu. To je rezultiralo otvorenijom (rijetkom) osnovom, sa širim razmakom između pojedinih niti (3 niti osnove po cm, sl. 15). Prva je varijanta rasporeda osnove tkanja konačno završena jednostavnim provlačenjem potke početne bordure naprijed-natrag, dok nije istkan centimetar kanice bez odvajanja niti, s ukupno 18 niti osnove buduće tkanine, koje su pri svakom odvajanju omotavane oko ortogonalno postavljenog stu-

made up the full width of the textile resulting in a textile width of approximately 25 cm. Due to the restricted time limits for our weaving experience we have decided not to make an attempt in weaving a broader and denser fabric.

Since the warping was always done in the same direction around the third pole, it was possible to separate the front and the back half of the warp threads merely by cutting the warp directly at the pole. The starting border was then removed from the two remaining poles and sewn onto the cloth beam of the loom. Due to the large diameter of the cloth beam, it took a fair amount of thread until the entire starting boarder was sawn and secured (Fig. 6).

Afterwards, the astragali loom-weights were warped on, starting with the back half of the warp. Before tying them to the threads, they were divided into pairs of approximately the same size and weight. In order to spread the astragali weights evenly and assure that the edges of the textile get the most tension, we decided to place the heaviest bones on the far right and far left. The aurochs astragali (Sample Numbers 1 and 2) were placed at the edges of the back warp, providing tension for 6 single and 3 double threads. Then, 4 lighter astragali were chosen for the middle section of the textile. Wrapping on the threads around the astragali and securing them easily with a slip knot at a desired height was extremely easy and gratifying. However, because of the aforementioned differences in size, it was hardly possible to place all astragali weights at the same level.

By putting the shed bar into place, the back half of the warp threads was arranged behind it. After that, the front set of astragali bones was attached in the same mode as in the back – the heaviest astragali were again warped on the

Sl. 6 Postavljanje početne bordure na tkalački stan prišivanjem na gornju gredu za pričvršćivanje tkanine
*Fig. 6 Sewing the starting border to the cloth beam*

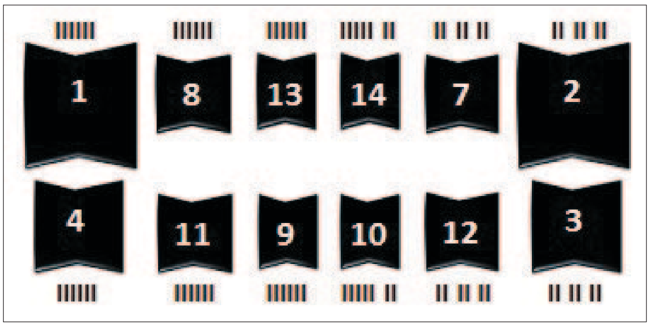
pa. Kod druge varijante, niti za buduću osnovu odvajane su kod svakog provlačenja potke, što je rezultiralo „zatvorenijom" (gustom) osnovom tkanine, s užim razmakom između pojedinih niti (4 niti osnove po cm, sl. 15) i otvorenom donjom stranom kanice, zbog izostavljanja stražnjeg tkanja. Ova postavka sadržavala je sveukupno 28, znatno gušće raspoređenih niti osnove za buduću tkaninu. Kod posljednje, treće varijante primijenjen je sličan način snovanja kao kod prve, ali s odvajanjem dvostrukih (duplih, no neuvijenih) niti potke za buduću osnovu tkanja, što je rezultiralo najvećim razmakom između pojedinih niti (2 niti osnove po cm, sl. 15). Kao i kod prve varijante, niti osnove naizmjenično su odvajane, odnosno za svaku odvojenu nit osnove svaka je druga nit stražnje utkana u kanicu početne bordure. Konačno, posljednji, tj. treći dio postavke tkanine sadržavao je sveukupno 14 dvostrukih niti za osnovu tkanja. Ne bi li se završila početna bordura i osigurala postavljena osnova budućeg tekstila, kanica je istkana još nekoliko centimetara. U tri različite varijante snovanja odvojeno je sveukupno 60 niti osnove tkanja, započetog početnom bordurom od otprilike 25 cm širine. Odabir uske širine tekstila i relativno otvorenih osnova tkanine uvjetovan je ponajprije ograničenim vremenom koje je bilo predviđeno za eksperiment tkanja s astragalima.

Budući da su sve niti osnove prilikom snovanja bile omotavane uvijek u istom smjeru oko trećeg, u odnosu na kanicu, ortogonalno postavljenog stupa, odvajanje prednjeg od stražnjeg dijela osnove bilo je uvelike pojednostavljeno i izvedivo prerezivanjem niti na mjestu omatanja. Početna je bordura po skidanju sa stupova postavljena na tkalački stan, prišivanjem na gornju gredu za pričvršćivanje tkanine. Za prišivanje kanice početne bordure na grubu gredu velikog promjera bila je potrošena velika količina lanene pređe (sl. 6).

Nakon postavljanja početne bordure, uslijedilo je postavljanje utega (astragala) na tkalački stan, njihovim namotavanjem na niti osnove tkanja, počevši od niti stražnjeg dijela osnove. Prije nego što su iskorišteni za napinjanje niti, uzorci kostiju podijeljeni su u parove slične veličine i težine. Najteži su astragali raspoređeni na krajnji desni i lijevi rub ne bi li se postigla ravnomjerna napetost tkanine. Astragali divljeg goveda (uzorak 1 i 2) iskorišteni su za napinjanje rubnih niti stražnje osnove, namotavanjem šest jednostrukih i tri dvostruke niti. Zatim su postavljena i četiri lakša koštana uzorka, radi zatezanja srednjeg dijela tkanine. Namotavanje niti oko astragala te njihovo osiguravanje na željenoj visinu, izvođenjem jednostavnog čvora „na omču", bilo je brzo i nekomplicirano. Doduše, zbog već raspravljenih razlika u dimenzijama, bilo je skoro nemoguće rasporediti i pričvrstiti sve uzorke na jednaku visinu.

Nakon što je uglavljena na mjesto, tj. odgovarajuću visinu osiguranu klinovima zabijenim u okvirne stative tkalačkog stana, niti stražnje osnove tkanine raspoređene su iza donje prečke. Potom su, na jednak način kao i kod stražnjeg, uzorci prednjeg seta astragala pričvršćeni na niti prednje osnove tkanine – najteže su kosti raspoređene na rubne niti, dok su preostala četiri primjerka, u silaznom redu težina, pričvršćivana prema sredini tkanine (sl. 7).

Nakon što su sve niti osnove bile raspoređene, prema ovoj, prvobitnoj postavci tkalačkog stana, tri primjerka ko-




Sl. 7 Shema prvotne postavke tkalačkog stana (s ukupno 60 niti osnove)

*Fig. 7 Initial setup scheme (thread count 60)*

outermost warp threads and the other 4 lighter specimens were warped in decreasing weight order towards the centre of the textile (Fig. 7).

Three astragali were left unattached (Sample Numbers 5, 6 and 15) after all the warp threads were arranged according to this initial loom set-up. A separate spacer thread of wool yarn was chained around both front and back part of the warp, which helped to maintain the distances between the threads (Fig. 8).

Finally, to finish the set-up of the loom, a heddle was knitted around the heddle bar using the same linen thread that was used for the warp and the starting border (Fig. 9). Knitting the heddle proved straining for the single warps attached to the aurochs astragali and after one warp broke, the heaviest astragali (Sample Numbers 1 and 2) were replaced with lighter cattle bones (Sample Numbers 5 and 6) in the final setup (Fig. 10 and 11).

## WEAVING EXPERIMENT – RESULTS

Even with bones of different weight and size derived from deer, aurochs and cattle, it was possible to eventually arrange them so they provide the appropriate weight tension per thread. Although it was impossible for us to position them to the same height, they remained stable while hanging side by side. Warp threads hung vertically and were evenly distributed. Due to the smoothness of the weight material, the shedding was very pleasant, which resulted in an even and regular weaving pace. Inserting the weft was easy and enjoyable. The warp threads hung safely in the bones' natural notch and the length of the warp was easily adjustable (Fig. 12). We felt that weaving on the warp weighted loom with astragali was similar to weaving with spool-shaped objects applied as loom-weights.

The weaving was done over all warp threads regardless of the different setups. The different densities of the warp setup resulted in very different appearances (Fig. 15) of the three parts in the final textile, with dimensions of 10.309 x 26.8 cm and weight of 11.05 grams. The middle part, having the densest warp spacing, left the warp threads visible between the wefts, but resulted in an almost balanced weave, even though weft threads of considerably different thickness were used. The outer two parts of the textile, more widely spaced, showed a clear weft faced weave, which stiju ostala su neiskorištena (primjer 5, 6 i 15). Zasebna nit vunene pređe poslužila je za lančano opletanje svake pojedine niti osnove u pletenicu ne bi li se fiksirao i osigurao razmak među njima (sl. 8).

Konačno su, kako bi se završilo postavljanje tkalačkog stana, ispletene i nićanice za gornju prečku. Za pletenje nićanica korištena je ista lanenu pređa kao i za osnovu i početnu borduru tkanine (sl. 9).

Pri konačnoj postavci tkalačkog stana (sl. 10 i 11), najteži uzorci kostiju, tj. astragali divljeg goveda (primjer 1 i 2), zamijenjeni su lakšim primjercima domaćeg goveda (primjer 5 i 6), jer je prilikom pletenja nićanice jedna od niti osnove pukla pod suvišnim opterećenjem, odnosno zbog prevelike težine astragala.

## EKSPERIMENT TKANJA – REZULTATI

Unatoč tomu što su komparativni uzorci astragala jelena, divljeg i domaćeg goveda bili različitih težina i dimenzija, naposljetku ih je bilo moguće postaviti tako da su osiguravali odgovarajuću težinu i napetost po niti osnove. Iako je kosti bilo nemoguće napeti na jednaku visinu, stabilno su visjele jedna do druge. Tijekom tkanja, niti osnove bile su ravnomjerno raspoređene i vertikalno obješene. Zbog glatkoće koštanog materijala, pomicanje gornje prečke (prečke s nićanicama) naprijed-natrag bilo je iznimno ugodno što je rezultiralo uravnoteženim i regularnim tempom tkanja. Niti osnove visjele su osigurane u prirodnim ulegnućima kostiju te je njihova dužina, prema potrebi, bila lako prilagodljiva (sl. 12). Tijekom eksperimenta sve su tkalje primijetile da ih tkanje s astragalima podsjeća na tkanje s utezima u obliku kalema.

Neovisno o tri različite varijante postavke, potku se provlačilo istodobno kroz sve niti osnove. Tri različite gustoće niti osnove rezultirale su prilično drugačijim izgledom (sl. 15) pojedinih dijelova tkanine, konačnih dimenzija 10,309 × 26,8 centimetara i težine 11,05 grama. Središnji dio tkanine koji je imao najgušće postavljenu osnovu, ostavio je vidljive niti osnove između potki. Dapače, rezultirao je skoro ujednačenim tkanjem iako je vunena pređa korištena za niti potke bila značajno različite debljine. Dva rubna dijela tkanine gdje su osnove bile otvorenije, odnosno rjeđe postavljenih niti, rezultirala su licem tekstila očite potke, što je uvjetovalo i veći broj niti potke po centimetru. Nepravilni izgled tkanine može se pripisati kako različitoj gustoći (zbog tri primijenjene varijante snovanja) tako i nejednakoj napetosti niti pojedinih dijelova osnove. Polazeći od pretpostavke da prapovijesni astragali nisu bili vagani prije upotrebe, u eksperimentu su napinjani u parovima na parne i neparne niti osnove u skladu s veličinom, a ne težinom. U skladu s time, napetost osnove varirala je od 19,38 do 9,7 grama po niti kod bočnih utega te od 7,4 do 6 grama po niti kod utega postavljenih u sredini. Relativno mali broj niti po astragalu, u kombinaciji sa znatnom širinom pojedinih primjeraka kostiju, utjecao je na veću otvorenost (prozračnost) tkanine, konkretno u njezinim rubnim dijelovima, tj. u slučaju prve i treće varijante osnove.

Sve je to utjecalo da se gušći, srednji dio tkanine zakrivljuje prema dolje, dok je na bočnim dijelovima potka ostajala znatno zbijenija (sl. 13). Nepravilnosti su na oba kraja tkanine ispravljene ubodnim tkanjem naprijed i natrag (sl.

Sl. 8 Vunena pređa lančano opletena oko svake pojedine niti osnove
*Fig. 8 Spacer thread of wool yarn chained around warp threads*

Sl. 9 Nićanice na gornjoj prečki tkalačkog stana
*Fig. 9 Knitted heddle around the heddle bar*

allowed more weft threads to be put in per cm. The irregular outcome may therefore be attributed to the difference in both warp spacing as well as warp tension. Assuming that astragali had not been weighted in the past, we connected them in pairs for even and uneven warp threads according to their size, not weight. The warp tension differed accordingly, from 19.38 to 9.7 g per thread for the side weights, and from 7.4 to 6 g per thread for the middle ones. Small number of warp threads attached to a single astragali combined with the thickness of the bones also resulted in a more open weave, especially in the case of the warp setup I and III.

All this resulted in the middle denser part of the textile curving down, while on both side sections the weft appeared considerably more compressed (Fig. 13). These irregularities in the weave on both sides were fixed by 'weaving wedges' or 'gores' back and forth into the textile (Fig. 14). The corresponding technique for managing irregular weaving has been recognized, for example, in the capes from Muldbjerg and Borum Eshøj, as reported by Barber (1991: 177, Fig. 6.5) as well as from Bronze Age Hallstatt textiles (Grömer 2013: 67, Fig. 22). Barber (1991: 177) attributes the-

14). Barber objašnjava upotrijebljenu tehniku korištenu za ispravljanje sličnih nepravilnosti pri tkanju (1991: 177, sl. 6.5) na primjerima plašteva iz Muldbjerga i Borum Eshøja. Ista je tehnika utvrđena i na brončanodobnim nalazima tekstila s Hallstatta (Grömer 2013: 67, sl. 22). Također, takve nepravilnosti moguće je pripisati manjku kontrole napetosti osnove, na osnovi čega je moguće pretpostaviti da su dotični tekstilni nalazi biti tkani na vertikalnom dvogrednom tkalačkom stanu, bez mogućnosti podešavanja napetosti osnove (Barber 1991: 177). S druge strane, prema Grömer (2013: 67), te su greške vjerojatno rezultat nedovoljnog sabijanja potke. Naposljetku, moguće je i da je ubodno tkanje bilo namjerno primjenjivano zbog proširivanja tkanine ili čak zbog dekorativnih razloga.

Jedna od očitih prednosti vertikalnoga tkalačkog stana s utezima, odnosno mogućnost prilagođavanja napetosti niti osnove ili barem grupa niti osnove, bila je samo neizravno testirana u eksperimentu. Zbog znatno drugačije postavljene osnove za tri različita dijela tekstila, što je rezultiralo rasponom od 2 do 4 niti osnove po centimetru (sl. 15), nije se ni mogla očekivati pravilna tkanina. Imajući to na umu, u slučaju ponavljanja sličnog eksperimenta bilo bi uputno koristiti ujednačeno postavljene niti osnove ne bi li se podrobnije testirala funkcionalnost utega i kod klasičnog tkanja.

## EKSPERIMENT S KALEMOM

U okvirima tekstilne arheologije, manji keramički predmeti cilindričnog oblika često su interpretirani kao kalemi ili špule, odnosno tip alatke korišten za namotavanje niti, tj. pređe. Tijekom eksperimenta tkanja, namatanje niti osnove na utege (astragale) pokazalo se vrlo ugodno i jednostavno. Također, pošto smo se uvjerile da prirodan oblik kostiju omogućuje, vrlo praktično, pohranu viška niti osnove, odlučile smo posebno testirati njihov kapacitet namotaja.

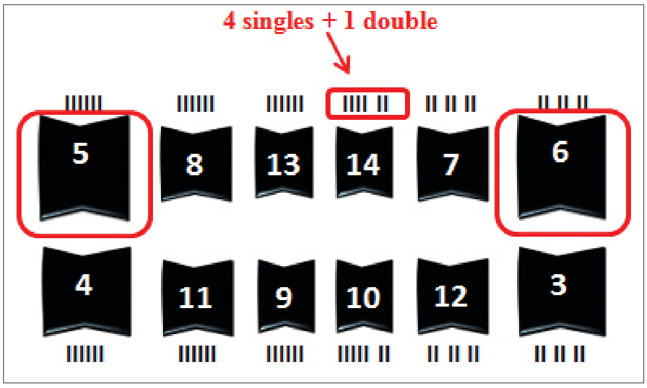
Na astragal običnog jelena, primjerak broj 15 (sl. 2), namotano je oko 80 metara lanene niti, iste kakva je korištena u eksperimentu tkanja. To je približno maksimalna dužina koju je bilo moguće pohraniti u prirodnom 'sedlastom' udubljenju između medijalnih i lateralnih grebena kosti, bez straha da se lanena nit odmota ili sklizne sa strane (sl. 16).

Oblik astragala pokazao se podobnim za držanje 'kalema' u jednoj ruci, što oslobađa drugu ruku za namotavanje pređe na kost, pritom osiguravajući namotanu nit. Prirodna glatkoća kosti, čak i kod neobrađenih primjeraka kakvi su korišteni u eksperimentu, predstavlja dodatnu kvalitetu zbog koje su se astragali pokazali prikladnim i ugodnim pri radu s pređom.

## NA TRAGU ZAKLJUČKA

Za interpretaciju pojedinih artefakata kao tekstilnih alatki ponajprije valja utvrditi njihova funkcionalna svojstva, pa tako i pozicionirati njihovu uporabu u lancu operacija (*chaîne opératoire*) proizvodnje tekstila. Čini se dosta jednostavno, no, na primjeru astragala s Gomolave, jasno se nazire kako kritika definicije proizlazi iz pokušaja raščlanjivanja stvarne funkcije od puke funkcionalnosti, odnosno uporabnog potencijala.

Iako smatramo da su eksperimenti s astragalima uspješno dokazali barem dio potencijala i više aspekata njihove funkcionalnosti, ipak nismo uspjele dati konačan odgovor




Sl. 10 Shema konačne postavke tkalačkog stana (ukupno 59 niti osnove)
*Fig. 10 Final setup scheme (thread count 59)*

se irregularities to a lack of control of the warp tension and therefore concludes that the loom used for these garments might have been a vertical two-beamed loom without the option to adjust the warp tension. On the other hand, according to Grömer (2013: 67), these errors are more likely a result of the irregular weft beating. Gores may have also been inserted intentionally in order to widen the fabric and, perhaps, for decorative effects.

One of the clear advantages of the warp weighted loom – the adjustability of the tension of the single warps or groups of warps – was tested in our experiment only indirectly. Due to the three warp setups resulting in uneven densities (2 to 4 warps per cm) (Fig. 15) of the different sections of the textile, a regular weave could not be expected. Having this in mind, for repeating the experiment, it would be advisable to set up a single warp for the entire textile in order to test the functionality of the weights for a more regular performance.

## SPOOL EXPERIMENT

Relatively small sized ceramic artefacts of cylindrical shape that often have prominent ends are commonly interpreted as spools, or textile tools used for thread coiling. During the weaving experiment, using astragali for thread warping proved to be very easy and simple. At the same time the bones, due to their shape, allowed for storing of extra warp. This led us to test their spooling capacity.

The red deer astragalus bone under the sample number 15 (Fig. 2) was used to spool ca. 80 m of the same linen thread used for weaving. This was roughly the maximum length that could be stored in the natural notch between the medial and lateral ridges of the bone without the thread uncoiling or sliding off the sides (Fig. 16).

Astragalus shape proved to be functional for holding the bone in one hand and spooling with the other, while securing the stored thread. The natural smoothness of the bone, even of the unworked specimen like the one used, proved to be another feature which makes astragali suitable and comfortable for handling threads.

Sl. 11 Astragali korišteni u konačnoj postavci tkalačkog stana
*Fig. 11 Astragali bones used in the final setup*

Sl. 12 Niti osnove tkanine napete astragalima u završnoj postavci tkalačkog stana
*Fig. 12 Warped astragali loom weights in the final setup*

Sl. 13 Gušći, srednji dio tkanine zakrivljen prema dolje
*Fig. 13 Curving down of the middle denser part of the textile*

na pitanje treba li se među brojne funkcije koje su mogli imati, ubrojiti i upotreba pri tkanju tekstila i namotavanju niti.

Pored praktičnosti i funkcionalnosti koje su potvrđene eksperimentom, tragovi korištenja i obrade također podupiru hipotezu da su dotični koštani predmeti imali svoje mjesto u tekstilnoj tehnologiji, konkretno kao utezi za tkalački stan i kalemi za namotavanje pređe. Nažalost, oba tipa tragova na kostima nerijetko upućuju na njihov višenamjenski karakter. Nadalje, naši kratki eksperimenti tkanja i namatanja nisu bili predviđeni niti planirani za odgovaranje na taj tip (tafonomskih) pitanja. Opetovana i učestala upotreba astragala kao utega na tkalačkom stanu bi u dugoročnijoj varijanti eksperimenta trebala rezultirati tragovima korištenja, prije svega zbog napinjanja i namatanja niti (zbog trenja između kostiju i pređe), te tkanja (zbog trenja kosti o kost). Dugoročniji eksperiment bi dakle mogao rezultirati i nužnim komparativnim materijalom što bi olakšalo utvrđivanje upotrebe dotičnih kostiju u proizvodnji i obradi tekstila.

Među astragalima koji su iskopani u kućama na Gomolavi, konkretno u slučaju primjeraka koji se podudaraju, kako po dimenzijama tako i po težini (što upućuje da su pojedini parovi pripadali istoj životinji), primijećene su polirane površine koje navode na pretpostavku da su odgovarajući parovi astragala (kost lijeve i desne noge) bili zajedno pri-

Sl. 14 Ispravljanje nepravilnosti na oba kraja tekstila tehnikom ubodnog tkanja
*Fig. 14 Fixing of the irregularities in the weave on both sides of the textile performed by "weaving wedges"*

## IN LIEU OF A CONCLUSION

To define an archaeological find as a textile tool presumes its functional role in the "chaîne opératoire" of textile production. It seems quite simple, yet criticism arises when we try to distinguish the actual function from a mere functionality. With the hope of having proved some new aspects of the astragali functionality, we are still unable to answer if

| | 1. varijanta/ 1st Setup | 2. varijanta/ 2nd Setup | 3. varijanta/ 3rd Setup |
|---|---|---|---|
| Lanena osnova/ Linen warp | 3 | 4 | 2 |
| Potka od bijele vune/ White wool weft | 5 | 4 | 4 |
| Lanena potka/ Linen weft | 14 dvostrukih / double | 11 dvostrukih / double | 17 dvostrukih / double |
| Potka od smeđe vune/ Brown wool weft | 3 | 3 | 3 |

Sl. 15 Istkani tekstil s prikazom broja niti po centimetru
*Fig. 15 Woven textile - threads per centimetre*


Sl. 16 Lanena pređa namotana na astragal
*Fig. 16 Linen thread wrapped on the atragalus spool*

čvršćivani na niti osnove s dorzalnim stranama okrenutima jedna prema drugoj (Blažić, Radmanović 2011: 132, 136). Dodatni eksperimenti posvećeni testiranju ove i drugih varijanti, kako napinjanja tako i namatanja, tj. pričvršćivanja niti osnove na astragale, mogli bi pružiti analogije i poduprijeti pretpostavke o korištenju različitih metoda za postavljanje kostiju na tkalački stan. Neki primjerci s Gomlove koji imaju jednu ili više perforacija, vjerojatno upućuju na različitu tehniku namatanja i pričvršćivanju astragala kod napinjanja niti osnove, od one primijenjene u eksperimentu tkanja, stoga preporučujemo dodatno testiranje nekoliko različitih metoda u budućim eksperimentima. Suvišno je napomenuti, ali postavljanje parova astragala s međusobno okrenutim dorzalnim stranama zajedno na niti, moglo bi poduprijeti interpretaciju da su evidentirani tragovi trenja na uzorcima astragala s Gomolave uzrokovani specifičnom tehnikom postavljanja na niti osnove tkanja (Blažić, Radmanović 2011: 132, 136).

Međutim, može se pretpostaviti da su kod odabira i korištenja ovakvih utega, nevezano za metodu namotavanja i napinjanja niti osnove, bili korišteni parovi astragala uzeti od iste životinje. Imajući na umu takvu pristupačnost i pogodnost alatki, očito je kako su astragali mogli uvelike pojednostaviti postavljanje tkalačkog stana, odnosno napinjanje niti osnove tkanine, olakšavajući ravnomjernu raspodjelu težine po niti. Širina i oblik utega tkalačkog stana pokazale su se kao bitne karakteristike koje uz težinu značajno utječu na proces napinjanja i raspoređivanja niti osnove tkanine. Parametar težine prije svega određuje broj niti po utegu, s obzirom na to da uvjetuje napetost, dok širina i oblik utječu na izgled, odnosno širinu i otvorenost tkanine. Stoga je kombinacija obiju varijabli krucijalna za matrice ili sheme, kako osnove tkanine tako i rasporeda utega na tkalačkom stanu. Zahvaljujući njihovim anatomskim osobinama koje omogućavaju da se više astragala zajedno postavi kao jedan uteg, čini ih, ne samo podobnima, nego i praktičnima za različite kombinacije napinjanja i pričvršćivanja niti osnove tkanine. Nadalje, kako uravnotežena napetost niti omogućuje ugodnije tkanje, kosti jednake ili slične težine (ne nužno, ali uput-

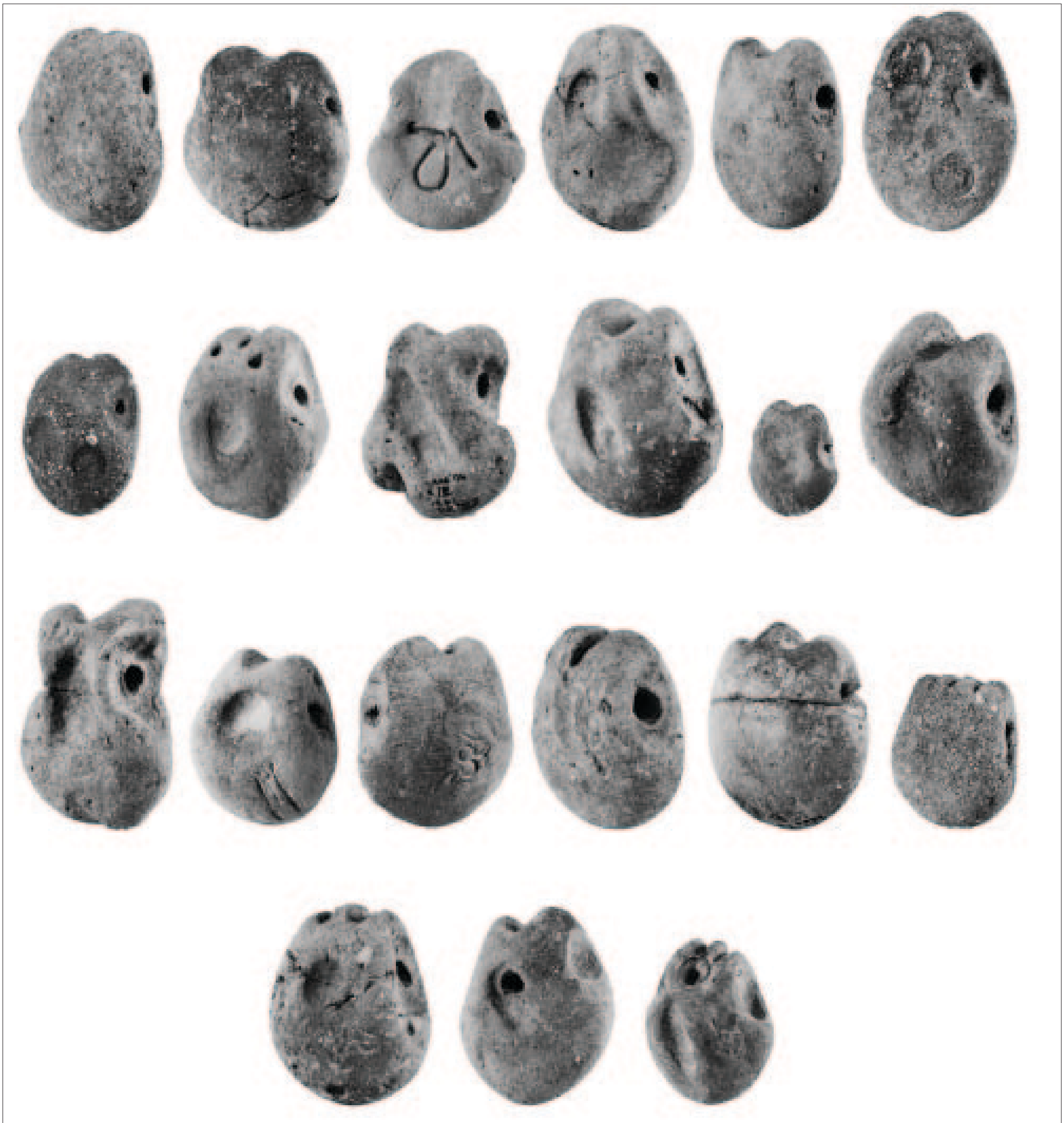
weaving and spooling were indeed among the presumably many functions they had.

What helps to support the hypothesis that some of the astragali bones belonged to the context of textile production, particularly weaving and spooling – besides their practicality and functionality, proven by the experiment – are the recognisable marks of use-wear and working. Unfortunately, both types of marks on the bones are often ascertainable for a single use and our weaving experiment was not designed or planned to answer questions on this particular issue. Their repetitive use as loom-weights in a longer term experiment could be helpful in providing control of marks in the case of use-wear from both warping (textile material to bone) and weaving (weight to weight/bone to bone) friction.

Examples with polished surfaces that correspond in size and shape, which suggest that they were used in pairs that belonged to the same animal – as right and left – with their dorsal sides facing each other – were found among the specimens from the three houses at Gomolava (Blažić, Radmanović 2011: 132, 136). Experiments exploring several different combinations of both warp and loom setups would certainly provide further insight regarding this possibility. Several specimens from Gomolava, which have one or more apertures, suggest different method(s) of warping than the one applied in the experiment. These should therefore be tested in the future. Needless to say, the testing of a pair of astragali tied together with their dorsal sides facing each other and used as a single loom-weight could further support the recorded traces of friction found on some of the Gomolava specimens (Blažić, Radmanović 2011: 132, 136) as the use-wear caused by a particular warping technique.

It is likely to presume that both astragali from a single animal would have been selected and used for loom-weights, regardless the warping method. This assumptive accessibility and convenience would facilitate a loom setup, where an even distribution of weight per thread is required. While warping, not just the weight, but also the thickness and the shape of the loom-weights have proved significant. Weights dictate the number of threads per loom, depending on the tension they provide, and thickness dictates the width of the textile being woven. Thus, the combination of both measures becomes crucial for setting up both the warp and the loom matrix. Thanks to their anatomical traits and the option to warp more astragali as a single loom makes them equally practical for different combinations of setups. Furthermore, having bones with corresponding or similar weights at hand (not necessarily from a single animal) is an advantage, since using the same tension provides more comfort during the weaving. Consequently, this results in a more even weave of the fabric.

Further experiments with astragali that would include different options of warping and different setups should be pursued to determine and record types and levels of friction wear indicative for weaving, which could occur due to the repetitive changing of the shed. Repetitive spooling tests should be undertaken to observe and record the handling as well as the fibre material polish wear. Without these experiments it is hard to eliminate the possibility that the polish and striated friction wear recorded on the specimens



Sl. 17 Ovalni utezi (fiddle-shaped) za tkalački stan s lokaliteta Krševica (Popović, Vranić 2006: 311, sl. 2)
*Fig. 17 Oval or fiddle-shaped loom weights from Krševica (Popović, Vranić 2006: 311, Fig. 2)*

no od iste životinje) predstavljaju prednost koja posljedično rezultira pravilnijom i ravnomjernijom tkaninom.

Daljnji eksperimenti s astragalima trebali bi uključivati razne metode napinjanja i pričvršćivanja osnove kako bi se omogućilo utvrđivanje tipa i jačine trenja zbog tkanja, tj. repetitivnog pomicanja gornje prečke tkalačkog stana. Isto tako, trebalo bi ponoviti testiranje namotavanja pređe na astragal koji bi kroz duže razdoblje bio upotrebljavan kao kalem, u svrhu dokumentiranja stupnja izlizanosti kosti, zbog finog trenja tekstilnih vlakana pređe. Bez dodatnog ispitivanja dugoročne i ponavljane upotrebe astraga-

from Gomolava came from other types of use, such as burnishing and/or polishing (Meier 2013: 166–173; Bolomez, Marinescu-Bîlcu 1988: 347).

It should be pointed out that the bones used in the experiment cannot be qualified as tools. We used prepared (boiled and dried) specimens, which were by no means worked. Unworked astragali proved to function perfectly as loom-weights, so this is another obstacle when trying to interpret their appearances in the archaeological record. If not used repetitively for a longer period of time, it is less likely for them to show the textile related use-wear marla, nemoguće je eliminirati mogućnost da su primijećene promjene na uzorcima s Gomlove posljedica drugih načina korištenja kostiju, npr. kao glačalica (Meier, 2013: 166–173; Bolomez, Marinescu-Bîlcu 1988: 347).

Također, valja napomenuti da komparativni uzorci kostiju koji su korišteni u eksperimentu tkanja *de facto* ne spadaju u kategoriju tekstilnih alatki. Neobrađeni primjerci astragala iz komparativne zbirke Zavoda za paleontologiju i geologiju kvartara u Zagrebu, doduše, jesu bili pripremljeni (prokuhani i osušeni) tijekom procesa čišćenja kostiju. Zaključno, astragali bez ikakve dodatne obrade pokazali su se jednako iznimno prikladnima za upotrebu umjesto utega na tkalačkom stanu što naravno predstavlja prepreku pri pokušaju interpretacije njihova značenja i/ili funkcije u arheološkoj evidenciji. Ako nisu bili učestalo korišteni, tj. ako njihova upotreba u proizvodnji tekstila nije trajala duže vrijeme, vjerojatnost pronalaženja karakterističnih tragova korištenja vrlo je mala (posebno ispoliranost i ulaštenost u prirodnim usjecima kosti koji su iznimno pogodni za osiguravanje namotane niti). Uzmemo li u obzir potencijalnu raznolikost njihove primjene (multifunkcionalnost), jasno je da očiti tragovi obrade i korištenja na astragalima kao i njihova perforacija (koje su se pokazale kao suvišne kod najmanje jedne tehnike namatanja i pričvršćivanja na niti osnove) ne spadaju među bitne, a još manje odlučujuće karakteristike njihove funkcionalnosti i praktičnosti unutar konteksta tekstilne proizvodnje. U skladu s time, one primjerke kod kojih se primjećuju spomenute karakteristike ne bi trebalo pripisivati isključivo tekstilnoj proizvodnji jer, štoviše, iste mogu upućivati i na druge oblike upotrebe. Vrlo je vjerojatno da su astragali mogli imati više funkcija te je u tom slučaju vrlo komplicirano i nezahvalno zaključivati koja je od mogućih primjena bila primarna. Nažalost, na komparativnom setu astragala, korištenom u našem *ad hoc* eksperimentu tkanja, dokumentacija tragova korištenja nije bila moguća. U tu svrhu, tkanje s astragalima moralo bi trajati znatno dulje i biti ponavljano više puta.

Dodatni argumenti za njihovu upotrebu kod napinjanja niti osnove tkanine na vertikalnom tkalačkom stanu svakako treba tražiti u kontekstu i posebno u broju te dimenzijama i težinama pronađenih primjeraka. Imajući to na umu, odgovarajuća kolekcija astragala, pronađena u redovima, predstavljala bi izravan dokaz da su bili korišteni kao utezi za tkalački stan. Iako, bez imanja njihova potencijala za napinjanje i namatanje niti na umu ne samo da je moguće nego je i vrlo vjerojatno da su pojedine slične *in situ* situacije bivale previđene i nezabilježene na terenu, posebno u kontekstu starijih istraživanja. Međutim, svako njihovo pojavljivanje u parnim brojevima, osobito u parovima slične težine i dimenzija, moralo bi se detaljnije istražiti za mogućnost upotrebe u proizvodnji tekstila. Nažalost, tekstilne alatke rijetko bivaju analizirane i objavljene kao zasebna cjelina, stoga velika većina koštanih alatki za proizvodnju i obradu tekstila završava u zooarheološkim izvješćima i ostaje zanemarena od strane tekstilnih arheologa, konkretno stručnjaka koji se bave tehnikama tkanja i koji su uglavnom upućeni na utege napravljene od uobičajenih materijala, kao što su nepečena glina, keramika i kamen. Nadalje, astragali, koji zbog izostanka tragova obrade, pa i uporabe, nisu interpretirani kao koštane alatke, imali su još manju šansu biti objavks (especially polish and/or shine expected in the natural notches of the bones, which proved suitable for storing of the thread) that could possibly prove their connection to weaving. Considering their apparent multiplicity of uses as textile tools (loom-weights/spools) without even minimal modifications on the bones, it seems that the heavy use wear marks, large abraded surfaces, even perforations (proved to be redundant for at least one warping technique) are not crucial features of their warping function. Therefore, the specimens that show these characteristics should not be exclusively attributed to the textile use. It is likely that they had many functions and, in this case, it is quite difficult to argue which was the primary one. Unfortunately, no use-wear marks were observed or documented on the bone specimens used for the ad hoc weaving experiment. The weaving part of the experiment should have been repeated or at least lasted longer to provide more information on the expected traces from the weight to weight friction.

Further prospective arguments for their use on a warp weighted vertical loom should be looked for in their in situ contexts and numbers. Finding an appropriate collection of astragali arranged in rows would be a clear indication of a plausible loom setup. However, without keeping their practical potential for warping in mind it is possible and quite probable that suggested situations were previously left overlooked and unrecorded in the field, especially in old excavations. Their occurrences in even numbers, particularly if found in pairs of similar weight and thickness, should be analysed for textile use in more detail. Unfortunately, in most of the archaeological publications, textile tools are rarely reported in their complete assemblages. The majority of bone textile tools analysed in the zooarchaeological reports are often overlooked by textile archaeologists that specialise in weaving, while their main finds of interest are mainly loom-weights made of more common materials, such as fired or unfired clay, and stone. Astragali that did not qualify as bone tools have even less chance of being published and/or thus noticed by the textile experts.

Although many of the textile tools from Gomolava still remain unpublished in detail, reported evidence of textile production during the Neolithic phase of the settlement suggests a fairly developed weaving technology. The amount of worked astragali bones (200) definitely comes close (if not even exceeds) to the total number of conventional clay weights dated to the Vinča settlement phase. It is very likely that these bones were multifunctional and their use in textile production should not be disregarded. The high occurrence of conventional loom-weights at the site raises a particular question of whether, despite their natural features that make them equally functional (e.g. the texture and the peculiar shape), there was a specific reasoning behind this specific use of the astragali bones. Having in mind that a sufficient set of astragali could have been collected only during a certain period of time, it is hard not to presume that these sets might have had a distinct purpose, or even meaning, at least in the context of textile manufacture.

One final remark about a curious type of clay loom-weights, which somewhat resembles an astragalus bone (and it is for that reason that some authors designate these weights as astragali) should be made as a separate ljeni te primijećeni od strane tekstilnih arheologa.

Iako velik broj tekstilnih alatki s Gomolave još uvijek nije detaljno obrađen, dosad istraženi i objavljeni dokazi proizvodnje upućuju na razvijenu tekstilnu tehnologiju tijekom neolitika. Ukupan broj astragala sa zabilježenim tragovima obrade i/ili uporabe (200 primjeraka) blizu je ukupnom broju konvencionalnih glinenih i keramičkih utega iz vinčanske faze naseljavanja tella. Vrlo je izvjesno da su astragali bili multifunkcionalne alatke i njihova upotreba u proizvodnji tekstila više je nego moguća. Imajući na umu prisutnost konvencionalnih utega na Gomolavi, postavlja se pitanje je li, osim prirodnih karakteristika kosti koje ih čine iznimno prikladnim i praktičnim (npr. tekstura i specifičnost oblika) za razne namjene, postojao i neki drugi, poseban razlog za korištenje astragala. Štoviše, kako je za sakupljanje pojedinog seta astragala ipak bilo potrebno određeno vrijeme, teško je za ne pretpostaviti da su takvi kompleti utega za tkalački stan mogli imati i određen oblik posebne namjene ili značenja.

Na kraju, kao dodatni argument, treba spomenuti i sličnost astragala s neobičnim tipom keramičkih utega (koji se često nazivaju astragalima). Dotičan tip glinenih utega često se pojavljuje naročito u makedonskoj literaturi (Šurbanoski 1987; Karpuzova 2005), u kojoj ih se datira u postprapovijesno (kasno željezno/helenističko) doba. Značajan broj utega toga tipa pronađen je na lokalitetu Kale–Krševica, kraj Vranja (Popović, Vranić 2006). Iako je teško pronaći izravnu vezu između glinenih utega čudnovatog oblika, nalik violini (*fiddle-shaped*), i astragalnih kostiju, njihova morfološka sličnost vrijedna je spomena (sl. 17).

Vrlo je zahtjevno biti svjestan tekstila i njihove proizvodnje u arheološkim kontekstima, osobito unutar okvira prapovijesne arheologije. Zbog njihova je brzog raspadanja lako zaboraviti na njihovu sveukupnu prisutnost. Rijetko je koji drugi tip artefakta više povezan s čovjekom, čak i ako ih se promatra kao isključivo utilitarne predmete, ogoljene dubljeg značenja, što je u arheologiji rijetko opravdan pristup. Od trenutka kada smo savladali vještine potrebne za njihovu izradu, tekstili postaju nesumnjivo najčešće korišten oblik materijalne kulture. Imajući to na umu, otvorenost novim tipovima dokaza, kako za njihovu proizvodnju tako i upotrebu, jest ne samo opravdana nego i nužna.

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argument. The name is common in the Macedonian literature (Šurbanoski, 1987; Karpuzova, 2005) and the particular weights in question date to post-prehistoric (LIA/Hellenistic) period. A significant number of this type, typologically designated as the 'fiddle-shaped' weights (Fig. 17), is published from the site Kale–Krševica near Vranje (Popović, Vranić 2006). Even though the direct connection between the peculiar shape and the actual astragali bones is difficult to establish, their morphological resemblance is worthwhile mentioning.

It is quite challenging to stay alert and to be aware of textiles in archaeological record, especially when dealing with prehistoric contexts. It is easy to forget their overall presence because they are so perishable. There is not a single piece of artefact that is in its essence more attached to a human, even if observed only as utilitarian objects deprived of any greater meaning (which very rarely accounts as an acceptable approach in archaeology). From the moment people obtained the knowhow to produce them, they became by far the most frequently used type of material culture. Having this in mind, openness to more new evidence of their production and use is, in our opinion, justifiable.

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# 3 SYNTHESIS[3]

Recorded textile tools from South East and Central Europe (Grabundžija, 2019) that were analyzed in this study clearly reflect major technological changes. In order to better understand the causality of these advancements, the influence of climate (Grabundžija & Russo, 2016) and "culture" (Grabundžija, 2018b) was separately examined. Within the socio-cultural sphere, possible direct consequences are addressed through developments in craft specialization and altering social structures (Grabundžija, 2018c).

Recorded temporary disappearance of conventional tools for weaving (Grabundžija et al., 2016) formed an important research question: how can textile archaeology explain a sudden increase in the frequency of thread making tools and a concurrent decrease in the frequency of weaving tools? Answering this question is of vital importance for further research, since accepting this kind of adjustments in the two fundamental stages of textile manufacture implies both meaningful causes and significant consequences. It inevitably proposes that textile technology went through profound adaptations in all aspects of the production.

Along with causing a transformation of the socio-cultural scene, it is expected that the proposed advancements and intensification in fibre production and use also affected the Holocene landscape (Schumacher et al., 2015).

## 3. 1 Discussion

Developments in textile fibre resources can be approached through indications of technological change. These are proposed to be recognizable as tool adaptation to the particular raw material properties.

Just like Kimbrough established functional categories for the analysis of Mesopotamian spindle whorls dated to the $4^{th}$ millennium BC (2006, pp. 135-6), several authors, i.e. Rast-Eicher (2005, p. 127) and Chmielewski and Gardyński (2010, p. 878) connected obvious changes in the morphology of the $4^{th}$ millennium BC spindle whorls with the early wool use in Europe.

[3] Parts of the **Discussion** and **Conclusions** subchapters are taken from the manuscript „Eneolithic Textile Production" (Grabundžija, 2018a) published in an exhibition catalogue (Balen et al., 2018) that featured a substantial amount of previously unpublished textile tools used for this research.

Even though the absence and disappearance of certain categories and types of tools does not necessarily indicate a lack of activity or practice, these changes in the archaeological record can be regarded as having specific technological implications. It is of great importance to observe these trends in an enlarged geographical context, as it can enable an estimation of both the reach and the significance of the particular adjustment.

Here presented studies of thread making tools from South East and Central Europe revealed that during the 4$^{th}$ millennium BC the whorl shape/size/weight variability developed significantly. A particular trend in the increase of spindle whorl height parameter was already initiated during the Middle Eneolithic period and continues into the Late Eneolithic, when it becomes more pronounced, due to the dominance of biconical and high conical forms (Grabundžija & Russo, 2016). In different parts of the Balkan Peninsula, especially in the area of the so called “Post-Cernavoda III-Boleráz Phenomenon” (Govedarica, 2001; Jevtić, 2001; Köninger, Kolb, & Schlichtherle, 2001), similar changes can be observed as well: in Kostolac and Vučedol cultures in the Central Balkans, Coţofeni and Ezero cultures in the Eastern Balkans, as in Early Bronze Age cultures in northern Greece. Some of the published examples come from the Early Bronze Age layer at Ezero mound in South East Bulgaria (Georgiev et al., 1979, pp. 388-90, T. 224), multilayer settlements in the northern Greece, like Sitagroi in the plain of Drama (Elster, 2004, pp. 231-33) and Thessaly (Christmann, 1996, p. 305).

A corresponding typological development is observed in other European regions as well. It can be traced in large and heavy examples attributed to the Jevišovice Cuture in Moravia and Lower Austria, as sets attributed to the Chamer Culture in Upper Austria and Southern Germany (Grömer, 2005, p. 109).

It is important to observe that this particular typological trend was not confined locally. On the contrary, it appears to have been universal, meaning both widely spread and almost simultaneous. This specific trend might be explainable through the optimization and adaptation of tools. If that is the case, this could imply a major and wide spread innovation, such as the introduction of new raw fibre material. Chmielewski also proposes this as an argument for explaining the biconization of the tools observed at Polish sites (Chmielewski, 2009; Chmielewski & Gardyński, 2010).

It has to be pointed out that by the end of the Eneolithic period, a trend that started as a pronounced morphological variability of spindle whorls resulted in a clear dominance of high types with a drastically increased size and weight. Late 5$^{th}$ and early 4$^{th}$ millennium BC spindle whorl types from the territory of South East and Central Europe, gradually, but drastically change form (Fig.

11). Flat, planate discoid and lenticular types, which can be seen in Retz-Gajary (Čeminac-Vakanjac, Cugovec-Barbarsko, Ivandvor, Jagodnjak-Napuštene njive, Josipovac Punitovački-Veliko polje) and Lasinja (Cepinski Martinci-Dubrava, Pajtenica-Velike livade, Tomašanci-Palača, Viškovci) contexts in northern Croatia, started to slowly transform into higher types of whorls (Grabundžija & Russo, 2016).

We can track a similar introduction of the first low conical and convex forms in the most remote areas: from Rachmani (Christmann, 1996, pp. 305-306, Taf. 162) and Krivodol-Salcuţa-Bubanj (Bonev & Alexandrov, 1996, pp. Fig. 42) contexts in the south-east to the later Chassey, Cortaillod (Odone, 1998, Fig. 21) or Pfyn/Horgen contexts (Leuzinger, 2002, pp. 148-150, Fig. 2) in the north-west of Europe.

The increase in the spindle whorl height that was accompanied by the increase in the overall size and weight as well, eventually leads to a higher variability of all the morphometric parameters during the Late Eneolithic period (Grabundžija & Russo, 2016). This slow development results in dominance of biconical and conical spindle whorls that eventually came to represent the 3$^{rd}$ millennium norm.

In order to investigate the extent to which the observed changes in Eneolithic textile technologies reflect an adaptation to the altering environmental conditions and to further discuss their socio-economic impact on the Eneolithic communities, an environmental approach should be incorporated. The observed patterns in early textile industries cannot be fully understood without incorporating geographic research.

In those parts of Europe in which forest cover was not restricted by climatic factors (arid and sub-arctic zones, wind exposed coastal fringes of western Europe), sheep husbandry can be expected to have gained importance only in the course of an increased anthropogenic opening of the primeval forest vegetation. Therefore, to follow the track of the woolly sheep in Europe it is necessary to include research on ancient landscapes (Becker et al., 2016, p. 103). The results of the study on the mid-Holocene herding-related landscape change (Schumacher et al., 2015, 2016, 2018) provide additional arguments for the early wool use, supporting the idea that it might have started during the 4$^{th}$ millennium BC. Schumacher's analysis suggests that the emerging use of secondary animal products did not cause large-scale landscape disturbances in South East and Central Europe, whereas landscapes seem to have been resilient enough to withstand early grazing pressure. Although, the initial intensification of herding activities can be traced in environmental records: during the Neolithic period, low herding impact was indicated throughout the South East and Central Europe study area, whereas intensified herding is noticed for the succeeding Eneolithic period and could be, as proposed by Schumacher (Schumacher et al., 2016), in accordance with the evidence of early transhumant pastoralism in the central Balkans (Arnold & Greenfield, 2006). Additionally, the sediment accumulation related to human activity in the Bükkalja foothill area is evident around 4800 cal BP (Schumacher et al., 2016) and it can be synchronized with the increased herding indication at nearby sites (Magyari et al., 2010, 2012).

## 3. 2 Conclusions

All the main objectives that modeled this research were successfully and independently addressed through separate publications. The primary and fundamental task of recording and cataloguing Eneolithic textile tools from the territory of South East and Central Europe resulted in an open-source publication of the complete dataset, which represents a solid reference material for future textile related research (Grabundžija, 2019). The statistical approach revealed that both the typological standards and the metric specifications of the investigated thread making tools displayed a significant dependence on what is in the traditional culture-historical discourse, meant by the term 'archaeological culture' (Grabundžija, 2018b). Bringing together the climate model and the results of the techno-typological analysis of the assembled textile tools clarified that animal fibre use intensified already in the 4th millennium BC and was probably driven by local environmental conditions (Grabundžija & Russo, 2016). Examination of the social aspects of thread production pointed to intensification and plausibly early specialization of the thread manufacture during the Eneolithic period (Grabundžija, 2018c). And finally, the experimental method supported the premise that the lack of direct and indirect evidence of production does not necessarily imply its absence (Grabundžija et al. 2016).

Even though the appearance of wool would have introduced a completely new element into the earlier fibre procurement strategies, which were mainly based on plant resources (Cybulska & Maik, 2007, p. 186), there are no indications that suggest plant fibre materials became an inferior good. On the contrary, the results of the spindle whorl analysis (Grabundžija & Russo, 2016) propose their growing importance at the turn of the 4th millennium BC, potentially related to the intensification of flax fibre cultivation. Cultivation of textile plants is assumed to be a natural consequence of the spontaneous vegetation resource depletion due to the type of economy specific to the Eneolithic period (Mazăre, 2014, p. 33). In the context of climate change pressure and dynamic cultural influences which were crossing the mountains (Alps, Carpathians and the Balkans) and percolating into the Pannonian Plain, the Eneolithic textile traditions apparently experienced several adjustments, explainable through two distinct trends in the raw material use, which indirectly propose the cultivation of both animal and plant fibres.

Vegetal fibres have not only been used in the production of woven textiles but also resourced for cordage, ropes and nets (Good, 2007, p. 182). The difficulties involved in growing textile plants, and flax in particular, as well as the laborious and time-consuming process of extracting fibres (McCorriston, 1997, pp. 522-523) most probably further magnified their importance and increased their value (Mazăre, 2014, p. 33).

The innovative element of wool would have fundamentally affected and changed all stages of the Eneolithic textile production. Its appearance would have drastically decreased the time-labour investment in fibre production and processing. Additionally, it inevitably remodeled the final product standards, due to its thermo-isolation, water-proof and dying properties.

The most recent research supports that wool was most likely introduced and exploited in the region already during the course of the Eneolithic period (Djurdjevac Conrad et al., 2018), as initially outlined by Sherratt (1981, 1983). Criticism around Sherratt's hypothesis mainly questioned the interconnectivity and simultaneousness (Chapman, 1982) of different forms of animal exploitation. Therefore, Sherratt himself has increasingly stressed the intricacy of local adaptions to secondary products use, pointing to the importance of social symbolism and prestige related to the particular innovations in the animal husbandry (Sherratt, 1986). It is possible that the more focused flax cultivation could be indirectly connected to the advancements in farming, due to the plough agriculture, which is yet another element from Sherratt's 'package'. In any case, it is more and more evident that textile fibre materials, both of animal and plant origin, played a significant role in the formation of Eneolithic economies and as such their cultivation and processing participated and possibly even stimulated social stratification.

In order to really understand the potency of particular triggers which promoted different raw materials in different contexts, further research is necessary. Focus on the relationship between different fibre resources and modes of their exploitation could provide more concrete answers to questions on cultural choices and environmental conditioning.

By the 3rd millennium BC both cultivated staple materials (wool and fibre flax) were probably very widely spread in terms of production, use and quite possibly trade across the South East and Central Europe. Transition from the Late Eneolithic to the Early Bronze Age period is characterized by profound socio-economic changes, which enable a more detailed study of developments in specialization, resource management and trade that were closely connected to fibre cultivation advancements. Proposed Eneolithic achievements in fibre cultivation resulted in development of complex resource repertoires. Later periods are particularly interesting for better understanding which decisive factors drove and conditioned the dynamics of different raw material exploitation.

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**STATUTORY DECLARATION**

I declare that my PhD thesis: "Archaeological Evidence for Early Wool Processing in South East and Central Europe" was not used in the same or in a similar version to achieve an academic grading. Any thoughts from others, or literal quotations are clearly marked.

Berlin, 13 January 2020

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**Papers on international conferences:**

**2014**

20th Annual Meeting of the European Association of Archaeologists (**EAA**) in **Istanbul**, Turkey

**2015**

"First Textiles. The Beginnings of Textile Manufacture in Europe and the Mediterranean"
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**2019**

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**Relevant Publications:**

**2016**

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**2020**

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