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Reconstruction of Archaeological Textiles

Abstract
Archaeological textiles are usually only fragmentarily preserved, colourless, and thus hard to appreciate and understand, even for specialists. Producing replicas of archaeological textile finds can be done on a loom. However, this approach is not always possible. This paper presents a new approach consisting in the application of computer graphics methods for the reconstruction of archaeological textiles on the basis of detailed structural and physicochemical analysis. Methods visualising different types of textile structures are described. They were applied to exemplary textile finds from the Roman period found during excavations in the area of Poland.

Key words: *archaeological textiles, virtual reconstruction, 3D-simulation.*

Introduction

Textiles found in archaeological excavations are usually only fragmentarily preserved and colourless[1)]. If we want to appreciate their real value i.e. the skills and taste of ancient manufacturers, we need to know their original appearance. Efforts to reconstruct them have been undertaken for a long time in the field of experimental archaeology. One of the best achievements in this area are the works of dr Karl Schlabow - founder and director of the Textilmuseum Neumünster. On a reconstructed warp-weighted loom, based on the analysis of residues found in offering deposits in Thorsberg and Vehnemoor bogs, he wove replicas of two *Prachtmantels* [2]. This kind of reconstruction is difficult and time-consuming (it took several months). It needs a replica of an ancient loom and the skills to weave on it. This approach is still very popular and scientists in Denmark, Great Britain and other countries work on ancient spinning and weaving techniques using the same kind of raw material, dyes and mordants which were in use in the past. In ***Figure 1*** one can see a replica of Tybrid Vig style looped fabric. The fibres used are manually softened and split juncus[2)]. This kind of activity is very helpful in the better understanding and interpretation of archaeological finds and supplements historical knowledge of ancient civilizations; however, it is very labour intensive and costly. Goods produced in this way need proper storage and conservation.

The growing popularity of 3D graphics and attempts made at the Institute of the Architecture of Textiles, TU Lodz, to apply computer methods in the field of modelling textile products have been instrumental in the formulation of the idea of using these methods in the reconstruction of archaeological textiles.

Methodology

The reconstruction of textiles based of excavated residues, both on a loom and virtually using 3D graphics methods, requires knowledge of historical manufacturing methods and structures, as well as data concerning the object reconstructed: raw material, dyes and the structure of the object and its components [11]. The whole procedure of reconstruction includes the following stages:

- Documentation of the object: photographic documentation of the whole object and its components, sampling the material for further physical and chemical analysis, and acquisition of microscopic images of the material[3)].
- Determination of the raw material and dyes.
- Structural analysis: the processing of registered images, determination of the structural parameters of fibres, yarns and fabric, and the determination of the object's technology, structure and colour scheme.
- Virtual reconstruction of all components of the object, i.e. fibres, yarns, woven structures, and the reconstruction of the whole object.

Visualisation of textiles using 3D graphics methods

3D graphics methods are more and more popular and widely applied not only in entertainment and advertising but also in the field of science, technology, and most importantly, textiles. Computer programs supporting engineers and designers of knitted and woven fabrics allow to simulate the final product without costly and time-consuming trials. However, this kind of software is not suitable for the reconstruction of archaeological textiles, which were constructed using specific ancient technologies and structures. This paper shows the application of 3dsmax 7 Discreet software tools and procedures developed with use of the "maxscript" programming language to simulate and model textiles. The most important advantage of 3dsmax software is the open programming code, enabling the creation of new specific tools. Script language is similar to some popular programming languages, such as C++. Numerous procedures for 3D modelling make programming easier for the inexperienced user or for those who do not know any programming language. It is also possible to

Figure 1. *Tybrid Vig style looped fabric from manually softened and split juncos.*

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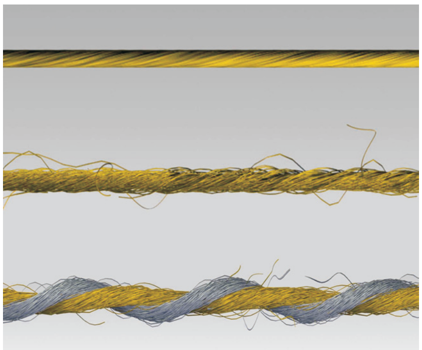

Figure 2. Visualisation of different types of thread.

develop some procedures which are not directly related to 3D graphics, such as procedures analysing the relationships between certain parameters or other mathematical calculations [7].

The appearance of textile cloth is a very complex phenomenon. It is the combined effect of many different factors, such as the raw material, the yarn and fabric structure, finishing and many other parameters resulting in different product properties, for example aerial mass, stiffness, width and so on. These parameters determine certain other factors, such as the fabric texture and drapeability. On the other hand, the product's appearance is determined by light reflection and refraction, translucency, colour, etc. All these parameters should be taken into account in the modelling and simulation of a textile product.

The basic element of the model of a product is the grid object, whose shape depends on the geometric properties of the element modelled. For instance, in the case of fibre or yarn, we can assume it is a kind of cylinder with different types of cross-section. Then the object can be modified using a variety of tools which can change the object's structure according to specified parameters of the product modelled or to the product technology, for instance by twisting, wrapping or bending the elements or by adding noise to reflect product unevenness. To create the effect of reality, we need to use some tools allowing to determine the texture of the object - smoothness, hairiness, relief, translucency, glossiness, reflection and refraction [8].

Visualisation of the textile product starts from the basic element - fibre or yarn. Then on the basis of predetermined parameters of the fibre, yarn, and fabric structure, we can simulate the fabric's appearance.

Using the software tools, one can create models of fibre characterised by different cross-sections, diameters and lengths. The procedures of the material editor can be used to determine selected surface properties of fibre. All fibre parameters can be further modified according to the material properties.

One can use two different methods of yarn modelling: The first one consists in giving the linear element a texture with properties determined by the yarn structure properties. The presence of fibres is reflected by concavities and convexities on the cylindrical yarn surface. This method can be used for the visualisation of multifilaments. In the case of staple yarn, the method is not sufficient to create a realistic model. Thus, the second method consists in forming yarn from previously created 3D models of fibres by wrapping, twisting or nodding them according to the yarn technology [8]. This method allows to set some predetermined features, such as yarn unevenness and yarn hairiness for staple yarn (***Figure 2***).

Simulation of the fabric proceeds in two stages: The first one consists in forming fabric from previously modelled linear elements. One can use both the exact simulations of yarn and yarn modelled by a simplified method. In the first case one can get a magnified image of fabric with clearly seen fibres. It is also possible to use elements plied from two or more linear elements as a warp or weft. The elements are interlaced according to the weave pattern previously chosen,

Figure 4. Fragment of woven fabric from the Roman period found in a bronze pot from the 'princess grave' in Leśno.

with the relative position determined by the yarn spacing. The next stage consists in simplifying the 3D model of the fabric by converting it into a flat object with a texture depending on the properties of the raw material one wants to use. The calculation window allows to determine selected physical properties of fabric, such as the aerial mass [8].

The last stage of modelling the textile object of interest consists in placing the previously designed and simulated fabric on the surface of a different kind of 3D object (***Figure 3***).

Experimental material

Woven fabric from Leśno

The first archaeological object analysed and reconstructed with use of the method described above was fabric found among numerous wool fragments during an ex-

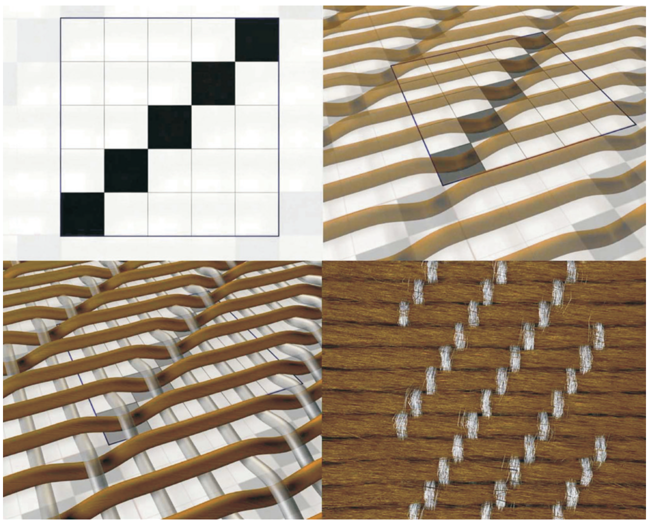

Figure 3. 3D modelling of woven fabri.

cavation near Leśno, Pomerania, in grave no 1, called the 'princess' grave due to the rich artefacts found where a young woman was buried [3]. Most of the fragments were found in close proximity to the skeleton. However, several fragments were found in, under and on the edges of a bronze pot (***Figure 4***). The arrangement gave the impression that the pot was wrapped in fabric and were deposited together as burial goods for the women for her journey to the other world.

Two coats from Gronowo

In male grave 1 of mound 3, dating from the B_2/C_1 phase of the Roman period, numerous fragments of two fabrics and fringes were found next to the man's feet [1]. They were all compacted into one ball with the metal spur inside. After cleaning the find, it occurred that the fabrics are residues of two *Prachtmantels* with tablet woven borders and fringes One of the coats was monochrome, whereas the second was polychrome chequered with dark and light brown threads (***Figure 5***). They were probably used to wrap the dead man's body.

Fragment of cloth from Odry

A fragment of cloth was found in inhumation grave 423 at the Wielbark culture burial site, Odry, Pomerania [5]. Archaeological excavations were conducted in the sixties of the 20th century by the Departament of Archaeology at the University of Łódz. The grave was richly adorned with bronze jewelery and ceramics. The fabric was found near a spur and was the corner of the Prachtmantel the body was wrapped in (***Figure 6***).

Results of analysis

Structural analysis of the threads and fabrics was done using computer assisted analysis of microscope and scanned images of the objects [6, 7]. Analysis of the dyes was done by Penelope Walton-Rogers from the York Archaeological Trust for polychrome fabrics [4]. Tannin was found in the dark threads from the fabric found in Gronowo, indicating a brown colour. There was no dye found in the light threads, thus it was probably the natural wool colour of the fabric from Lesno. Analysis of the dyes indicated the presence of indigotin, giving a blue colour to the wool. Flax, as cellulose fibre was not yet dyed in that period, hence it was assumed that the linen threads were in the natural colour of flax. Results of the analysis are presented in ***Table 1***.

Figure 6. *Fragment of cloth from Odry.*

Figure 5. *Fragments of two cloths from Gronowo.*

Table 1. *Properties of the threads and fabrics.*

Property		Monochrome from Gronowo	Polychrome form Gronowo	Polychrome form Leśno
Thread diameter, mm	weft light	x	0.472	x
	weft dark	0.416	0.603	0.52
	warp light	x	0.454	x
	warp dark	0.401	0.597	0.52
	warp-tablet	0.171	0.243	
CV of thread diameter, %		22	16.5	23
Twist, t.p.m.	weft light		564	x
	weft dark	587	678	290
	warp light		564	
	warp dark	672	678	290
CV of the twist, %		17.5	12	16.2
Number of threads per 100 mm	weft	163	130	145
	warp	168	139	163
Fabric cover factor, %	weft	67.8	78.4 (dark) 61.4 (light)	x
	warp	67.4	83.0 (dark) 63.1 (light)	x
	total	89.5	96.3 (dark) 85.8 (light) 93.4 (light & dark)	x
Dyes	dark	X	tannin	indigotin
	light	x	undyed	undyed

Reconstruction of the archaeological textiles

Woven fabric from Leśno

The fabric was initially classified as open work wool fabric [4]. However, microscopic analysis allowed to state that originally it was woven from wool and linen. The last one had become almost completely putrefied. Residues of the linen threads did not give any information about their structure, therefore it was assumed they had structural properties close to those of woollen threads, which could result in the uniformity of the structure of fabric. The weave was determined as 2/2Z will. The sequence of threads in diffrent colours creating a checquered pattern sheme was determined. The reconstructed scheme presented in ***Figure 7*** (see page 106) includes 175 warps and 152 wefts.

On the basis of the analysis of structure and dyes, the reconstruction of the fabric was done using 3D graphics methods (***Figure 8***, see page 106).

The reconstructed fabric can be presented in different ways: we can show certain details of the fabric structure, a larger fragment, or what seemed to be the most reasonable way it was put in the young woman's grave together with the bronze pot as a precious funeral gift (***Figure 9***)[9, 12].

Reconstruction of prachtmantels from Gronowo

Reconstruction of weaves

As was stated before, all textile finds from Gronowo are fragments of two Prachtamantels – parade coats. One of them was monochrome of unknown colour, whereas the other one was polychrome chequered, light and dark brown. The coats were made on a vertical loom using 2/2 Z twill weave in the case of the monochrome coat and 2/2 S twill in the case of the polychrome one. The edges were woven on a tablet loom in different manners. Because of the very few fragments found, it was not possible to determine the size of the coats. However, we could determine the width of tablet-woven edges, the number of warps in the tablets, and the way they were turned.

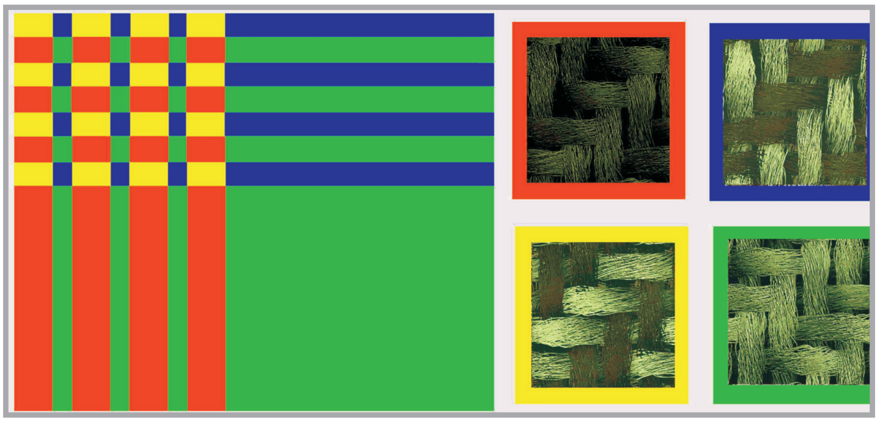

Figure 7. *Checquered pattern of Leśno fabric.*

To reconstruct the edges of the coats, the visualisation of different types of tablet woven fabrics identified among the finds was undertaken on the basis of structural analysis, which is presented in ***Figure 10***. The corner of the coat was elaborated on the basis of the analysis of the fabric from Odry. We were able to do it for two reasons: No corner fragment survived in Gronowo, and the structure of the Odry fabric is very similar to those from the Gronowo finds.

The most difficult was to visualise the fringes, which were formed from two or four double twisted threads. However, the corner fringes were usually different: They were made from a higher number of threads, more decorative and complicated.

Finally, we obtained different kinds of structures that had to be merged together in the way it was done in the original coats. For instance, in the place where there are basic twill fabric ends, the warps became wefts at the woven end edge of the tablet.

Reconstruction of the prachtmantels

If the fragments representing the reconstructed cloth are very few, we need to make some assumptions concerning the size of the whole cloth and the lacking fragments. It was assumed that the coat was of the same size as the Prachtmantel form Moorleiche ([1], Figure 64) - 180 cm wide and 300 cm long. It was

Figure 8. *Reconstruction of the weave pattern- woven fabric from Lesno.*

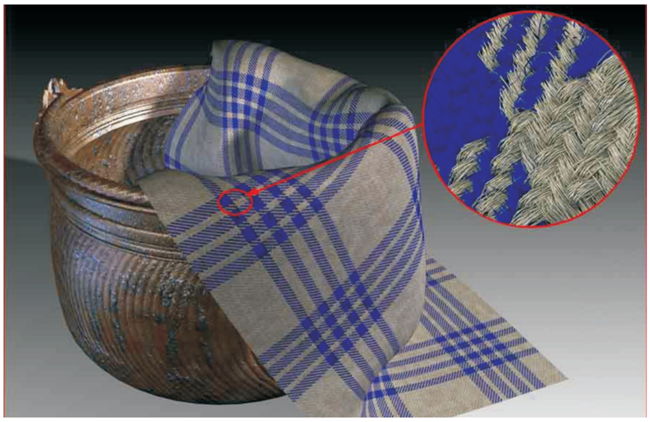

Figure 9. *Reconstruction of the fabric from the 'princess' grave found in Leśno.*

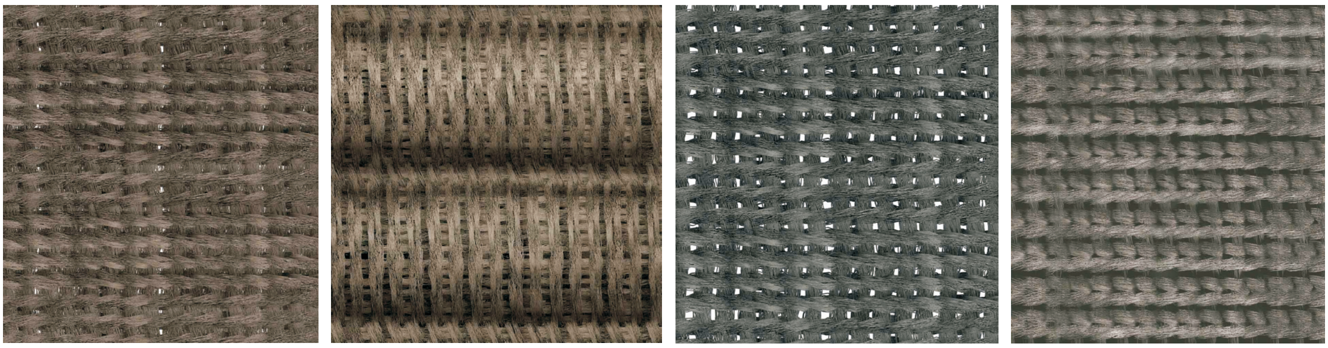

Figure 10. *Visualisation of the different types of edges of cloth.*

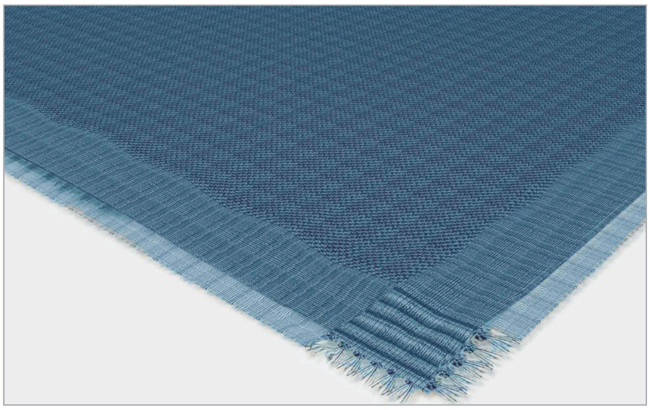

Figure 11. Visualisation of the corner of the monochrome prachtmantel from Gronowo.

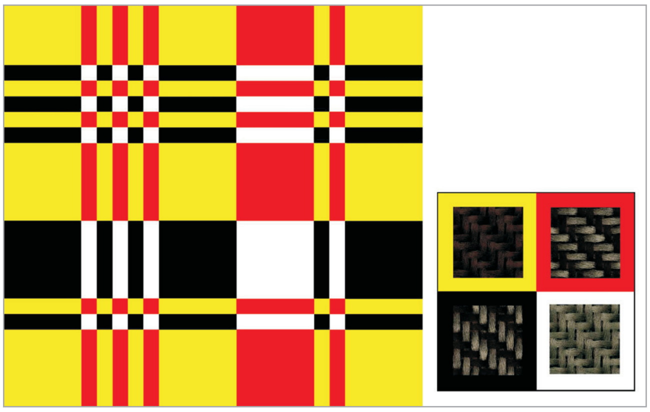

Figure 12. Checquered pattern of the polychrome fabric from Gronowo.

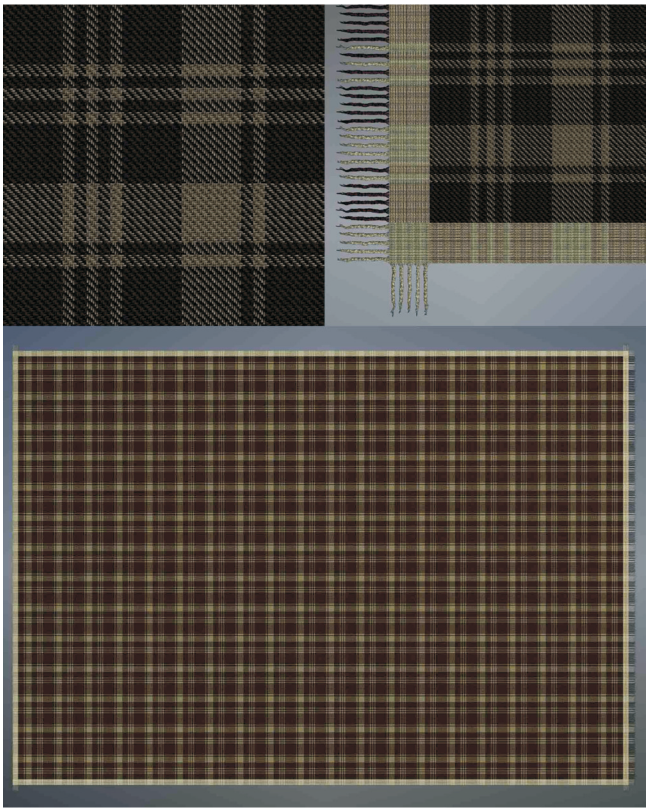

Figure 13. Reconstruction of the polychrome Prachtmantel from Gronowo.

Figure 14. Polychrome prachtmantel from Gronowo on a phantom.

also assumed that the end edge and one of the side edges were decorated with fringes, with the form of the corner as in the cloth from Odry - with thick decorative fringes.

The edge of the monochrome coat was made on 40 tablets with four wholes, which means that single basic fabric warps were used as wefts in tablet weaving. The structure of the edge is presented in ***Figure 10*** (at the top,on the left). Because in this case the analysis of dyes was not done, it was assumed the coat was blue. The bottom left corner of the coat is presented in ***Figure 11***.

To reconstruct the polychrome chequered coat, we assumed it was of the same size as the previous one. Only the end edge and the corners were decorated with fringes made by twisting three doubled threads together.

Firstly, we had to identify not only the weave, as was done for the monochrome coat, but also the sequence of threads in different colours, thereby determining the chequered pattern. From wefts and warps in two different colours, we obtain four different arrangements of threads, as presented in ***Figure 12***, together with an identification of the pattern of the fabric. The pattern included 162 weft and warp threads, which means it was multiplied 30 times along the width and 14 times along the length of the coat. Borders were made on 30 tablets, with a density of 13 tablets per 1 cm. Fringes were in different colours, depending on their position in relation to the main fabric.

In the next stage all elements were virtually reconstructed, including the main fabric, borders, corners and fringes. All these elements were used to reconstruct the whole coat (***Figure 13***).

Visualisation of the coat on a phantom is presented in ***Figure 14***. The reconstruct-

Figure 15. Six shots from a film illustrating the way the prachtmantel was worn.

ed prachtmantel can then be visualised using different scenes. For instance, one can show the way it was worn. ***Figure 15*** shows six action shots presenting one of the ways: It is folded in half, put on the arms and buckled up under the chin [13].

Conclusions

Archaeological textiles represent a variety of structures, materials and technologies, sometimes complex and often distorted, which makes them especially difficult to analyse by an archaeologist. In most cases documentation of textile collections is incomplete; it is done with the use of traditional, manual methods and thus not precise. Moreover, it does not give us any idea of what the object originally looked like. Archeological textiles are fragmentarily preserved, colourless, and thus hard to appreciate and understand by the unprepared visitor. Reconstruction of these textiles can be done on a loom. However, this approach is not always possible and sometimes even unreasonable. Reconstructed this way, the object needs proper storage, exhibiting and conservation, which is much more costly.

The main advantage of virtual reconstruction is its accessibilty, not only in the museum, but also on the Internet, both for professionals interested in the subject and general society. Apart from the way it is presented, it can clearly show the whole reconstructed object and some details of the structure. The educational role of the reconstruction is also very important. When studying any archaeological object in its current state, the chance to know its original structure and appearance is very valuable. Archaeological textiles are a very good example – coloured and shapeless residuals can get back their form and beauty. Virtual reconstructions of archaeological textiles can also serve as a good and interesting supplement to museum collections, as well as technical documentation for a replica.

Editorial notes

1) *The problem of the biodterioration of archaeological textiles was described in detail in the first paper of a series presenting studies on archaeological textiles made at the Institute of the Architecture of Textiles, TU Lodz in cooperation with the Institute of Archaeology and Ethnology of the Polish Academy of Science [10]*

2) *The bracelet was made by dr Linda Hurcombe from the Department of Archaeology, University of Exetr. She also works on some other fibres, such as lime bast, willow bast, and nettles fibres processed by hand.*

3) *The methods of chemical analysis of the raw material and dyes and their exemplary applications in the analysis of archaeological textiles have been presented in a paper published in F&TinEE [11].*

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