A Study of Fibers and Weave Structures of three old Egyptian Textile Fragments

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Abstract: *Three archaeological textile fragments were recently discovered in three separate excavation sites in Sohag1, ca.500km south of Cairo. These textile pieces were examined by Stereo Microscopy and Scanning Electron Microscopy (SEM). More data were obtained through the characterization of the natural fibers, their characteristic features in addition to the determination of the weaving structure techniques and the spinning torsions. The yarns of the three examined pieces were made of wool, dyed with different natural dyes. The plain weave technique together with the derived weaves such as ribs, whether regular or irregular warp ribs, were also recognized. All of the three pieces were in a bad state of conditions. They are so damaged that the fibers are completely brittle. As the results of this research, we were able to detect the type and origin of fibers, the dyes, and the weaving techniques that disclose exceptional information that helps in their conservation methods.*

Introduction

This study is mainly concerned with the identification of the morphology of wool fibers and their weave structures; plain and twill weave, that were made for old textiles. These stuffs are useful for understanding the type and origin of natural fibers, by which we can define where and when they were made.

Three old textile pieces were discovered in three separate excavations in Sohag (the white monastery ‹Deir el-abiad›, Abydos and Akhmeem) in 1998, 2001 and 2008. This study also correlates the information about the history of these objects with the manufacturing technique. Identification of the fiber types is also very important since some previous studies suggest that wool fiber was not used in textiles in ancient Egyptian ages (pharoahnic period), but was known during the Byzantine period of Egypt (284-641 AD) (Abdul-hamid & Mohamed, 2001). Information about these pieces of textile will also allow us to determine the type of the dominant weave structures in that old time. The classical approach to analyzing textiles by Stereo microscopy reveals the weave structure and hand-made spun yarns. The shapes of fibers allow us to determine the warp›s and weft›s fibers in the three textile pieces. In addition to the determining the directions of twist of spun yarns, (SEM) imaging was carried to investigate the shape in more details.

Scanning electron microscopy was used to identify the wool fibers, whether in warp or weft threads, by comparing the characteristic features of the wool fibers such as fiber scales, morphological structure, to the standard micrographs especially that of the longitudinal fiber section. On the other hand, Plain weave with its derived weaves such as warp ribs, whether regular or irregular warp ribs, were identified in the three fragments. Moreover, twist direction of the spun yarns in the three objects were categorized in (S) or (Z) twist both of warp and weft yarns.

Fig. 1: The three archaeological sites in Sohag where the ancient textile fragments were found out in their excavations.

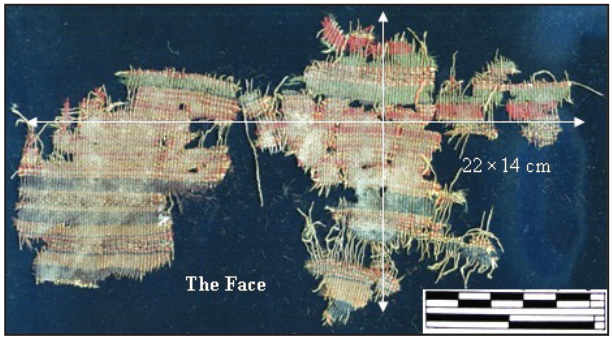

Fig. 2: represents the face of the first fragment that found out at the white monastery's excavation in Sohag. (22.0*14.0cm).

2. Methodology

2.1 Description of three textile fragments

Ancient textile fragments were found at three different sites in Sohag; the first fragment was found to west of white Monastery ‹Deir el-abiad› (4th century) west of Sohag; the second fragment was found in the southern excavation of the temple of Ramses II (1290-1224 B.C) in Akhmeem city east of the Nile River; and the third fragment was found north of Osireion›s temple in Abydos (5000 B.C.) southwestern of Sohag (11km west of the Nile) Figure 1.

Three textile fragments were investigated and reported. Technical analysis and specifications of the fragments are addressed in table 1 that demonstrates the type of natural fibers, type of spinning and weave structures, as well as the number of warp or weft yarn /cm2 and number of plies /yarn for both warp/weft yarns.

Characteristics	Descriptions of three fragments		
	1	2	3
Measure	21× 14.1 cm	12.2 × 11.4cm	26 × 9.8cm
Warp density	8 yarns	6 yarns	9 yarns
Weft density	30 yarns	7 yarns	12 yarns
Fibers	Wool	Wool	Wool
Diameter of fiber (warp/weft)	18-20/16-18µm	23-25/20-22 µm	20-22/18-23 µm
Colors	Red, green and dark blue	Red and traces from dark violet	Yellow and brick red
Yarn twist direction	(S) direction/ warp and weft	(S) & (Z) direction/ warp and weft	(S) direction /warp and weft
Ply yarn (warp)	3ply yarn	2ply yarn	2ply yarn
Ply yarn (weft)	1 ply yarn	1 ply yarn	1 ply yarn
Weave structure	PW* 1/1 and IWR** 2/1	RWR*** 2/2 and IWR 2/3	PW 1/1and RWR2/2
Ornaments	Horizontal ribbons	Without	Without

* PW=plain weave,

** IWR= irregular warp reps,

*** RWR= regular warp ribs

2.2 Investigation methods and techniques

The stiffened samples were investigated with SM (Bausch& Lomb) and then were covered with a layer of an alloy of 18 nm thick of (Au-Pd) to give suitable contrast and allow good observation of the SEM scanning (Jeol model JSM5300). The morphological analysis carried out with such microscopes allowed the identification and detection of the sample's features besides the natural fiber's components .Also it showed the yarn's torsion directions set by the spinning process, the manner by which the warp and weft yarns were woven to produce each sample. The weave graphical patterns were displayed on graph paper where the spaces between the vertical and the horizontal lines represent the yarns of the warp and weft respectively. Moreover, the squared spaces formed by the weave of the weft and warp are filled in when the warp passes over the weft yarn.

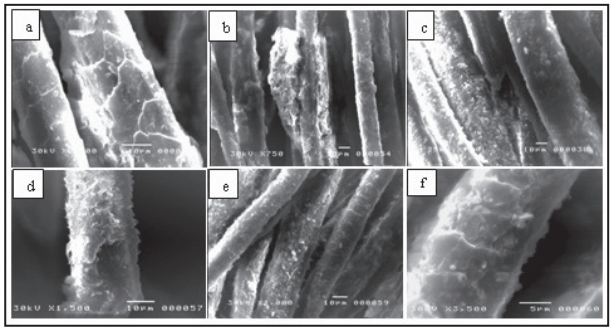

Fig. 3

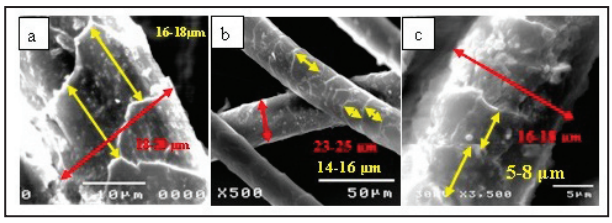

Fig. 4

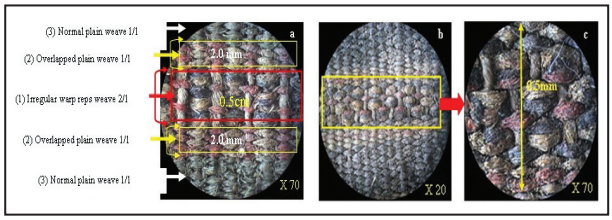

Fig. 5: SM images showing the weave structures for the 1st fragment (Normal plain weave and its derivates)

3. Results

3.1 Morphological analysis

Figure 3 shows the SEM-micrograph of the textile sample which represents the warp and weft yarns; the longitudinal section shows that the fibers are certainly wool fibers where scaly layer is one of the unique features of wool fiber. The scales are arranged very closely on the fiber surface in a single layer that the edges of separate scales partially cover the adjacent ones (Sadov, F., et al; 1970). Their upper parts protruding on the fiber surface have their ends always directed to the top part of the hair. Within this layer, the scales overlap each other like shingles on a roof, which imparts to it the features of a protection sheath. As the name implies, the scales form an irregular network over the surface of the fiber.

Another characteristic feature of the scale cells is the form of their margin. The scale pattern is a useful tool to distinguish certain fiber types (e.g. fine wool and cashmere, medium wool and mohair). In addition to the scale pattern, the visible scale length (i.e., the distance between serration along the fiber axis) is useful, but by no means an infallible aid to fiber identification (Menkart & Bray, R. 1962). So when the photographs of the wool fibers were investigated, we found that scale length in wool fiber of the second fragment (warp) is 16-18 µm, while lengths of scales of wool fiber in the weft threads are 14-16 µm. Also the wool fiber in the first fragment (warp) is 8-10 µm while in weft threads are 5-8 µm, figure 4. In this context, the fiber diameters of wool fibers were assessed by using (SEM) micrographs (Müller, M. et al; 2004). The averages of wool fibers for each fragment range in mean diameter from 16-20 µm, figure 4.

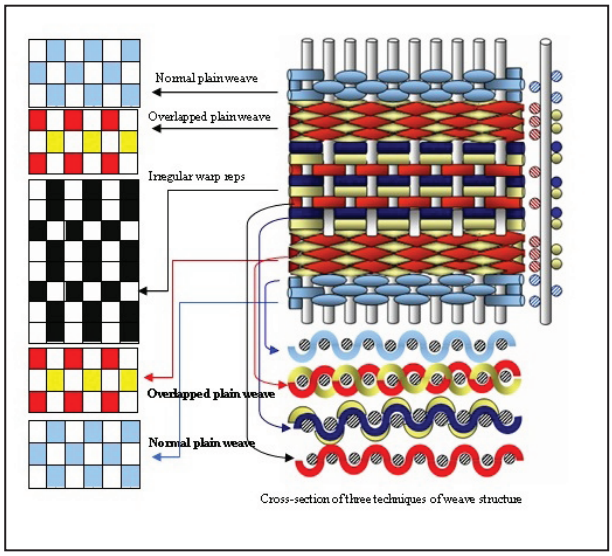

Fig. 6: representing the figured texture pattern showing the graphical pattern, design and cross-section of weave structure techniques in the 1st fragment.

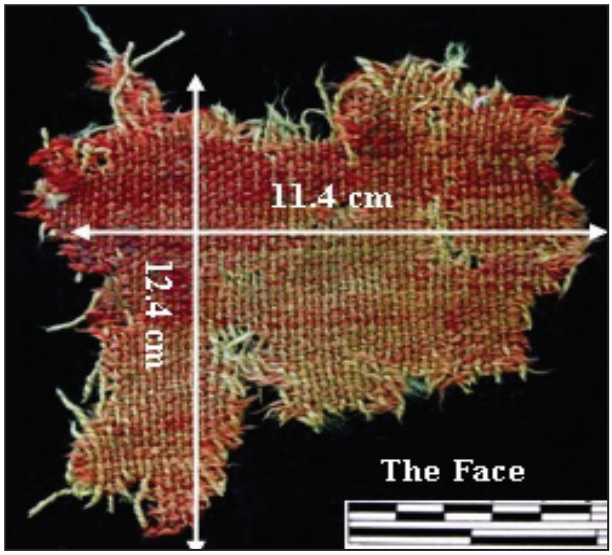

Fig. 7: the face of the second fragment that was found out at the southern excavation of temple of Ramses II in Akhmeem city.

3.2 Technical analyses

3.2.1 The first textile fragment

Figures 5 and 6 show microscopic photographs and micrographs of one of the most important parts in this fragment and illustrate three techniques of weave structures: normal plain weave 1/1, overlapped plain weave 1/1, and irregular warp ribs weave 2/1. The plain weave technique is considered the simplest of all patterns. The warp and the weft are crossed over each other one by one alternately up and down, and they are interlaced (Nakamura, A. 2000). While irregular warp ribs 2/1 was made in 0.5 cm, figure 5 (c) among two regions were woven with overlapped plain weave 1/1(2.0mm), figure 5 (a).

3.2.2 The second textile fragment

Although this piece is considered very small, 11.4cm × 12.4cm, figure 7, it has enough details to help recognize the spinning yarn method and the weave structure. This fragment is therefore considered very important because it makes clear that it was part of a large garment. Also, it ascertained the progress of the textile industry in the ancient period. This fragment involves two weaving techniques: a regular warp ribs 2/2 and irregular warp ribs 2/3, figure 8. These techniques were derived from the plain weave. If the weft of plain weaving pattern are arranged 2 at a time and put in as shown in figure 9 (a) fine ridged is shown in direction of warp yarn regularly, so this technique is called regular warp ribs 2/2 (Orazio, L., D., et al; 2000). However, if the weft threads are arranged 2 at a time and 3 at another time in direction of warp yarn, it is then called irregular warp ribs 2/3, figure 9 (b).

3.2.3 The third textile fragment

The microscopic investigation showed that

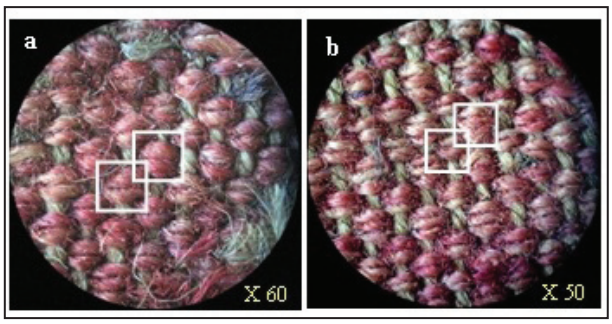

Fig. 8: SM images at different multiptcation values illustrating two techniques of weave structure; (a) regular warp ribs 2/2 and (b) irregular warp reps 2/3, in addition to, warp and weft density.

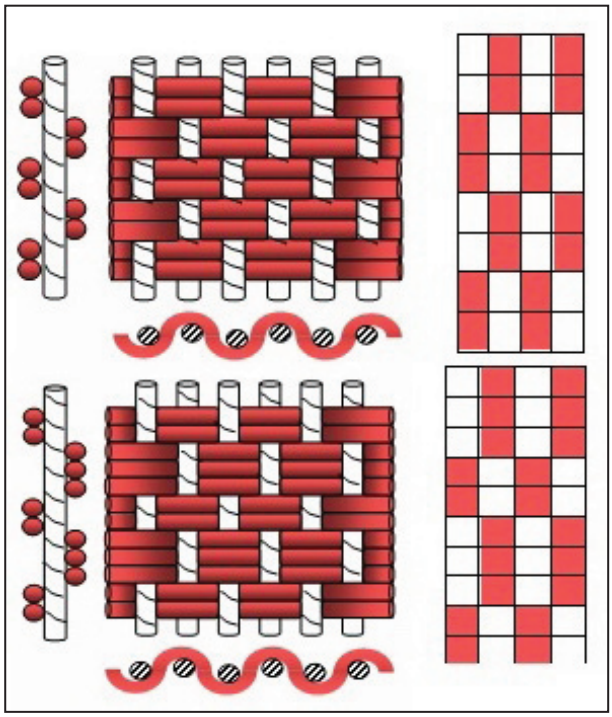

Fig. 9: figured texture pattern showing two types of the weave structures of the 2nd fragment; (a) regular warp ribs 2/2 and (b) irregular warp ribs 2/3.

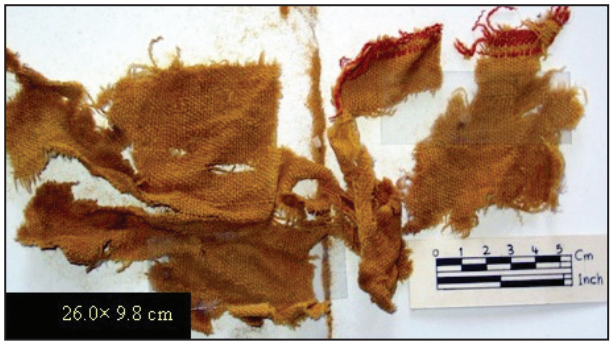

Fig. 10: showing the 3rd fragment that was found out at the northern excavation of

the plain weave 1/1 is the dominant technique in this fragment, but there are very small areas that are ornamented by two weft yarns and others with a different color (red). They were weaved with warp yarns as Figures 10, 11 and 12 show.

3.3 Investigation of the spun yarns

This investigation aims to identify the yarn's twist direction, Z or S of the yarn and number of ply of the twisted yarn, in warp and weft, for each fragment. Such information can be used in determining originality and manufacture's location of these fragments since every country had its distinguished styles for twisting direction and number of plies of yarns. For example, (S) is the twist direction of yarns Egypt prefers, while in the other countries, the twist direction is (Z). As shown by the data reported in table 1, the spinning process was made both in a dextrorse, from left to right, Z twist of the yarn, and in a sinistrorse, from right to left, S twist of the yarn. In particular, (S) spinning proves is usually used for warp and weft yarns in the three fragments. On the other hand, (Z) spinning proves to have been used only for weft threads in the second fragment, figure 13.

In this context, the microscopic investigation indicated that ply numbers for warp yarns are triple, double and single plies respectively,

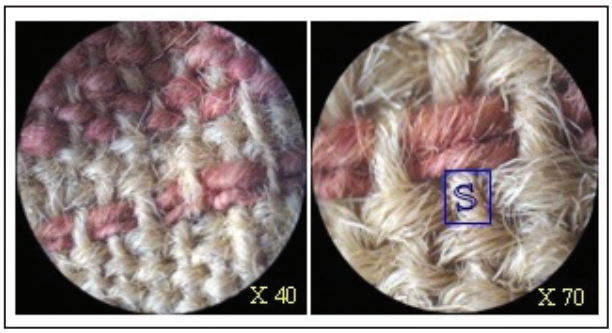

Fig. 11: SM images at different multiplication values showing the weave structure in the third fragment and warp/ weft density in cm2.

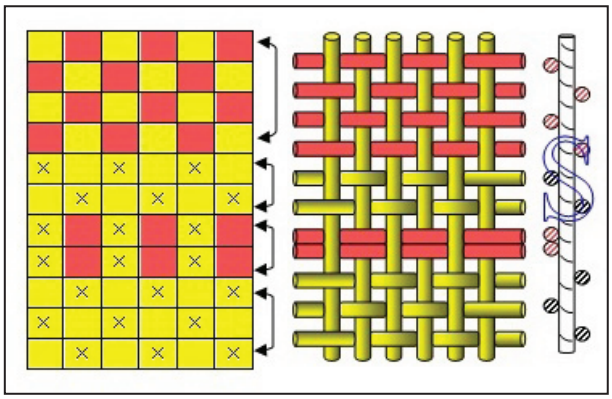

Fig. 12: figured texture pattern representing the main weave structure of the plain weave 1/1.

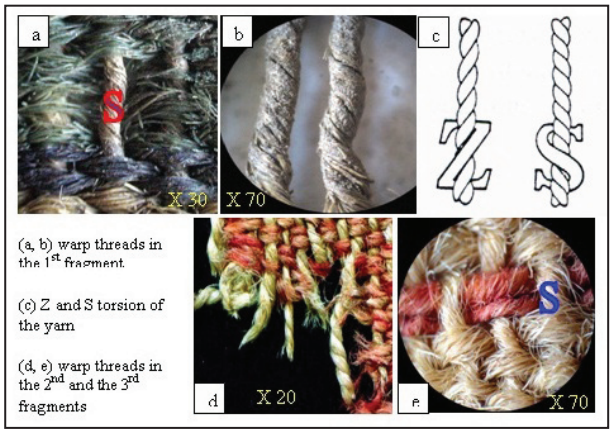

Fig. 13: images at different multiplication values and a drawing showing the twist directions of warp and weft yarns of the three fragments.

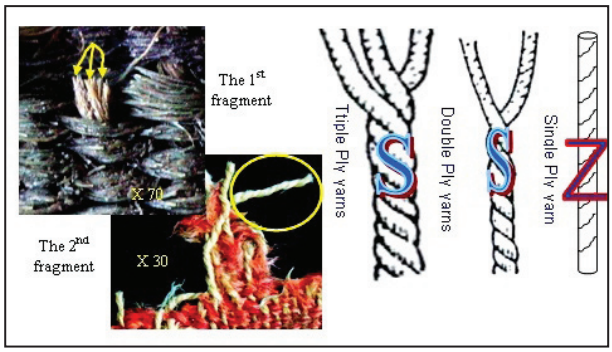

Fig. 14: microscopic images and drawings show number of ply of warp yarns for each fragment.

(tight yarn). Against this, the number of plies of weft yarns is single yarn (non-tight yarn) for each fragment, figure 14.

4. Discussions and Conclusions

Investigation by Scanning Electron Microscope (SEM) allowed us to identify the nature and origin of the natural fibers composing the textile fragments through the morphological features. Wool fibers were recognized as natural fibers used in three fragments in both of the warp and in the weft threads. In this context, this microscopic investigation is considered a non-destructive technique using only single fibers; a few µm in diameter of the fiber material. However, it should be noted that the epidermic layer of such fibers is composed of scales which are close to one another and only slightly protruding, and characterized by non-indented edges (see figure 3 a, d). These morphological characteristics are distinctive of wool fibers.

Characteristic features of wool fibers such as the length of scales and diameter of wool fiber were detected; the average visible scale length of wool fibers for the first fragment ranges in length from 8-10 µm for warp threads and from 5-8 µm for weft threads. While the scale length of wool fibers for the second fragment ranges in length from 16-18 µm for warp threads and from 14-16 µm for weft yarns, the average diameter of wool fibers for the 1st fragment ranges from 18-20 µm for warp yarns and 16-18 µm for weft yarns. The second fragment ranges from 23-25 µm for both warp and weft. This information means that the used wool fibers are considered fine and thin fibers for the first fragment and thick and coarse for the second. From the technological point of view, the mean fiber diameter of a lot of wool is its most important single property: it largely—but not entirely— determines the grade or count assigned to the lot in the usual expert assessment. So it is thought that the wool fibers in the first fragment are from a medium type, while those of the second fragment are from the thick type. These descriptions may interpret the numerous counts (or high density) of warp and weft yarns woven in the cm2 (8 warps ×30 wefts) in the first fragment and, in contrast, the little counts (or low density) of warp and weft yarn woven in the cm2 (6 warps × 15wefts) in the second fragment. Moreover, it is believed that these fibers could have been original textiles made of Egyptian wool fibers.

The microscopic investigation technique, Stereo microscope (SM), was used to determine the weave structures for each fragment (a plain weave technique and its derivates such as ribs technique whether regular or irregular warp ribs used in the three fragments). This technique proves that the three fragments were nearly

woven in one period and place. This textile type is considered one of the most important techniques used in Egypt; therefore, it is thought that these fragments were part of clothes woven in Egypt.

For each fragment studied, the type of spinning and weave used for production of the textile were also determined. The spinning process of the fibers composing the fragments were studied conducting both in a dextrose sense with (Z) twist direction, and in a sinistrorse sense with (S) twist direction. The (S) spinning proved to be prevalently used for the manufacturing of the three fragments, especially in the warp yarns, while the (Z) spinning was only used for the weft yarns in the second fragment. According to many previous studies (Pfister 1934, Lamm 1936 and Künhnel & Lousia 1952), most of spun yarns (which were made in Egypt) were twisted from right to left ('S' twist direction) (Maher, S. 1977). Therefore, it could be suggested that these fragments were spun and made in Egypt.

Finally, we have to study any textile objects which may be found in the excavations because these objects can lead to understanding the origin and technology of archaeological textiles (type of spinning and weave). In addition, this may help coordinate archaeological inquiries of historical background with the applied techniques and manufacturing methods.

Acknowledgements: The author wishes to thank his colleagues in the Superior Council of Archaeology for granting the author permission to investigate the 3 textile fragments. The author would also like to thank all of his colleagues at the Unit of Scanning Electron Microscopy, Sohag University, for their efforts in identifying the textile samples.

Endnotes:

(1) The sites of excavation where these 3 textile pieces are as follows:

(a) White Monastery 'Deir el-abiad', 12km west of the Nile, (fourth century A.D), (b)Temple of Ramses II in Akhmeem, 10km east of the Nile, (1290-1224 BC),

(c) Osireion's temple in Abydos, 11km southwestern of the Nile, (5000 B.C.).

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ملخص: اكتشفت حديثا ثلاث قطع من المنسوجات في ثلاثة مواقع حفرية مختلفة في سوهاج (٥٠٠ كلم جنوب القاهرة)، وتم فحصها بالمجهرية ثلاثية الأبعاد وبمجهرية مسح الالكترون (SEM). وقد تم تحديد انسجتها الطبيعية، و خصائصها المائزة، إضافة إلى كشف آليات بنياتها النسيجية وغزلها. فالصوف هو مادة نيسج القطع الثلاثة، وألوانها جاءت من مواد أصباغ طبيعية مختلفة. كما حددت آلية النسيج البسيط وتفاصيل حبكه الأخرى (مثل ما إذا كانت خيوط نسج سداه منتظمة أو غير منتظمة). والقطع الثلاثة كانت في حالة سيئة، لدرجة أن انسجتها منكوثة كليا. ونيجة لهذه الدراسة استطعنا تحديد نوع الأنسجة ومصدرها، وكذلك أصباغها وآليات حياكتها التي تمدنا بمعلومات هامة من شأنها الإعانة على طرق حفظها وصيانتها.

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