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The analysis and conservation of a 5th century CE child's tunic from Egypt

Abstract

This paper presents the conservation and analysis of an excavated child's linen tunic originating from Egypt, which was donated to a museum in the late 19th century. The tunic had repeatedly treated and altered during its museum life, starting as early as the 1930s when it was wet cleaned, and later in the 1970s, when it received an adhesive support. It was probably during this treatment that it lost its three-dimensional shape. In 2015, the tunic was conserved as part of an EU co-funded refurbishment of the museum to which it belongs. During this conservation, the tunic was returned to its original three-dimensional shape, the purple dye used to decorate it was identified as a mixture of madder and indigoid, and it was also dated between the fifth and seventh centuries CE using radiocarbon 14 dating techniques.

Keywords excavated textiles, tunic, Egypt, wet-cleaning, HPLC-DAD, radiocarbon dating, adhesives

Introduction

A child's linen funerary tunic was part of a collection of objects excavated in Egypt (including materials other than textiles) and given to the National Archaeological Museum (NAM) in Athens by two donors, namely Demetriou in 1880 and Rostovitch in 1904 (Apostolaki 1999, 3-4). Similar textile finds, also referred to as "Coptic" textiles, found their way into museums as early as the beginning of the 20th century (O'Connell 2008; Rutschowskaya 1990; Hall 1982). Coptic textiles are native to Egypt, where they originated as a pagan and later became a Christian art form. In the fourth century CE, Christianity became the official religion of Egypt. This was followed by the Arab conquest in the seventh century CE, when Egypt converted to Islam, at which time Islamic designs replaced Coptic ones, particularly in textiles (du Bourguet 1971; Badawy 1978; Carroll 1989).

In 1921, the tunic, together with the rest of the textiles at NAM, were separated from the donated collection,

and in turn donated to the Museum of Decorative Arts in Athens, as textiles were then perceived as decorative objects rather than archaeological finds. The textiles remained in this museum, now renamed the Museum of Modern Greek Culture (MMGC). The tunic, together with 13 other textiles, was selected for the new permanent exhibition of the MMGC, and was therefore conserved by the textile conservation laboratory of the Directorate of Conservation of Ancient and Modern Monuments (DCAMM) in 2015.

The tunic (MMGC accession number 764)

It is a cross-shaped tunic woven in one piece of maximum dimensions 1.2 m length and 1.08 m width with a neck opening of approximately 215 mm (fig. 1). It is an undyed linen tunic with narrow sleeves (as revealed after conservation) decorated with tapestry bands (*clavi*) woven into the main fabric, and squares, known as *tabulae* (Gabra 2014, 262), woven into the main fabric and secured along two sides by stitching (Apostolaki 1999, 95). The tapestry bands are

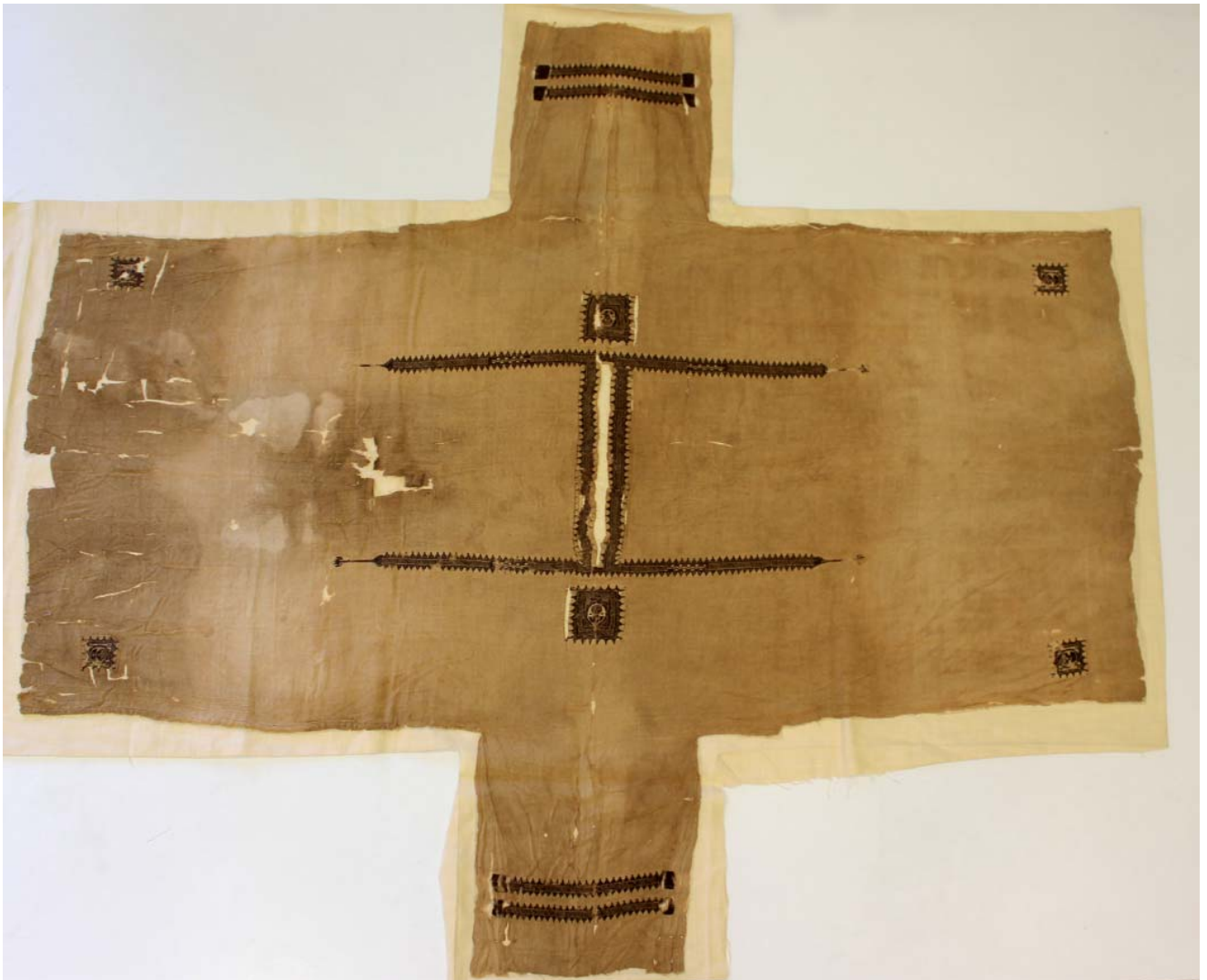


Fig. 1: The tunic before conservation (Image: Christina Margariti and Tina Chaniadaki)

approximately 25 mm wide with stylised geometrical patterns and jagged edges. They decorate the neck opening and the ends of the sleeves, known as *manicae* (Stern and Hadjilazaro Thimme 2007, 34). Similar width bands with jagged edges, a stylised floral pattern, ending in leaves with long stems, decorate the front and back of the neck opening. The tunic is also decorated with six square tapestry patches with figurative patterns (*tabulae*). There is one on each shoulder approximately 55 mm x 65 mm, and one on each bottom corner of the hem approximately 40 mm x 40 mm (fig. 2). Traces of a waist tuck have been preserved in the form of three straight and parallel creases running across the width in the middle of the tunic. The creases are approximately 40 mm apart and there is no evidence of stitching holes along them.

Waist tucks are found in the majority of narrow-sleeved tunics and would have been a method of adjusting the length, either by stitching or to accommodate a drawstring (Kwaspen & Verhecken-Lammens 2020; Pennick Morgan 2018, 102, 104). Measurements and evenness of the width seem to provide evidence as to whether the height adjustment was done by stitching or a drawstring (Pennick Morgan 2018, 102). A combination of tunnel and whip stitch was used along the sleeves and sides of the tunic to give it its three-dimensional shape.

Condition on receipt

Upon receipt, the condition of the tunic was poor. It was creased, deformed and stained, with tears and missing parts, and it had lost its original three-dimensional

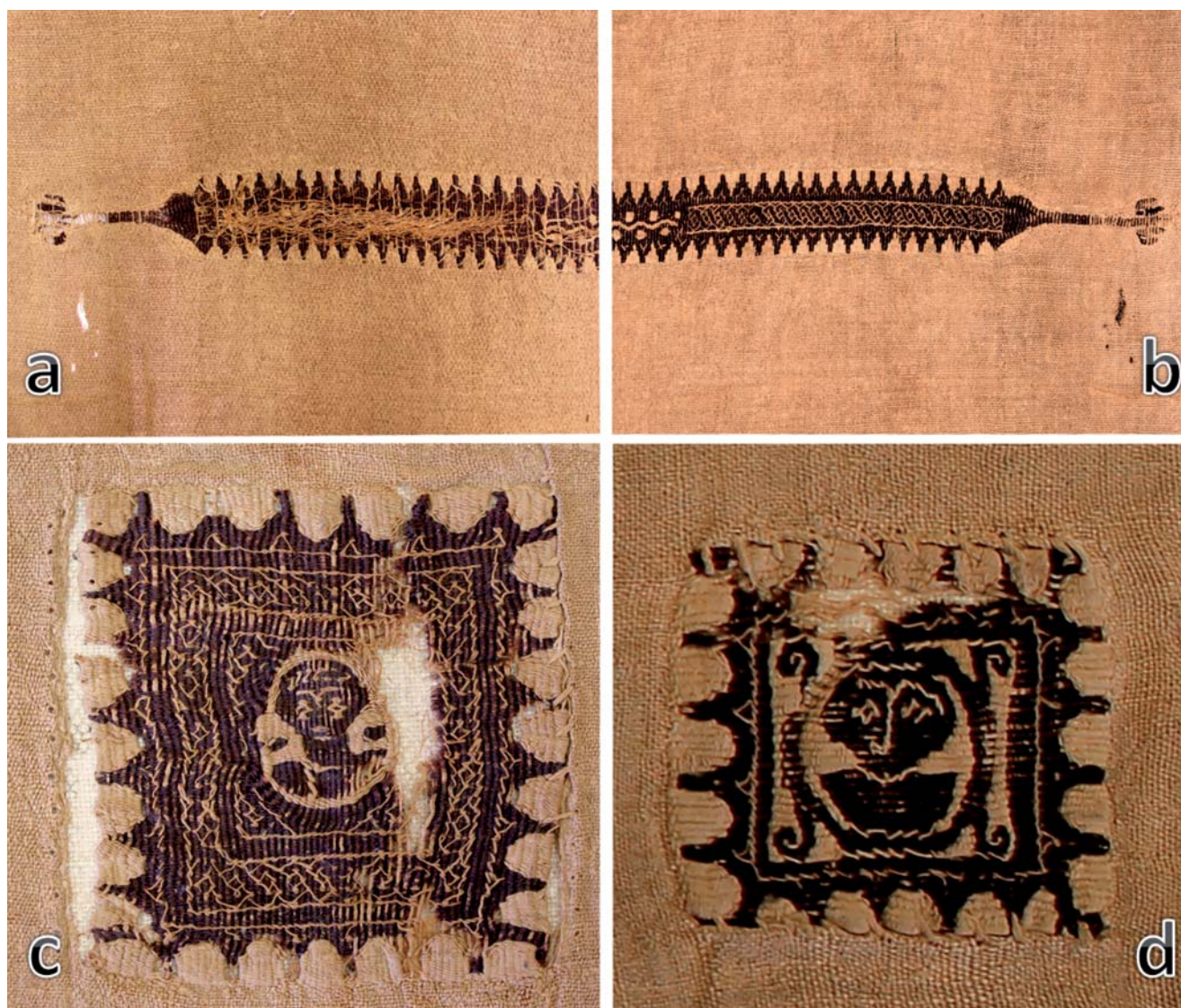


Fig. 2: a) Front of one of the decorative bands; b) Reverse of one of the decorative bands; c) One of the larger square tapestry decorations; d) One of the smaller tapestry decorations (Images: Christina Margariti and Tina Chaniadaki)

shape during a previous treatment, as explained below. The tunic was lined with a modern off-white textile. The new textile was secured in place with a coarse synthetic net, double coated with synthetic adhesive, and with additional stitching around the edges of the object. The adhesive bond between the net and the new textile had failed and, as a result, the net was not adequately supporting the lining. However, the adhesive bond was still strong and adequately supporting the object-net layer, but the coarse net was causing mechanical stress to the object, and the original textile was impregnated with the aged adhesive and had become brittle and mechanically weak (fig. 3). One side of the tunic, from the middle

down towards the hem, was heavily stained, had lost sections, and the remaining fabric was extremely brittle. In all probability, the stains were caused by the decomposing body of the deceased, which established an acidic environment which accelerated the deterioration of cellulosic fibres (Timár-Balázs & Eastop 1998, 28).

Analysis of the tunic

Past analyses and study

Anna Apostolaki, curator and later director of the museum that housed the textiles collection, studied the weave and construction and dated the textiles,



Fig. 3: Detail of one of the sleeves, showing stress and deformation caused by the previous treatment and support (Image: Christina Margariti and Tina Chanielaki)

based on their technical characteristics and decoration typology (Apostolaki 1999). Before the second world war, she collaborated with Konstantinos Zeggelis, professor and later dean of the National Technical University, on the analyses of the dyes in several textiles. Unfortunately, this study, along with many others, were lost, when her house “was completely looted during the *Katochi* (Axis occupation 1941-1945) and the *Dekemvriana* (civil uprising 1944-1945)” (Apostolaki 1952; Stassinopoulos 1997; Charalambides 2014). Thankfully, a small fraction of her collaborative work with Zeggelis has been preserved as part of the Apostolaki Archive at the Benaki Museum in Athens. In a letter from to Apostolaki dated 16 January 1935 (Apostolaki 1935), Zeggelis describes the analyses of red, yellow and blue colours from three objects, and concludes that the dyes alizarin and indigotin and combinations of the two had been applied (Chanielaki et al. 2016). In the same letter, he rules out the possibility of any of the purple colours having been dyed with shellfish purple, a fact that concerned Apostolaki and later researchers (Rutschowskaya 1990, 28; Trojanowicz et al. 2004).

Current analyses

Weave and construction analysis, fibre and dye identification, and radiocarbon dating were undertaken. Study of the weave and the construction was aided by the use of thread-counters, an Olympus

CX40 stereomicroscope, and a Dino-Lite AM413T digital stereomicroscope. Fibre identification was performed with an Olympus AX70 optical microscope, with fibre samples mounted on glass slides with Entellan® medium; and a JEOL JSM-6500F scanning electron microscope, with samples coated with gold/palladium and viewed at high pressure at 15keV. High Performance Liquid Chromatography-Diode Array Detection (HPLC-DAD), was used for the purposes of dye analysis at the Royal Institute for Cultural Heritage in Belgium. Dyes were extracted from the fibres using harsh acidic conditions (Vanden Berghe et al. 2009). Dye identification was based on comparison of the dye compounds with an extensive reference library of spectra from natural and synthetic dyes developed in-house there. Radiocarbon 14 dating determinations were measured on the Accelerator Mass Spectrometer (AMS) at the Horia Hulubei

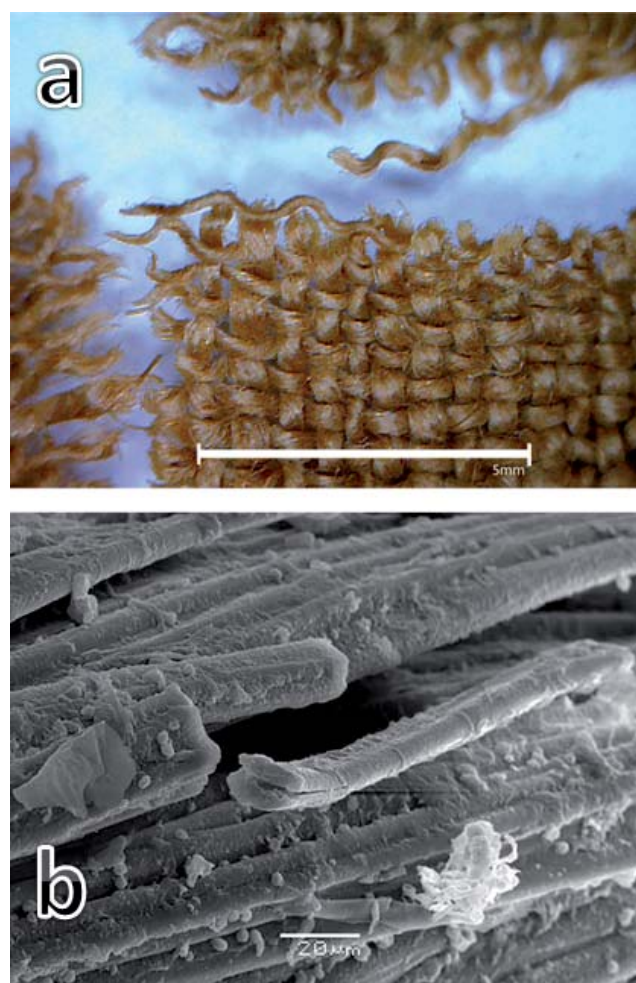


Fig. 4: a) Detail of the main textile; b) Scanning electron micrograph of the linen fibres of the main textile (Images: Christina Margariti and Tina Chanielaki)

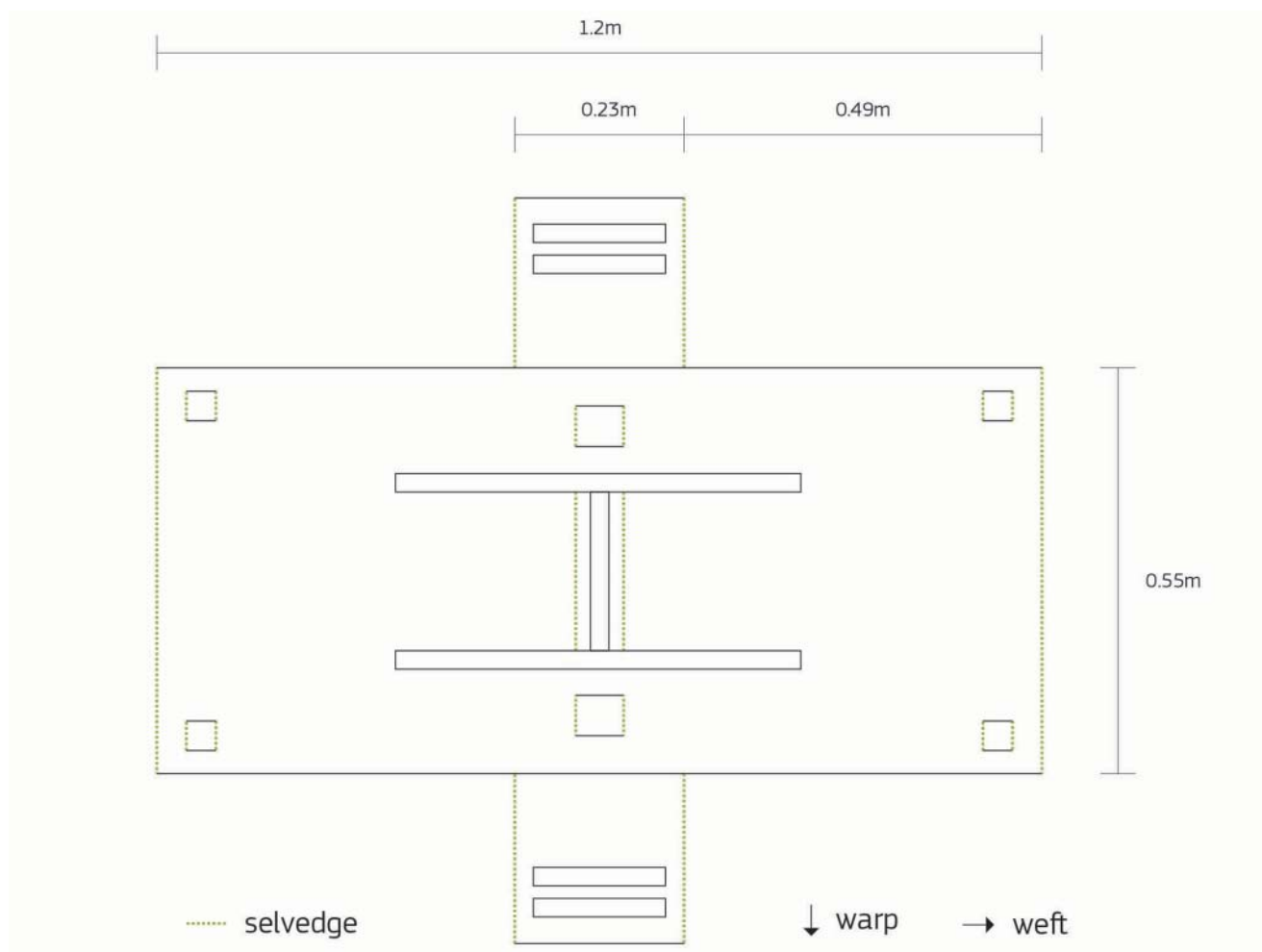


Fig. 5: The tunic with an indication of the selvages (Image: Tina Chanielaki and Andreas Koutouvalas)

National Institute for Research and Development in Physics and Nuclear Engineering, Romania (lab code RoAMS). Graphitisation was performed with the system CHNOS Elemental Analyser/AGE 3 (Wacker et al. 2010; Sava et al. 2019). Dating calibrations were performed using OxCal and the IntCal13 calibration curve date (Bronk Ramsey 2009; Reimer et al. 2013).

The main fabric of the tunic is a plain balanced weave 18 x 18 threads per cm of undyed, s-twisted linen yarns with varying diameters (fig. 4). The warps of the textile run horizontal to the finished tunic and selvages have been retained along the neck opening, the sides of the sleeves, the front and back hem, and the top and bottom sides of the decorative tapestry squares (fig. 5). The decorative bands and squares were made with a slit-tapestry technique, of approximately 8 x 16 threads per cm square, with undyed double linen warps, and purple wool z-twisted and off-white (undyed) linen s-twisted wefts (fig. 6). The presence of z-twisted

yarns is quite a rare occurrence for an object of this time period originating from Egypt (Bender Jørgensen 2017, 238-239, 243; Verhecken-Lammens n.d.). Pattern details were executed by undyed, s-twisted linen thread with a flying-thread brocading technique (Verhecken-Lammens 2013) described as embroidery by Apostolaki (1999, 95) (fig. 2a). The sides of the tapestries that are not woven into the main fabric were secured to it by whip stitching with Z3s undyed, linen cord (fig. 7).

The extract of the purple wool contains the following dye composition: purpurin (71), alizarin (14), indigotin (6.5), munjistin (5) and isatin (3.5). The numbers represent the relative ratio of each compound, in percentages, based on the peak area of the compound after integration at 255 nm wavelength. More significant is the relative ratio between purpurin and alizarin is 83/17 (peak area ratio of both molecules at 255 nm, expressed in percentages) (Vanden Berghe et

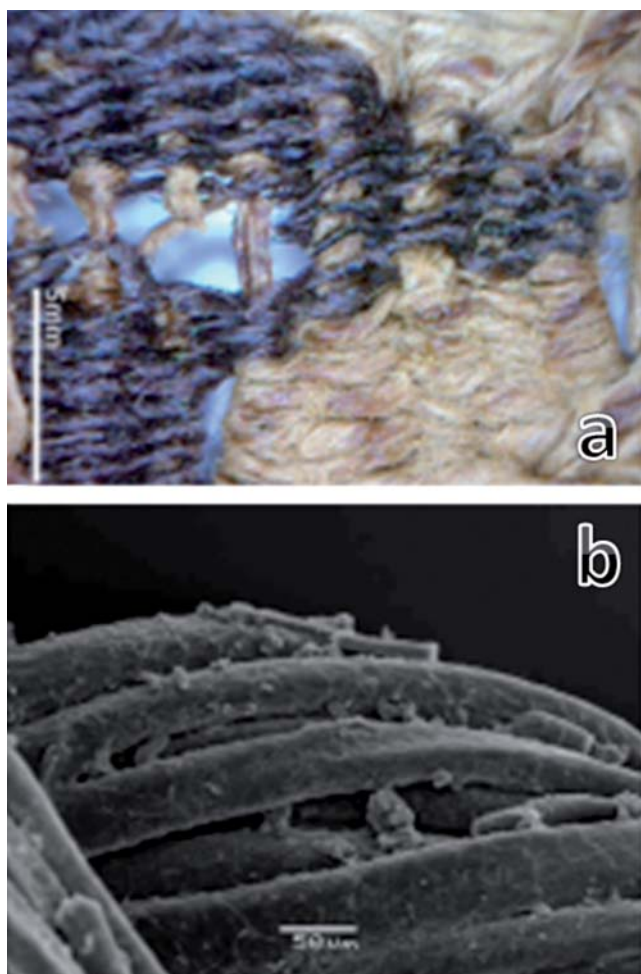


Fig. 6: a) Detail of the tapestry decoration; b) Scanning electron micrograph of the wool fibres of the tapestry decoration (Images: Christina Margariti and Tina Chanielaki)

al. 2017).

It was concluded that the purple colour of the wool threads was not produced by shellfish but obtained after mordant and vat dyeing with red anthraquinone dyes from the roots of a Rubiaceae family plant and the blue vat dye indigotin from from an indigoid plant source, respectively. The given purpurin/alizarin ratio indicates the use of dyer's madder (*Rubia tinctorum* L.), while the indigoid dye refers to either woad (*Isatis tinctoria* L.) or indigo (*Indigofera* or *Polygonum* sp.). No distinction can be made between the two sources of the blue dye, either through its chemical composition or by its historical context.

This method of dyeing purple is entirely in keeping with the well-known Egyptian tradition for it (De Moor et al. 2010; Wouters et al. 2008). This is repeated proof of the dyeing techniques used in Egypt from the second century onwards, which are based on

combining two (or more) colour sources from a very limited palette, consisting of a red, a yellow and a blue dye source, in order to create a wide range of shades (Vanden Berghe 2011).

According to radiocarbon 14 dating analysis, the find was placed between 424 and 611 calAD, i.e the middle of the fifth to the early seventh centuries CE (RoAMS-625.73: 1527±41BP). This falls within the range of Apostolaki's (1999, 95) dating, based on the typology of the textiles which placed the tunic between the fourth and sixth centuries CE. Bearing in mind that the dating of Egyptian tunics before the sixth century CE was based on woven-in tapestry decorations by Apostolaki (1999, 46) and the radiocarbon 14 dating results, it would be acceptable to date this tunic to the fifth century CE. Radiocarbon dating of the tunic was not very straightforward and had to be repeated. The first test placed it between 1504 and 1396 calBC (RoAMS-569.73: 3169±30BP), which was probably impossible. The reason for this deviation could potentially be attributed to the combination of the poor condition of the find with the presence of synthetic adhesives (polyvinylacetate - PVA) that had impregnated the fibres during the 1970s treatment. It was therefore decided to repeat the analysis, this time subjecting the sample to an advanced pretreatment with more than one solvent (namely hexane/acetone/ethanol) to remove the synthetic adhesive residues. This pretreatment is generally not applied to cellulosic samples straightaway, since it might dramatically reduce the volume of the sample's organic matter, which is crucial for the execution of the analysis (Hajdas et al. 2014).

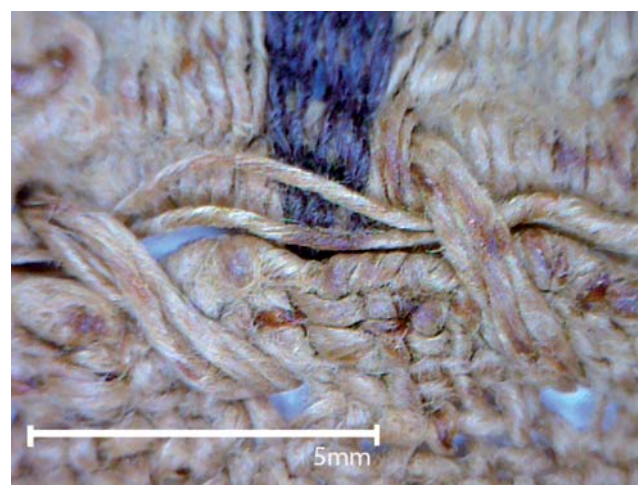


Fig. 7: Detail of the stitching which secures the tapestry decorations on the main fabric (Image: Christina Margariti and Tina Chanielaki)

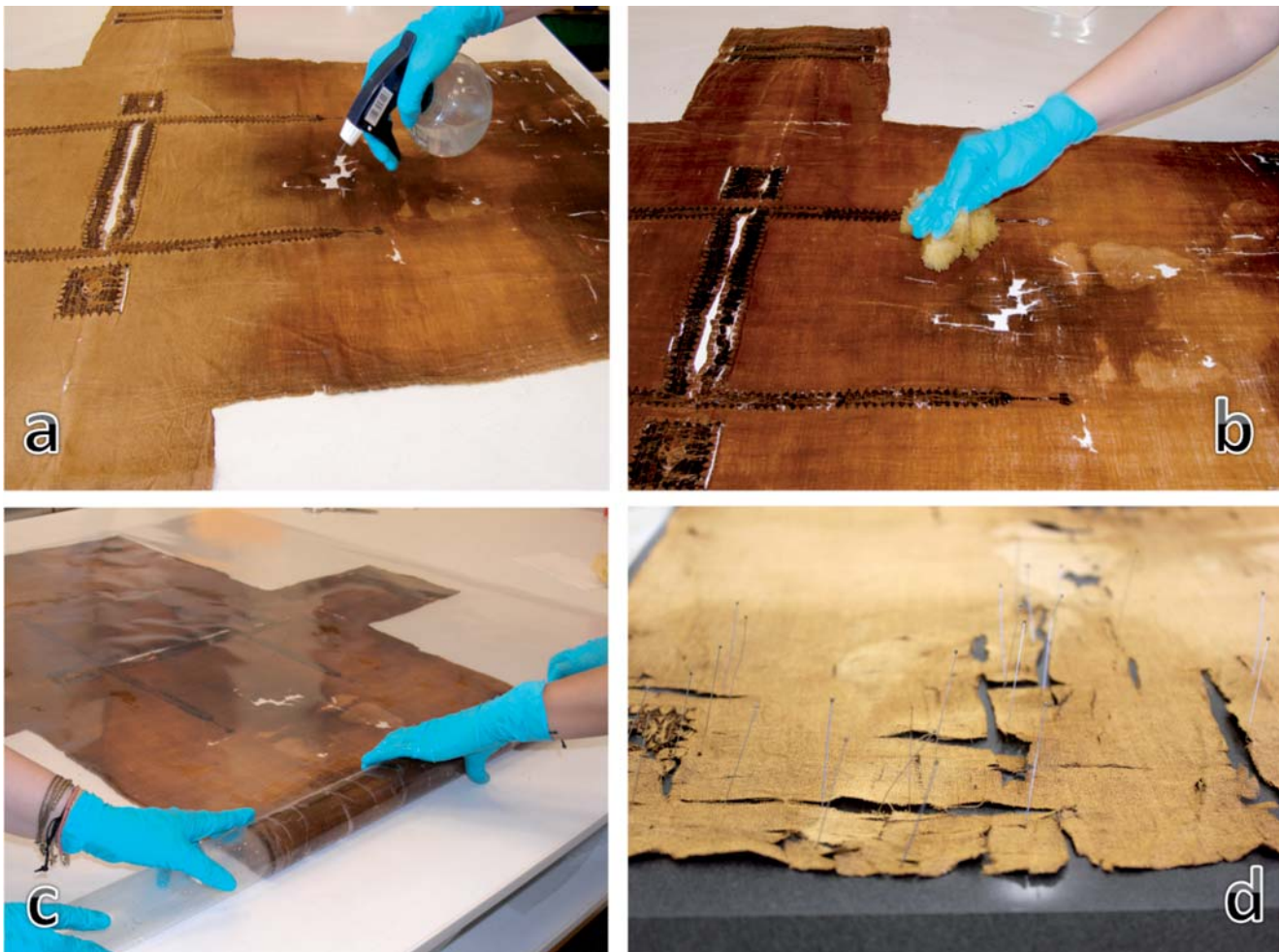


Fig. 8: a) Spraying water on the tunic; b) Blotting excess water with natural sponges; c) Rolling the tunic to turn it upside down; d) Using entomological pins to secure the loose fragments during drying (Images: Christina Margariti and Tina Chanielaki)

Conservation of the tunic

Past interventions and treatment applied

Apostolaki (1999, 3-4) observed perceptively that the finds were cut by the looters and stitched in pieces on different objects. Moreover, in a draft letter, she reports that the museum was “full of moth”, and that the Coptic textiles had suffered from this the most (Apostolaki 1926-1932). She also wrote that she wet cleaned them with natural soap and subsequently supported them on new linen fabrics with stitching (Apostolaki 1999, 3-4, 40).

There is no evidence or documentation that the collection was conserved during the following decades but this would have been impossible because the museum was closed and its collection transferred to the safer storages of the National Archaeological Museum during the second world war, where it remained for many years (MMGC 2020). Much later,

during the 1970s after the collection had already returned to the MMGC, a trained textile conservator treated the tunic with synthetic adhesive and coarse net and linen supports. This technique was popular in the United States and the United Kingdom from the 1960s (Brooks and Eastop 2011; Hackett and Hillyer 2019; Hillyer 2010, 181). It was described in detail by a senior conservator who witnessed the procedure at the time. First, a coarse synthetic net was sprayed with a polyvinyl acetate adhesive (Mowilith D65) on a glass surface. After drying, the net with the adhesive was ironed onto the reverse of each object (Kavassila 2013). Based on that evidence and the first published image of the tunic (Apostolaki 1999, 45), it was deduced that the tunic lost its three-dimensional shape during the 1970s intervention. The fabric was originally stitched along the sides to give the tunic its three-dimensional shape. When the object was flattened out to receive the adhesive support the stitching was not undone, but



the fabric was cut, preserving in this way the original stitching along the front side of the tunic.

Recent conservation of the tunic

Conservation work started with the removal of the modern linen lining, which was achieved mechanically since the adhesive bond had failed. This was followed by mechanical surface cleaning with a low power vacuum. Then, the net lining was removed by deactivation of the synthetic adhesive with solvent. The object was placed on a silicon-coated polyester film (with the reverse side of the object upwards). The silicon release film was used to avoid adhesion of the object to the working surface after reactivation of the adhesive with the solvent. Blotting paper pads cut in 10 x 10 cm squares and impregnated with pro analysis ethanol (purity 99.5% denatured with $\leq 1\%$ methyl ethyl ketone) were placed on the net for 10 seconds and pressed lightly with glass weights (Timár-Balázszy & Eastop 1998, 324). A 10 x 10 cm area was treated each time, and when the net was successfully removed, treatment progressed to an adjacent area. According to the Teas solubility chart (a triangle diagram of solvents first published by Teas 1968), among the non-toxic solvents, acetone is the one that dissolves polyvinyl acetate adhesives, while ethanol has a borderline dissolution effect (Horie 1997, 198). However, complete dissolution of the adhesive might have driven its molecules deeper into the fibres, the fragile condition of which would not permit sufficient rinsing. In addition, preliminary testing with acetone showed that it affected (melted) the synthetic net used in the past to carry the adhesive. It was therefore decided to apply ethanol that would swell rather than dissolve the adhesive (Timár-Balázszy & Eastop 1998, 324). The selected treatment was very efficient in removing the net easily with limited fibre loss (the majority of which was used as samples for the instrumental analyses described above).

When net and adhesive residue removals were complete, it was revealed that the object was in a fragmentary condition, brittle, and deformed. The application of ethanol probably increased the dessication of the fragile fibres because alcohols are known to form azeotropic mixtures with the bound water molecules within fibres, and extract it during evaporation (Timár-Balázszy & Eastop 1998, 177). It was therefore decided to continue treatment of the tunic with floating/bench solvent and wet cleaning, to ensure further removal of the swollen adhesive (solvent), removal of polar dirt accumulated from the long years of storage (water), humidify the brittle fibres, and move and align the fragments with

minimum fibre loss and stress (water) (Bresee 1986; Breeze & Eidelheit 1995; Timár-Balázszy & Eastop 1998, 194, 275). As Apostolaki (1999, 4) documented, the tunic had been wet cleaned before, therefore no ethical issues applied. The process took place with the tunic placed on the laboratory bench rather than immersed in a bath, to avoid mechanical stress of the fragile textile. A mixture of 75:25 ethanol in deionised water was lightly sprayed first on the inside and then on the outside of the tunic and blotted with natural sponges and blotting paper. The mixture was changed to 50:50 ethanol in deionised water for the next two applications and finished with deionised water in the last two. In total, the process was repeated six times, each time turning the textile upside down. It was protected inside with two layers of silicon-coated polyester film (the upper layer always removed during washing) (fig. 8). No surfactants were added to the mixture as bench washing would not allow for sufficient rinsing. When wet cleaning was complete the object was realigned, secured in place with very

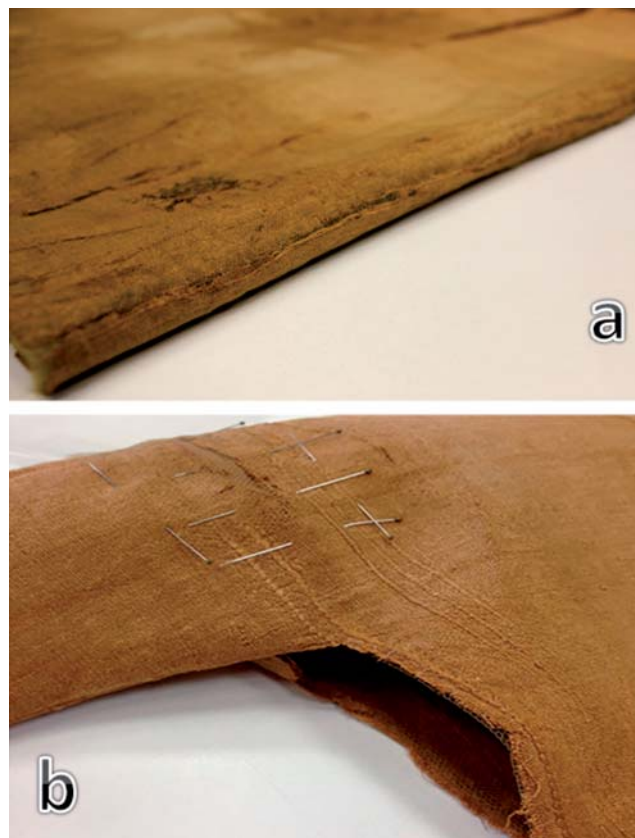


Fig. 9: a) The nylon net was used to stitch the tunic back to its original three-dimensional shape; b) Stitching the sides revealed the underarm openings of the tunic (Images: Christina Margariti and Tina Chanialak)

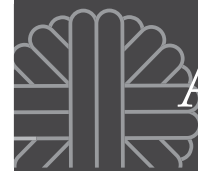


Fig. 10: a) Side A (possibly the front) of the tunic after conservation; b) Side B (possibly the back) of the tunic after conservation (Images: Andreas Santrouzos)

fine entomological pins (size 00 and 000) on archival polyethylene foam (Plastazote®), and left to air-dry, locally aided with blown air (using hair dryers on a cold setting). Drying of the object was complete in approximately one hour.

After treatment, the fibres were more relaxed and elastic, i.e. they had regained some of their lost moisture. Colour measurements before and after solvent and wet cleaning were used to evaluate the efficiency of the treatment in successfully removing the old adhesive and dirt by measuring the colour changes with a HACH LANGE spectro-color chromameter using CIE L*a*b* coordinates. These demonstrated that the colour of the tunic became lighter, and that of the main fabric moved to yellow, while the purple decorations moved to the blue and red areas of the colour spectrum. Based on these results, it was considered that a great amount of the discoloured (darkened) adhesive and dirt had been removed.

After cleaning, the missing areas were in-filled with cotton percale sheeting fabric dyed to the appropriate

colour in the lab with Solophenyl, Ciba Geigy® dyes. Cotton was chosen for two reasons: first, as it is a lighter fabric than linen it adds less mechanical stress to the fragile object; and second, deeper colour tones can be achieved when dyeing it in a conservation laboratory. In addition, the tunic was fully supported on the inside by stitching on nylon bobbinet with silk monofilament threads, both dyed in the lab with Lanaset, Ciba Geigy® dyes. Full support with nylon bobbinet rather than cotton was selected because it is much lighter and much more elastic than the latter, and to allow future access to the inside of the tunic's main fabric and the reverse of the tapestry elements for further study. An overlay support of nylon bobbinet was placed over the most fragmented, stained area to provide additional support. The full net support was used to return the tunic to its original three-dimensional shape by laid-thread couching that would provide better support than running stitch, using a silk monofilament thread (fig. 9a & fig. 10). This action featured the small size of the tunic, the narrow sleeves and the apertures on the underarms areas (fig. 9b and fig. 10).

An acrylic (Plexiglas®) hollow rod padded with two layers of cotton domette, covered with an undyed silk habutae, with an additional sleeve case made of one layer of cotton domette and covered with dyed-in-the-lab silk, were prepared for the future display of the tunic. Finally, the tunic was padded and placed in an acid-free box for storage.

Conclusion

Conservation afforded unrestricted access to sample the object and to perform analyses that provided interesting evidence and information on the construction, material identification and dating of the tunic. Radiocarbon 14 dating had to be repeated twice since the first time the analysis gave totally unexpected results. This was possibly due to a combination of the very poor condition and heavy impregnation of the fibres by synthetic adhesives. On the other hand, despite the presence of the synthetic additives, the procedure used still allowed the dyes to be extracted from the fibres so that analysis was possible. This showed that the purple was obtained by the use of madder and woad or indigo, the well-known procedure for the purple dyeing wool in Egypt. However, little is known about the influence of the impregnation products on dye behavior and dye extraction in general. This emphasises that the influence of previous treatments and interventions have to be taken into account when planning such analyses and interpreting the data. Conservation greatly improved the condition of the brittle fibres



and restored the original shape of the object. Viewing the tunic in its three-dimensional form illustrated the staining pattern from the decomposition products of the body, and highlighted the fact that the tunic was made for a child, making the provenance of the object more intelligible to the museum visitor.

Acknowledgements

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