INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE
ISSN: 2067-533X Volume 14, Issue 4, October-December 2023: 1485-1506 www.ijcs.ro
DOI: 10.36868/IJCS.2023.04.16

CONSERVATION PROCESSES OF A WOODEN COFFIN COVERED WITH A BLACK RESIN LAYER AND COLORED MATERIALS IN DAHSHUR ARCHAEOLOGICAL AREA

Abdelmoniem M. ABDELMONIEM[1,*], Wael S. MOHAMED[2], Naglaa MAHMOUD[1], Saleh MOHAMED[1], Mostafa Ahmed ABDEL-FATAH[3], Ali M. OMAR[4], Nahed WALY[5], Rim HAMDY[5]

[1]Fayoum University, Faculty of Archaeology, Conservation Department, Al Mashtal, 32 Zaid Ibn Haretha, 63514 Fayoum, Egypt.
[2]National Research Centre, Polymer Department, Dokki – Cairo, Ad Doqi, 33 El Buhouth St, 12622, Egypt.
[3]Ministry of Tourism and Antiquities, Adress, 33 El Buhouth St, 12622, Egypt
[4]Grand Egyptian Museum, Conservation Center, Al Giza Deser, Kafr Nassar, 3513204, Egypt
[5] Cairo University, Faculty of Science, Botany and Microbiology Department, Giza District, Oula, Egypt

Abstract

This paper describes the results of a multi-technological analytical protocol performed on the painted surface of an Egyptian wooden coffin and documents the conservation processes of a wooden coffin covered with a black resin layer and coloured materials in Dahshur Archaeological Area dating back to the late period. It uses visual observation, optical microscopy (OM), technical imaging, 2D and 3D programmes, and a scan made using an electron microscope coupled with an Energy Dispersive X-ray (SEM-EDX), X-ray diffraction (XRD). Wood identification was also carried out. The results showed the use of yellow ochre for the yellow painted layer; the ground layer was calcium carbonate with gypsum, and the fabric layer was linen. The conservation processes of the wooden coffin included mechanical and chemical cleaning; reassembling the separated wooden parts, ground layer, and black resin layers; filling the edge of the ground layer; and consolidating the wood, black resin, and painted layer. The conservation processes included mechanical cleaning using soft brushes, chemical cleaning using xylene and distilled water for the black resin layer and ethyl alcohol and distilled water for the painted layer, stabilisation of the separated ground layer using Paraloid B72, filling the cracks of the ground layers using glass microballoons with Paraloid B72, and consolidating the painted layer with nano-silica with Klucel G (hydroxypropyl cellulose) (0.5% concentration).

***Keywords**: Polychrome Wooden Coffin; Black Resin; Restoration; Nano Materials; Reassembling*

Introduction

Wood is one of the key materials in archaeological research [1]. Degradation mechanisms are active during long-term exhibition and storage due to temperature, moisture, and lighting effects; thus, a stable (controlled) environment should be provided for wooden objects [2].

The materials used for these processes proved to be stable and retrievable by many researchers. The general requirements of wood consolidation materials include reversibility,

* Corresponding author: ama63@fayoum.edu.eg

compatibility, and re-treatability [3]. The use of nanosized metal preservatives allows for deeper penetration and more homogenous uptake of particles in the wood [4]. The main reason to use nanotechnology in wood science and technology is the unique characteristic of nano-based materials being able to penetrate deeply into wood substrates effectively, which, in turn, alters the wood's surface chemistry. This use subsequently causes an improvement in the wood properties [5]. The conservation of the coffin has great importance to future generations [6].

The studied coffin was found in the Dahshour storeroom and measured 190cm long, 51cm wide, and 55cm high. It consists of the body and lid. However, the lid was broken into more than 16 pieces. Due to the difficulty of assembling them in the previous restoration, they were wrapped and placed inside the coffin. The body of the coffin was separated because of the damage to the tenon. In addition, there was a missing part on the left side of the body and the lid, and the face of the lid was missing. The outer surface of the coffin was covered with a textile layer at some parts under the preparation layer, and the black resin layer was decorated with painted layers (yellow, red, and blue), while the inner surface was covered with a yellow-painted layer. The painted layers suffered from many deterioration aspects, including flaking, cracking, and missing parts. It was covered with a thick layer of dust resulting from bad storage inside the storerooms of the Dahshour Archaeological Area. Therefore, this study aims to investigate the pigments, ground layer, and black resin layer, identify the wood species used on the coffin, and provide necessary information for suitable conservation work using 2D and 3D documentation and different techniques [7, 8].

Materials and Methods

It is used to identify the condition of the wooden coffin, using the examination with the naked eye in order to diagnose the existing manifestations of damage [9-12].

The coffin was documented using computer software to illustrate the decoration of the painted layer on the black resin layer.

Photographic documentation was used to document the current state of the coffin and the aspects of damage. The images were also used in 2D and 3D documentation using a smartphone camera and a Sony A6000 digital camera.

Agisoft PhotoScan program was used for photogrammetric documentation to make a 3D model of the images [13, 14] because there must be an overlap among the photos [15].

Adobe Illustrator CC 2014 was used to highlight the decoration of the black resin layer.

Microscope - Inverted Microscope Carl Zeiss AG Cell Culture PNG was used to identify the wood species. Thin sections were obtained in the three principal anatomical directions: Transverse (TS), tangential (TLS), and radial (RLS) [16-20].

The surface of the coloured materials and the stratigraphic composition of the preparation layer and black resin were studied using a USB Digital Microscope with a magnification capacity between 20 and 500× [21, 22].

The samples were examined under the stereomicroscope in order to describe their color and general structure (surface condition, presence of color grains and black resin, number and thickness of the various layers, etc.) [23-26] by stereo microscopy (Zeiss Stereo Discovery V 20, equipped with Axio Cam MRC5).

Upright microscopes have been used to identify the type of textile material using Zeiss Upright microscopes-Axio Imager. M1 equipped with AxioCam camera MRC5.

SEM-EDX was applied to characterize the elemental composition of the layers of the black resin layer and yellow pigments. Analyses were performed by means of a Quanta 250 FEG with SEM-EDX (Energy Dispersive Xray Analyses). The accelerating voltage was 30kV [27-29].

XRD is the most consistent technique for the identification of crystalline materials, allowing for the identification of each component in a mixture [30-33], Panalytical X, pert pro

PW 3040/60 with Scan Axis: Gonio Cu-target tube and Ni filter at 40kV and 30mA were used. (X'Pert Highscore) software was used for identifying the components of the ground layer and yellow pigment [34].

Results and discussion

The coffin was in bad condition. It was previously restored by primal AC33. It was covered with a thick layer of dust (Fig. 1a-e). Bad storage plays a major role in deterioration because wooden artifacts undergo complex alteration and degradation during aging [35]. There was a lot of damage to the coffin, e.g., separations, loss of the ground and painted layers (Fig. 1f), and missing parts from the head area because of the bad condition of the coffin.

Fig. 1. The deterioration of the coffin and missing parts and previous restoration: a) fading of the black resin layer; b) broken parts of the lid of the coffin; c) Previous restoration intervention; d) fading of the black resin layer; e) Previous restoration intervention; f) missing parts

Two-dimensional documentation was used to identify the decorations on the surface of the coffin, as well as to identify the places of the previous restoration used in the completion (Figs. 2a, b, 3 and 4a, b).

Fig. 2. 2D documentation of the inscriptions of the wooden sarcophagus: a) the right side; b) the left side

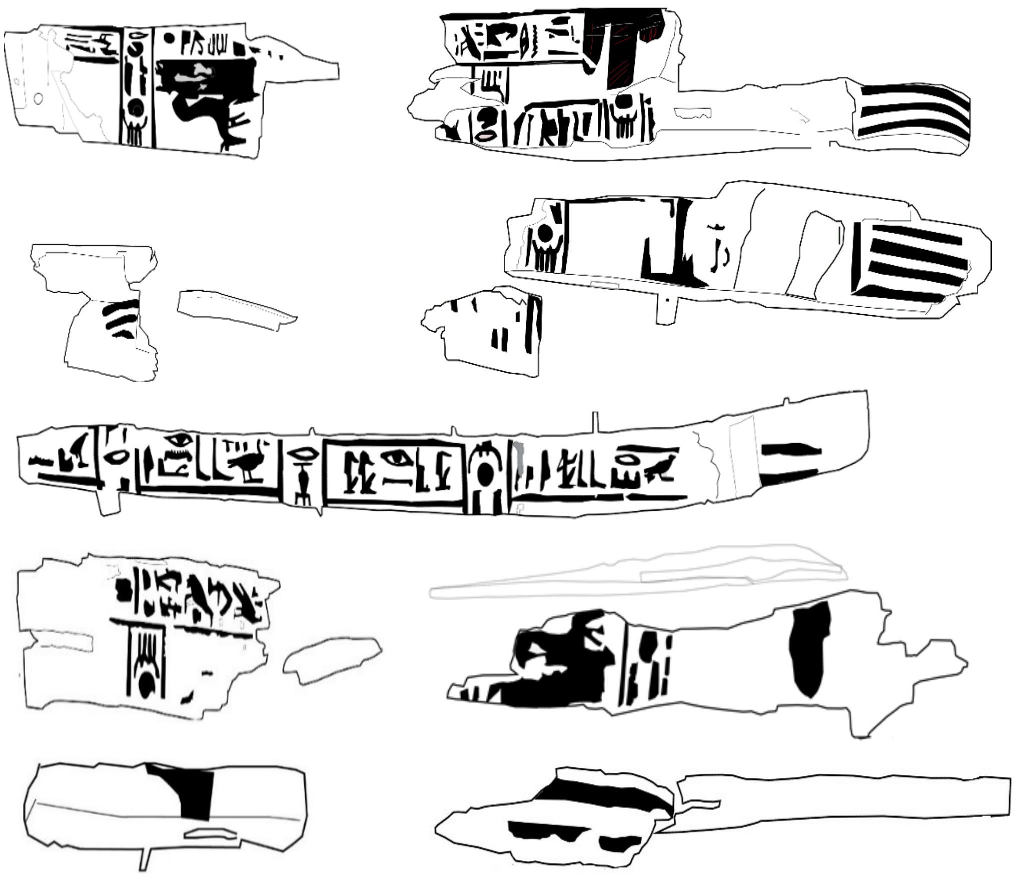

Fig. 3. 2D documentation of the lid of the wooden coffin

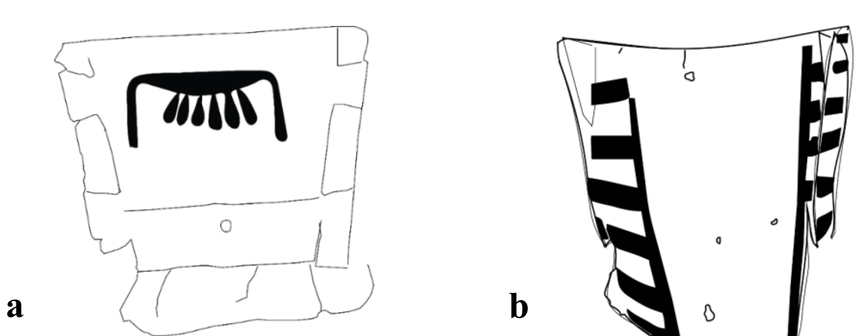

Fig. 4. 2D documentation of the lid of the wooden coffin:
a) the head area; b) the foot area

Photogrammetric documentation

To accurately document the condition of the coffin and save the 3D modules in the Dahshour archaeological area's archive (Fig. 5), the 3D modules enabled computer users to view all sides of the coffin. This could make it easier for the conservator to monitor changes to the coffin's surface. The ancient Egyptian cultural treasure can be seen by experts and regular people alike by uploading the 3D module to the Internet [36].

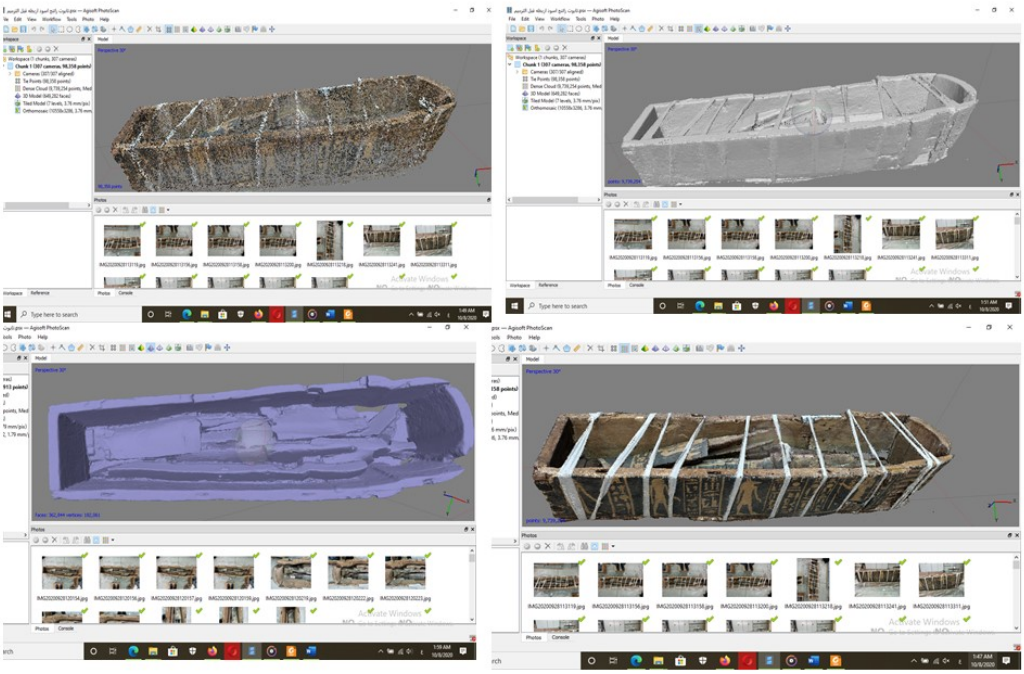

Fig. 5. Stages of producing a 3D model of the coffin

Black resin layer

The OM (Optical Microscope) of the black resin layer showed that these black resin layers were covered with shiny layers resulting from the previous consolidation materials and covered with a white material as a result of the previous restoration (Fig. 6a,b).

The SEM of the black resin layer revealed crystallization of salt grains on the surface and the uneven surface of the black resin layer, as well as deterioration of parts of the surface. EDX of the black resin layer (Fig. 7a) showed the elements carbon (C) and oxygen (O), resulting from the organic materials used in preparing the black resin layer, and the presence of sodium elements (Na) and chlorine (Cl) due to the presence of sodium chloride salt on the surface of the black resin layer. The EDX wasn`t useful for the analysis of the black resin layer, so research must exclude it.

The digital microscope revealed deterioration and loss in the layer of coloured materials and the presence of a black resin layer, on top of which is the yellow-colored material and also above it the layer of the red-coloured material. Also, there are some cracks and fine cracks in the red-coloured material in the lower part of the centre of the coffin (Fig. 6d).

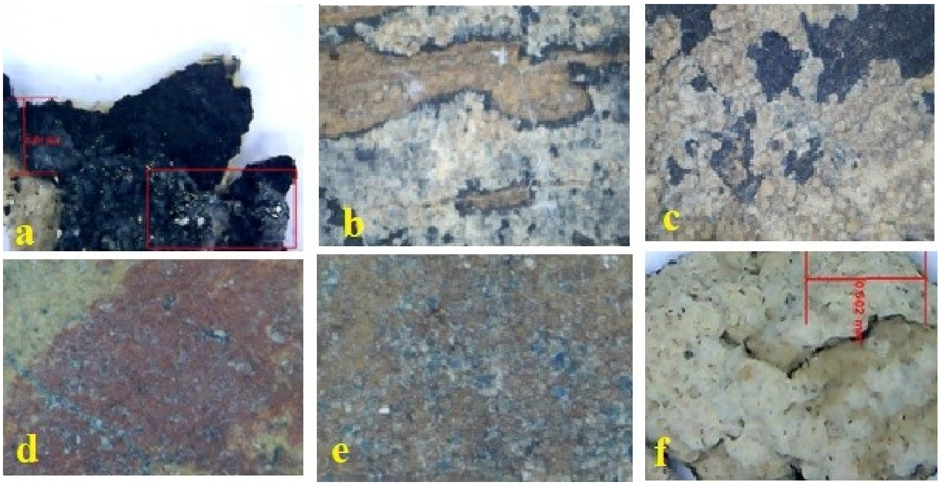

Fig. 6. Optical photomicrographs showing the course morphology of the black resin layer and painted layers surface used in the coffin: a and b) the black resin layer; c) the yellow pigments; d) red pigment; e) blue pigment; f) the ground layer

The pigments

The OM of the yellow pigment on the top of the black resin layer showed loss, damage, cracks, and microcracks, as well as parts of the reinforcing material used in the previous restoration.

OM of the yellow pigment on top of the black resin layer shows loss, damage, cracks and microcracks (Fig. 6c), as well as parts of the reinforcing material used in the previous restoration .The SEM of the yellow pigment on top of the black resin layer shows the heterogeneity of the surface of the coloured material as well as the effect of the reinforcing material used in the previous restoration In the EDX analysis (Fig. 7b) of the yellow pigments on top of the black resin layer, it was found that carbon (C), calcium (Ca), and oxygen (O) are due to the calcium carbonate compound used in the ground layer and the lack of good coverage of the coloured material used. The blue color of the coffin lid is in a deteriorated condition and show signs of loss and fading (Fig. 6e).

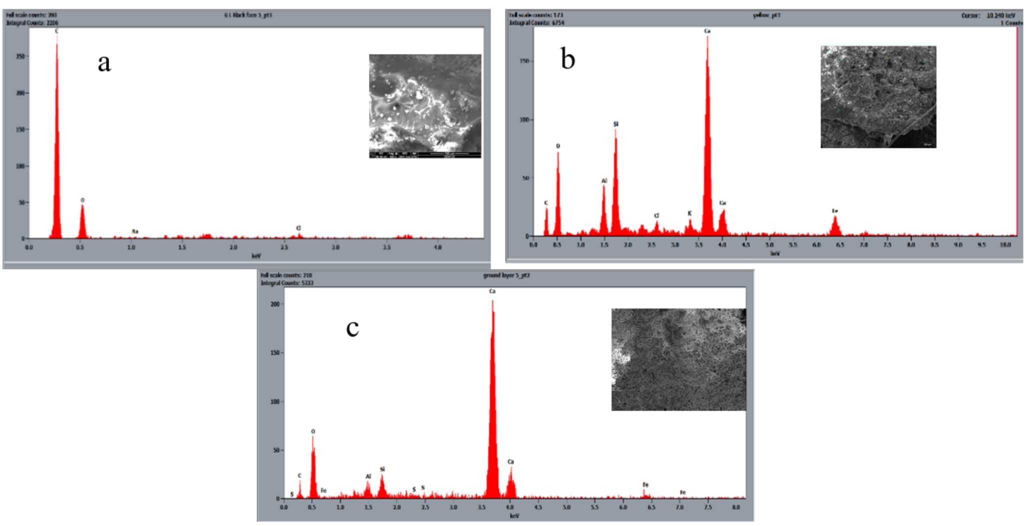

Fig. 7. SEM-EDX spectrum of a) black resin layer, b) yellow pigment, c) ground layer

The presence of the aluminium elements (Al), silicon (Si), is due to the aluminium silicate present in the dust or to the impurities in the coloured material, and the silicon (Si) element may be due to the quartz present on the surface of the sample due to the presence of the store in a desert area, and the iron elements (Fe) and oxygen (O) due to the presence of a compound goethite used in the yellow-coloured material. From the analysis by X-ray diffraction (Fig. 8a), it was found that the yellow coloured material consists of the mineral goethite FeO(OH). The most common yellows are goethite, yellow ochre, α- FeOOH [37-39].

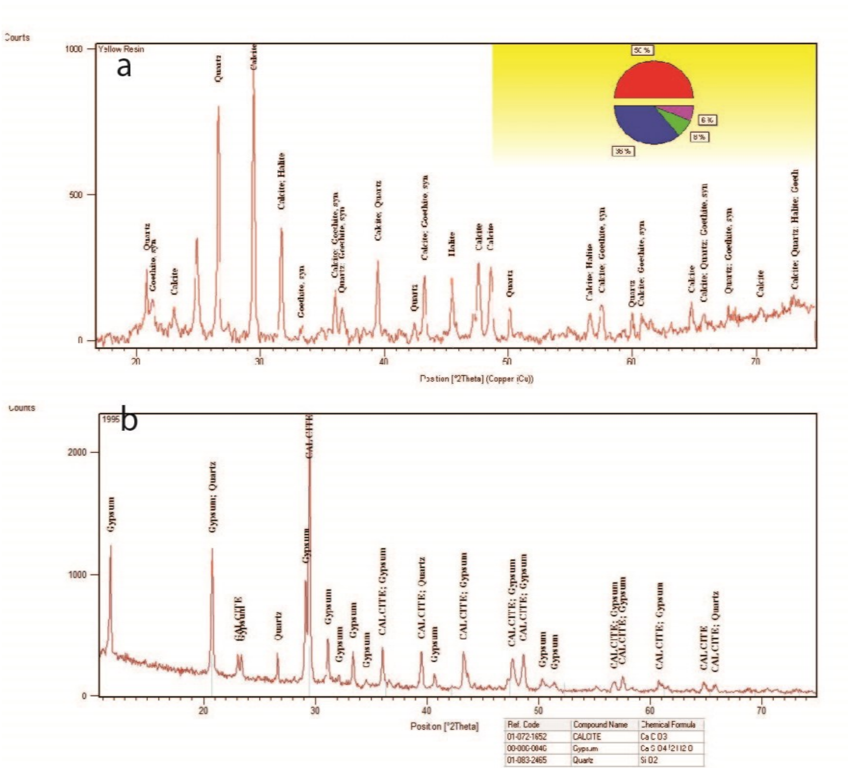

Fig. 8. XRD patterns of the painted coffin components:
a) yellow painted layer; b) ground layer

OM of the ground layer of the black resin shows some cracks and fine cracks (Fig. 6f). The SEM of the ground layer of the black resin preparation shows the homogeneity of the surface. The EDX of the preparation layer (Fig. 7c) showed the presence of calcium (Ca), and oxygen (O). These elements suggest the preparation layer consists of the mineral calcite (calcium carbonate) $CaCO_3$ used in the preparation layer. And in the X-ray diffraction analysis (Fig. 8b) it was found that it consists of $CaCO_3$ and gypsum.

Textile

The OM of the textile under the black resin layer illustrated that it consisted of basic weave types: (a) plain weave [40].

The OM of textile fibres (Fig. 9) showed that the textile fibres were covered with the consolidation material. They were linen fibres because they appeared under the microscope in the form of smooth cylindrical bundles with some swollen areas along the fiber. They were characterised by transverse slits at the site of the bulge (similar to the shape of a forest).

Moreover, the cylinder consisted of a thin interior channel filled with protoplasm and surrounded by fibroblasts. Flax fibre cells were characterised by enlarged walls of cellulose and adhered to each other as well as to cells surrounding the pectos [41-50].

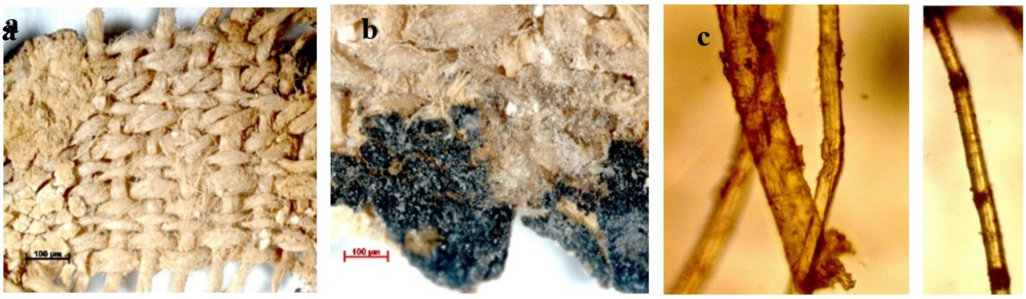

Fig. 9. The fiber on the wooden coffin ground layers

Identification of Wood Species

Examination by a light microscope was used to identify the type of wooden stand in the coffin after making the necessary sectors. It was found that the coffin consisted of sycamore wood.

Ficus sycomorus L. (Moraceae – Fig. 10)

The growth ring was indistinct or absent. The wood was diffuse-porous. Vessels were solitary or in radial multiples of 2 to 4. The mean tangential diameter of earlywood vessel lumina was 100-200μm. There were less than 5 vessels per mm^2. Fibres were septate and nonseptate, thin- to thick-walled. Tension wood was present. Apotracheal parenchyma was diffuse. Axial parenchyma vasicentric was often confluent or in bands more than three cells wide.

Rays were of two distinct sizes, and larger rays were commonly 4 to 10 seriate. Ray cells procumbent had 1 to 4 rows of upright and square marginal cells. Prismatic crystals were present in axial parenchyma cells.

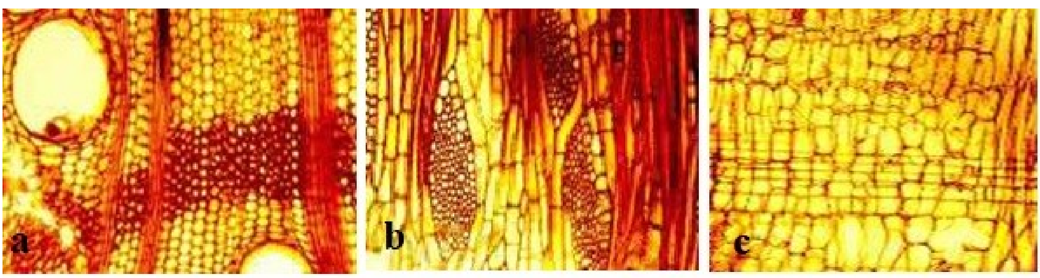

Fig. 10. Microphotographs of the wood sections showing the anatomical characteristics of *Ficus sycomorus*: a - Transverse section (TS); b - Tangential section (TLS); c - Radial section (RLS).

***Quercus cerris* L. (Cupressaceae –** Fig. 11**)**

Transverse section

Growth ring boundaries were distinct by the difference in vessel size between latewood and earlywood and by radially flattened latewood fibers. Wood rings are porous. Vessels were in a diagonal and radial pattern, predominantly solitary. The mean tangential diameter of earlywood vessel lumina was more than 200μm, 5–20 vessels per mm^2. Fibres were thin- to thick-walled. Axial parenchyma diffused into aggregates. Apotracheal parenchyma was in narrow bands or lined up to three cells wide.

Rays had two distinct sizes. Larger rays were commonly more than 10 seriate and more than 1mm high. Aggregate rays were present.

All ray cells were procumbent. Prismatic crystals were in ray parenchyma cells.

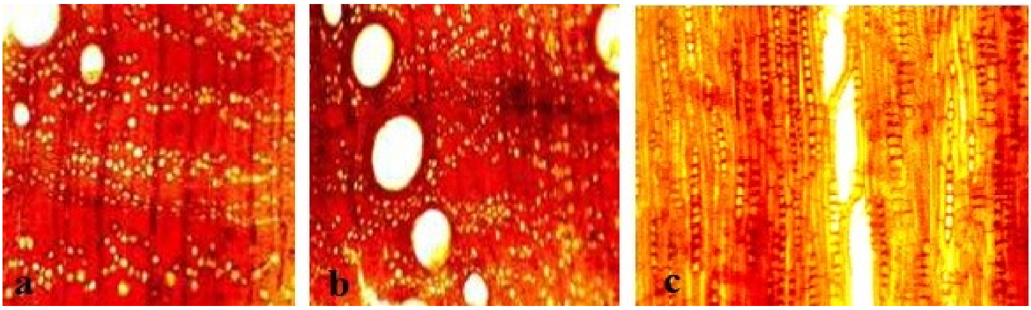

Fig. 11. Microphotographs of wood sections showing the anatomical characteristics of *Quercus cerris L.*: a and b - Tangential and longitudinal section (TLS); c - Radial longitudinal section (RLS).

Treatment and Conservation

Surface Cleaning

Soft brushes and rubber pumps were used to remove the loose dust on the lid and base of the coffin (Fig. 12a). Klucel G was used for the complete assembly of the base of the coffin (Fig. 12b)., and Paraloid B72 (15%) was used for injecting cracks inside the wooden coffin (Fig. 12c)..

Fig. 12. Conservation process of the wooden coffin: a) Mechanical cleaning; b) During the application of Klucel G; In preparation for the complete assembly of the base of the coffin; c) During the injection of cracks inside the wooden coffin

Xylene and distilled water (1:1) were used for the chemical cleaning of the black resin layer (Fig. 13a-f). There was a remarkable change in the appearance of black resin after the previous restoration (Fig. 13c). A whitish layer was formed on the surface. It was decided to opt for the chemical cleaning of the black resin layer after making several tests.

Adjustment and reassembly

During assembling the parts of the wooden coffin, the uneven surface of the coffin base was observed. Therefore, an adjustment was made to the base of the coffin by using Klucel G

(1%). Three times, some blocks of different weights were placed on the base of the coffin to return it to its original shape and complete the reassembly of the coffin (Figs. 13-22).

These parts were separated, and the condition of the tenon and mortise deteriorated, and sometimes there was a break in the wooden coffin. Therefore, the broken dowels were removed and replaced with new dowels, and the separated and broken parts were reassembled again using paraloid B72 (50%). While reassembling the wooden pieces, beech wood dowels were used because of their great hardness and suitability for the size of the coffin. They were used at different lengths. We removed the dowels used from balsa wood in the previous restoration because they were very weak, and some were broken.

Loss Compensation

Cotton was used in paraloid B72 (15%) in acetone to fill the voids in the wooden coffin. After complete drying, a glass microballoon was used in paraloid B72 (15%) to level the surface and prepare for the colouring process of the completed parts [51-55].

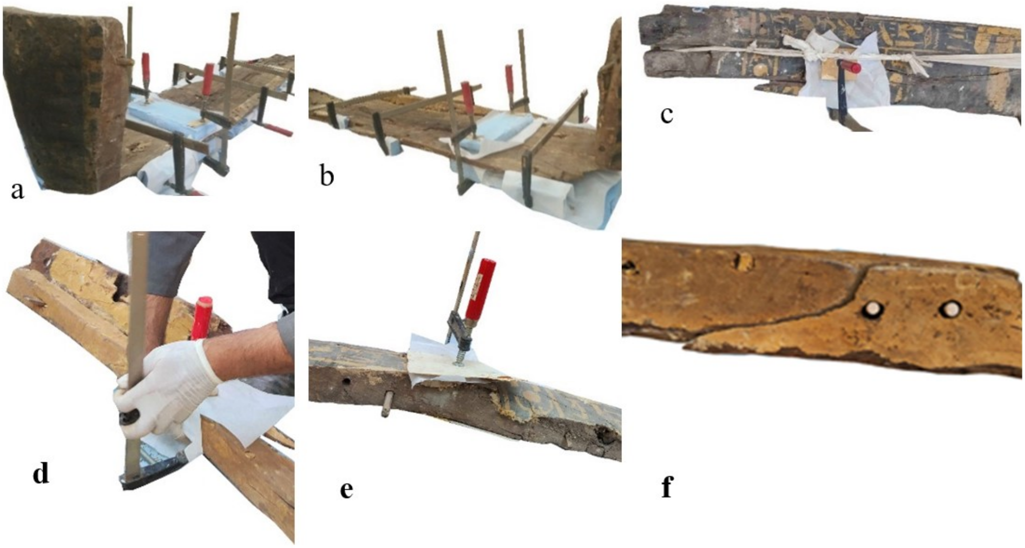

Fig. 13. a, b) assembling the coffin base parts; With metal swaddles, and a parloid B72; c-f) Reassembling part of the coffin lid

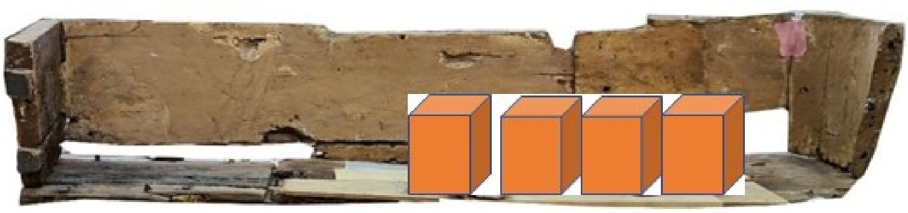

Fig. 14. Laying the loads on the base of the coffin from the inside to straighten out

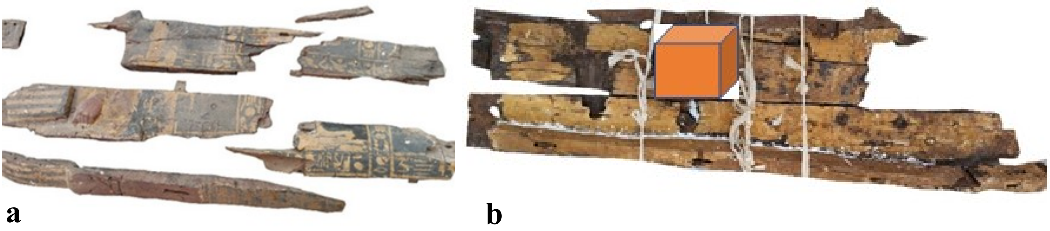

Fig. 15. a) the coffin lid parts before restoration; b) the coffin lid inside during the reassembly process

Fig. 16. During the assembly of the coffin lid

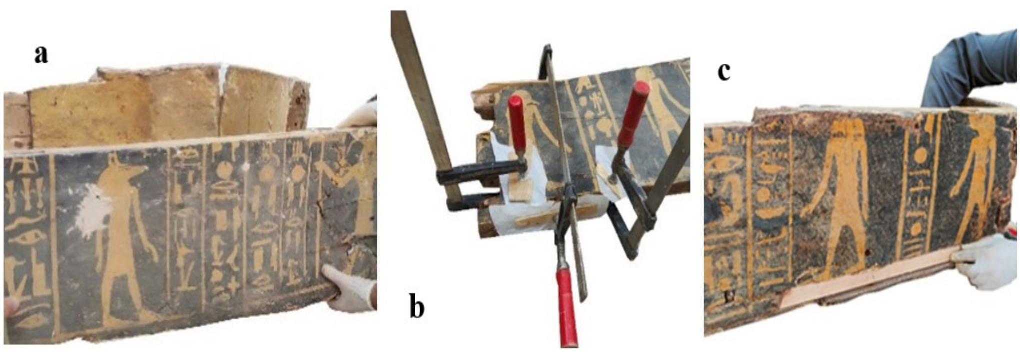

Fig. 17. Coffin reassembly process: a, b) the right side; c) the left side

Fig. 18. a) the base of the coffin after assembling the base part; b) the left side of the coffin during the process of preliminary assembly of the coffin; c) the coffin during initial assembly, left side, from the inside; d) during the initial assembly and installation of new dowls, to reinstall; e) after strengthening the missing part on the left side of the coffin, in the head area; f) after assembling the right side of the coffin

Fig. 19. During filling cracks and separations using a glass microballoon:
a) the right side of the coffin; b) the base of the coffin; c) the lid of the coffin from inside

Fig. 20. The coffin, after reassembly and completing the missing part:
a) the left side; b) the right side; c) the coffin base, from the inside;
d) the lid of the coffin, from the inside

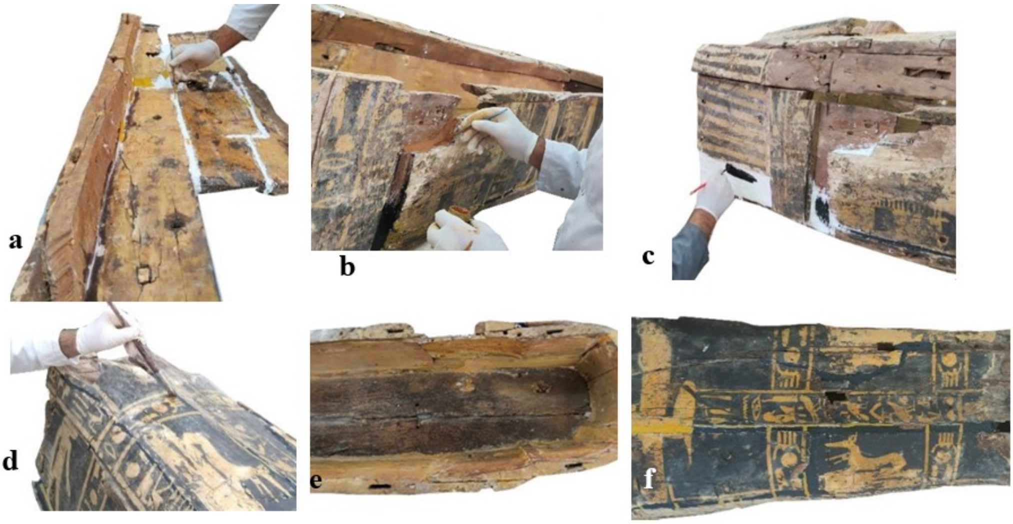

Fig. 21. a-c) during the colouring process of the glass microballoon; d) during the consolidation process of the black resin layer; e) the coffin base, from the inside, after restoration; f) the lid of the coffin, after restoration

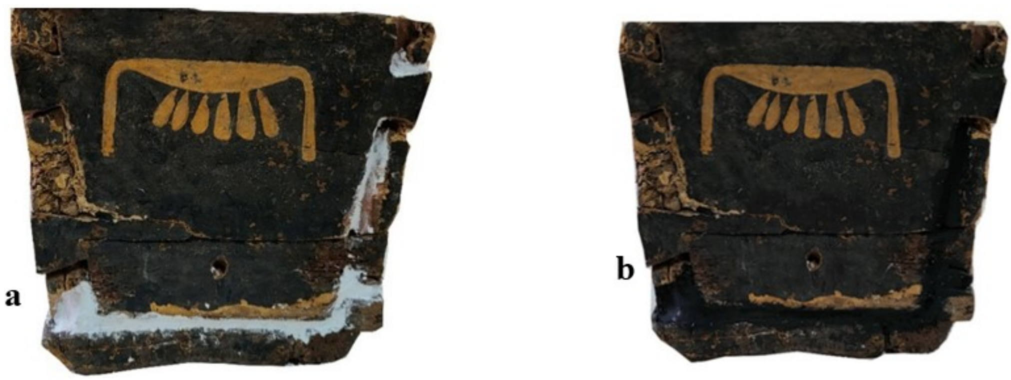

Fig. 22. The outside part of the foot area: a) after the process of completing the microballoon, b) after the restoration process

The coffin base was reassembled from the inside by making a dowel in the broken parts, and paraloid B72 (50%) was used to inject the dowel from the inside to complete the installation process at the base of the coffin. There was a large separate part, urging the use of a dowel with a length of 15cm to reinstall because of the large size of the separate part [56, 57]. After the assembly of the parts, the base was completed. The left side of the coffin was reassembled, and other dowels were made instead of the broken ones in the coffin (Figs. 23 and 24). The dowels used in the previous restoration were removed because of the wrong assembly and the weakness of these dowels, which were unsuitable for the size of the coffin. Therefore, new dowels were made to fit the size of the coffin, and the left side was initially assembled. Paraloid B72 was used in the final assembly to install the dowels, and deep cracks were injected into the coffin.

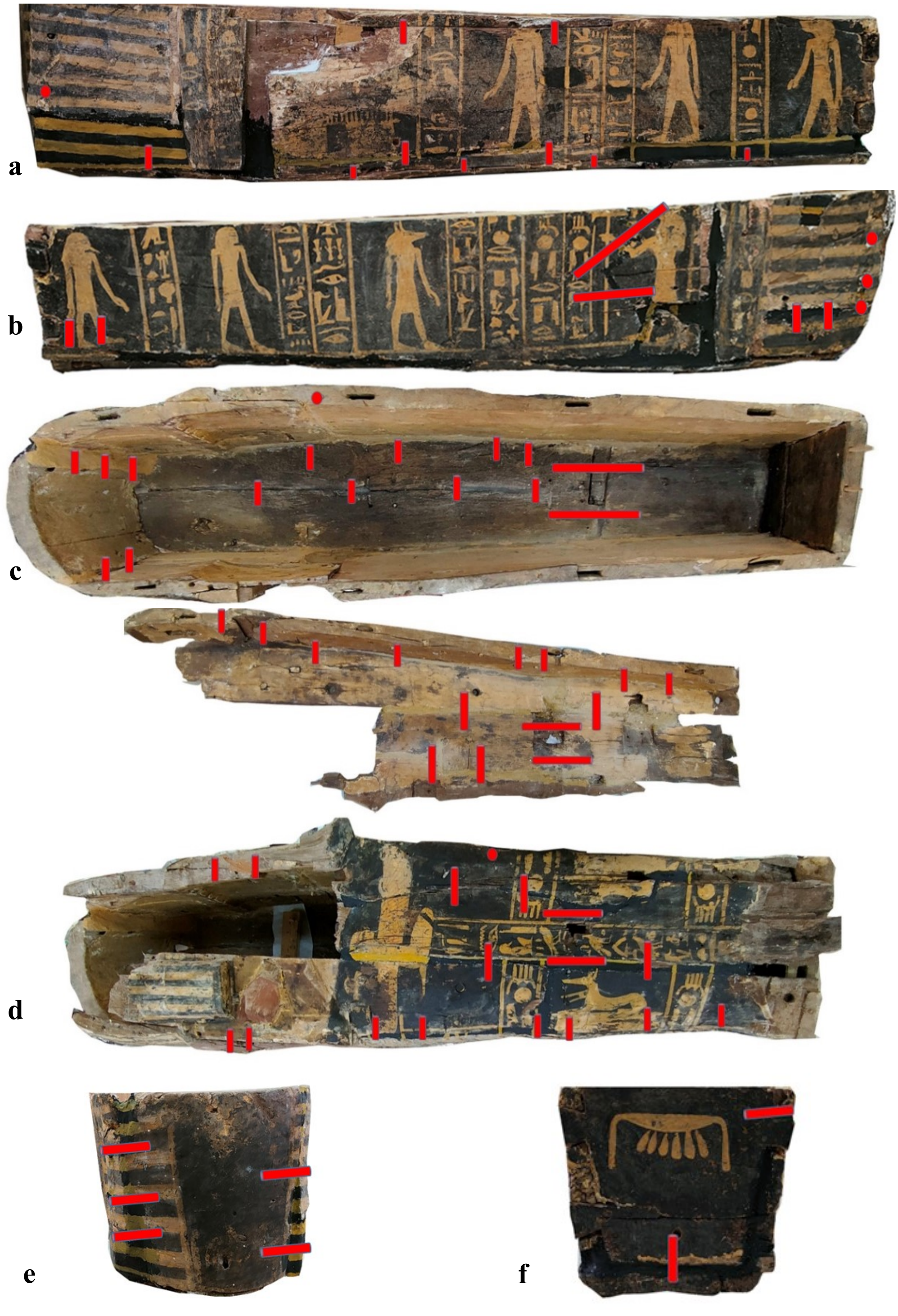

Fig. 23. The places of the modern dowel that was installed during the assembly process are:
a) the left side of the coffin; b) the right side of the coffin; c) the base of the coffin, from the inside; d) the lid of the coffin, from inside and outside; e) the head area of the coffin

Fig. 24. The left side of the coffin, from the outside, before the assembly process; b) the base of the coffin, from the inside, before reassembly; c) the right side of the coffin, from the outside, before the assembly process; d) the lid of the coffin, showing the components of the lid, before reassembly

Consolidation

From the experimental study of the different consolidation materials and after making the appropriate evaluations, the lowest colour change rate of nanocellulose and nanosilica was 1% in water to consolidate wood samples (Fig. 25). Therefore, nanocellulose was used with 1% Klucel G to consolidate the coffin from the inside using the brush. The consolidation process was done for the black resin layer and the coloured materials with 0.5% nanosilica in alcohol.

Fig. 25. The coffin after restoration: a) the right side of the coffin; b) the left side of the sarcophagus; c) the coffin lid from inside; d) the coffin lid from outside

A wooden support was used inside the coffin after restoration to support the lid from the inside. It was made without the use of chemical materials. To make it removable or modified in the future, silicone paper was used to isolate the new wooden stand used for the reinforcement from the wood of the coffin (Fig. 26).

Fig. 26. The coffin after restoration: a) the head of the coffin area; b) the coffin foot area.

Conclusions

The paper presents the investigation and documentation of the coffin and documents the conservation process. The coffin suffered from several deterioration phenomena, including damage to the coffin, separations, loss of the ground and painted layers, and missing parts because of bad storage and previous conservation. Therefore, a 2D programmeme was utilised to illustrate the decoration of the black resin layer, and a 3D programmeme was used to make a 3D model of the coffin. Optical microscopy was applied to investigate the surface of the black resin and painted layers. In addition, wood was identified as Sycamore (*Ficus sycomorus*), and tenon was *Quercus cerris L*. (Cupressaceae).

The phases of restoration were documentation, mechanical and chemical cleaning, consolidation, reattaching the ground layer to the support, and filling the ground layer edges. Paraloid B72 (50%) was used for the reassembly of the ground layer, while a mixture of microballoon, Paraloid B72 (15%), and earth pigments was used to maintain the edge of the ground layer. Nanocellulose was used with 1% Klucel G to consolidate the coffin from the inside using the brush. The consolidation process was done for the black resin layer and the coloured materials with 0.5% nanosilica in alcohol.

References

[1] I. Stelzner, J. Stelzner, J. Martinez-Garcia, D. Gwerder, M. Wittkoepper, W. Muskalla, M. Egg, P. Schuetz, *Non-destructive assessment of conserved archaeological wood using computed tomography,* **Transcending Boundaries: Integrated Approaches to Conservation. ICOM-CC 19th Triennial Conference Preprints**, Beijing, 17–21 May 2021, (Editor: J. Bridgland), International Council of Museums, Paris, 2021.

[2] S.A.K.M. Hamed, M.Z.M. Salem, H.M. Ali, K.M.E.S. Ahmed, *Investigating the Impact of Weathering and Indoor Aging on Wood Acidity Using Spectroscopic Analyses,* **BioResources, 15**(3), 2020, pp. 6506-6525.

[3] M.C. Timar, M. Campean, A.A. Tuduce-Trăistaru, *Compatibility indicators in developing consolidation materials with nanoparticle insertions for old wooden objects*, **International Journal of Conservation Science, 1**(4), 2010, pp. 219-226.

[4] T.J. Teng, M.N.M. Arip, K. Sudesh, A. Nemoikina, Z. Jalaludin, E.P. Ng, H.L. Lee, *Conventional technology and nanotechnology in wood preservation: A revie,* **BioResources**, **13**(4), 2018, pp. 9220-9252.

[5] A.N. Papadopoulos, H.R. Taghiyari, *Innovative wood surface treatments based on nanotechnology*, **Coatings, 9**(12), 2019, Article Number: 866.
[6] Z. Walsh, E.R. Janeček, J.T. Hodgkinson, J. Sedlmair, A. Koutsioubas, D.R. Spring, M. Welch, C.J. Hirschmugl, C. Toprakcioglu, J.R. Nitschke, M. Jones, *Multifunctional supramolecular polymer networks as next-generation consolidants for archaeological wood conservation,* **Proceedings of the National Academy of Sciences, 111**(50), 2014, pp. 17743- 17748.
[7] A.M. Abdelmoniem, N. Mahmoud, W.S. Mohamed, A.Y. Ewais, A. Abdrabou, *Archaeometric Study of a Polychrome Wooden Coffin From 26 Th Dynasty-Egypt,* **Mediterranean Archaeology & Archaeometry**, **13**(1), 2020, pp. 7-17.
[8] A.M. Abdelmoniem, N. Mahmoud, W.S. Mohamed, *Application Methods of a Black Resin Layer on the Funerary Equipment from the New Kingdom to the Ptolemaic era of Egypt*, **Poster at AIC 49th**, 11-15 May 2021 Annual Meeting.
[9] M. Abdallah, H.M. Kamal, A. Abdrabou, *Investigation, Preservation and Restoration Processes of An Ancient Egyptian Wooden Offering Table*, **International Journal of Conservation Science**, **7**(4), 2016, pp. 1047-1064.
[10] M. Abdallah, A. Abdrabou, *Tutankhamen's Small Shrines (Naoses): Technology of Woodworking and Identification of Wood Species,* **International Journal of Conservation Science, 9**(1), 2018, pp. 91-104.
[11] W.K. Elghareb, *Analysis and Restoration of Pottery Artefacts from Tell El-Hir, North Sinai, Egypt. a Case Study*, **International Journal of Conservation Science, 12**(4), 2021, pp. 1327-1342
[12] F.M. Helmi, W.N. Wahba, A. Brania, M. Abdelnasser, *Characterization of a Historical Leather Cover of Manuscript 'Ensaan Elaauon fe sert Elameen Elmaamon', Al-Azhar Library, Eygpt,* **Advanced Research in Conservation Science, 2**(1), 2021, pp. 40-52.
[13] A. Wiegmann, *The Application of Photogrammetry in Archaeology in the Jerusalem* **Photogrammetry**, **Digital Photogrammetry Applied to Archaeology**, 2016.
[14] L. Karasaka, M. Yakar, F. Yildiz, A.G. Korumaz, E. Karasaka, *3D Modelling and Detail Drawing of Inceminare Medresseh by Digital Photogrammetry and Laser Scanning Method*, **https://www.cipaheritagedocumentation.org/wp-content/uploads/2018**/12/Karasaka-e.a.-3D-Modelling-and-Detail-Drawing-of-Inceminare-Medresseh-by-Digital-Photogrammetry-and-Laser-Scanning-Method.pdf.
[15] M. Chodoronek, *The Use and Application of Photogrammetry for the In-field Documentation of Archaeological Features: Three Case Studies from the Great Plains and Southeastern Alaska,* **PhD Thesis**, Anthropology Department Theses and Dissertations, University of Nebraska – Lincoln, 2015.
[16] C. Richter, **Wood Characteristics: Description, Causes, Prevention, Impact on Use and Technological Adaptation,** Springer International Publishing Switzerland, 2015.
[17] C. Plomion, G. Leprovost, A. Stokes, *Wood formation in trees,* **Plant Physiology**, **127**(4), 2001, pp. 1513-1523, DOI: 10.1104/pp.127.4.1513.
[18] D. Tamburini, J.J. Łucejko, B. Pizzo, M.Y. Mohammed, R. Sloggett, M.P. Colombini, *A critical evaluation of the degradation state of dry archaeological wood from Egypt by SEM, ATR-FTIR, wet chemical analysis and Py (HMDS)-GC-MS,* **Polymer Degradation and Stability, 146,** 2017, pp. 140-154, DOI: 10.1016/j.polymdegradstab.2017.10.009.
[19] S.W. Hwang, J. Sugiyama, *Computer vision-based wood identification and its expansion and contribution potentials in wood science: A review*, **Plant Methods, 17**(1), 2021, Article Number: 47, DOI10.1186/s13007-021-00746-1.
[20] Y.A. Elmoaz, M. Moustafa, M. Soliman, *Characterization Study of a Silver Tray Fixed to A Wooden Frame of Prince Mohamed Ali Museum, Cairo, Egypt*, **International Journal of Conservation Science, 11**(3), 2020, pp. 639-646.

[21] M.F Ali., S.S. Darwish, A.M. El Sheikha, *Multispectral Analysis and Investigation of Overlapping Layer,* **Cartonnage Fragments** (Egyptian Museum, Cairo), **6**(3), 2020, pp. 25-36.
[22] H.M. Mahmoud, *An effective polymer nanocomposite based on tetraethoxysilane (TEOS) and SiO2-Al2O3 nanoparticles for super protection of damaged ancient Egyptian wall paintings,* **Pigment & Resin Technology**, 51(3), 2021, pp. 344-353, DOI: 10.1108/PRT-01-2021-0013.
[23] L. Avlonitou, *Pigments and colours: An inside look at the painted decoration of the Macedonian funerary monuments,* **Journal of Archaeological Science: Reports**, **7**, 2016, pp. 668-678.
[24] G.M. Ingo, A. Çilingiroğlu, G. Di Carlo, A. Batmaz, T. De Caro, C. Riccucci, F. Faraldi, *Egyptian Blue cakes from the Ayanis fortress (Eastern Anatolia, Turkey): micro-chemical and-structural investigations for the identification of manufacturing process and provenance,* **Journal of Archaeological Science, 40**(12), 2013, pp. 4283-4290.
[25] V. Danilov, A. Ayzenshtadt, N. Kilyusheva, A. Belyaev, *Wood surface modification with an arabinogalactan–silica composition,* **Journal of Wood Chemistry and Technology**, **41**(6), 2021, pp. 269-281.
[26] M. Abdallah, A. Abdrabou, H. M. Kamal, *Analytical study and conservation processes of tutankhamen decorated stick: A case study,* **Scientific Culture**, **4**(1), 2018, pp. 93-100.
[27] S.A.M. Hamed, *Investigation of Deterioration in Archaeological Wood Used in Architectural Elements*, **Microscopic Study**, 2014, pp. 857-862.
[28] E.J. Schofield, R. Sarangi, A. Mehta, A.M. Jones, F.J. Mosselmans, A.V. Chadwick, *Nanoparticle de-acidification of the Mary Rose*, **Materials Today**, **14**(7-8), 2011, pp. 354-358.
[29] R. Linke, M.A. Ziemann, *The Detection of Copper-Based Pigment Darkening by Biuret-Reaction in Mural Paintings by Sem-Edx, Micro-Xrf and Micro-Raman Spectroscopy,* **International Journal of Conservation Science**, **5**(2), 2014, pp. 129-138.
[30] I. Garofano, J.L. Perez-Rodriguez, M.D. Robador, A. Duran, *An innovative combination of non-invasive UV–Visible-FORS, XRD and XRF techniques to study Roman wall paintings from Seville, Spain,* **Journal of Cultural Heritage, 22**, 2016, pp. 1028-1039.
[31] T. Nazel, M.L. Abd El-Latif, R. Abuel-Ela, M. Abo El-Magd, *Experimental Comparative Study on the Performance of Nano lime and Phosphate-Based Treatment as Consolidants for Monumental Limestone*, **Journal of Scientific and Engineering Research, 8**(3), 2021, pp. 40-49.
[32] M.M. Rifai, N.M. El Hadidi, *Investigation and analysis of three gilded wood samples from the tomb of Tutankhamun.* **Decorated surfaces on ancient Egyptian objects, Technology, deterioration and conservation**, 2010, pp. 16-24.
[33] I.C.A. Sandu, M.H. de Sá, M.C Pereira, *Ancient 'gilded' art objects from European cultural heritage: a review on different scales of characterization,* **Surface and Interface Analysis, 43**(8), 2011, pp.1134-1151, DOI: 10.1002/sia.3740.
[34] A. Abdrabou, M. Abdallah, M. Abd El Kader, *Analytical study and conservation processes of a painted wooden Graeco-Roman coffin*, **International Journal of Conservation Science**, **6**(4), 2015, pp. 573-586.
[35] L. Zoia, D. Tamburini, M. Orlandi, J.J. Łucejko, A. Salanti, E.L. Tolppa, F. Modugno, M.P. Colombini, *Chemical characterisation of the whole plant cell wall of archaeological wood: an integrated approach,* **Analytical and Bioanalytical Chemistry, 409**(17), 2017, p4233.
[36] A.M. Abdelmoniem, N. Mahmoud, S. Mohamed, M.A. Abdel-fatah, M. Mohammad, N.M. Badr, *Multidisciplinary approach for documentation of an Anthropoid Wooden Coffin from*

the Late Period in Egypt, **Advanced Research in Conservation Science (ARCS), 3**(2), 2022, pp. 15-26, DOI: 10.21608/arcs.2022.136413.1026.
[37] D.A. Scott, *A review of ancient Egyptian pigments and cosmetics,* **Studies in Conservation, 61**(4), 2016, pp.185-202.
[38] M. Uda, S. Sassa, S. Yoshimura, J. Kondo, M. Nakamura, Y. Ban, H. Adachi, *Yellow, red and blue pigments from ancient Egyptian palace painted walls,* **Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 161**, 2000, pp. 758-761.
[39] A.M. Abdelmoniem, N. Mahmoud, M.A. Abdel-Fatah, S. Mohamed, N.M. Badr, *Multi analytical techniques of anthropoid wooden Coffin from Egypt's late period*, **International Journal of Conservation Science**, **13**(4), 2022, pp. 1087-1100.
[40] N.S. Karaduman, Y. Karaduman, H. Ozdemir, G. Ozdemir, *Textile reinforced structural composites for advanced applications (Chapter),* **Textiles for Advanced Applications (**Editors: B. Kumar, S. Thakur**)**, **87**, 2017, DOI: 10.5772/intechopen.68245.
[41] N. Al-Sharairi, I.C.A. Sandu, V. Vasilache, I. Sandu*, Recognition of natural silk fibers, dyes and metal threads of historical Romanian textile fragments using the multi-analytical techniques approach,* **Textil Research Journal, 90**(15-16), 2020, pp. 1671-1688
[42] N. Al-Sharairi, Z. Al-Saad, I. Sandu*, Identification of Dyes Applied to Ottoman Textiles*, **International Journal of Conservation Science**, **8**(2), 2017, pp. 251-258.
[43] N. Al-Sharairi, I.C.A. Sandu*, Characterization of Dyeing Techniques of Late 19th Century Ottoman-Style Costumes from the Jordanian Museum of Cultural Heritage,* **Revista de Chimie, 69**(4), 2018, pp.901-905.
[44] A. Bourmaud, J. Beaugrand, D.U. Shah, V. Placet, C. Baley, *Towards the design of high-performance plant fibre composites,* **Progress in Materials Science**, **97**, 2018, pp. 347-408.
[45] J.A. Suomela, K. Vajanto, R. Räisänen, *Seeking nettle textiles–Utilizing a combination of microscopic methods for fibre identification*, **Studies in Conservation**, **63**(7), 2018, pp. 412-422.
[46] C. Bergfjord, B. Holst, *A procedure for identifying textile bast fibres using microscopy: flax, nettle/ramie, hemp and jute,* **Ultramicroscopy, 110**(9), 2010, pp. 1192-1197.
[47] https://ncch.gov.mn/Files/Method/identification_of_fibres_and_fabrics_SCHWENCK.PDF [accessed on 25.11.2023].
[48] J.W. Hearle, W.E. Morton, **Physical Properties of Textile Fibres,** Elsevier, 2008
[49] A.R. Bunsell, (Ed.), **Handbook of Tensile Properties of Textile and Technical Fibres,** Elsevier, 2009.
[50] I. Markova, **Textile Fiber Microscopy: A Practical Approach**, John Wiley & Sons, 2019.
[51] N.M. El Hadidi, *Changing research trends in the field of archaeological wood at the Conservation Department, Faculty of Archaeology, Cairo University,* **Studies in Conservation**, **60**(3), 2015, pp. 143-154.
[52] E.M. Montaser, N.M. El Hadidi, E.A.E. Amin, *Evaluation of wood gap fillers composed of microcrystalline cellulose, paper pulp, and glass microballoons*, **Pigment & Resin Technology, 52**(4), 2022, pp. 422-430, DOI: 10.1108/PRT-08-2021-0096.
[53] A.A.T. Trăistaru, M.C. Timar, M. Câmpean, C. Croitoru, I. Sandu, *Paraloid B72 Versus Paraloid B72 with Nano-ZnO Additive as Consolidants for Wooden Artefacts,* **Materiale Plastice, 49**(4), 2012, pp. 293-300.
[54] M.C. Timar, I.C.A. Sandu, E. Beldean, I. Sandu, *FTIR Investigation of Paraloid B72 as Consolidant for Old Wooden Artefacts Principle and Methods*, **Materiale Plastice, 51**(4), 2014, pp. 382-387.

[55] A.A.T. Trăistaru, I.C.A. Sandu, M.C. Timar, G.L. Dumitrescu, I. Sandu, *SEM-EDX, water absorption, and wetting capability studies on evaluation of the influence of nano-zinc oxide as additive to paraloid B72 solutions used for wooden artifacts consolidation,* **Microscopy, Research and Tehnique, 76** (2), 2013, pp. 209-218, DOI: 10.1002/jemt.22155.
[56] I. Huțanu, I. Sandu, V. Vasilache, L. Nica, I.C.A. Sandu, *Study on the Consolidation of Degraded Pictural Layer with Acrylic Binder*, **Revista de Chimie, 66**(6), 2015, pp. 895-900.
[57] M. Marius, I. Sandu, I. Huțanu, L. Nica, *The study of stages and operations involved in the preservation and restoration of two XIX-th century icons, on wooden support,* **Present Environment and Sustainable Development, 8**(2), 2014, pp. 131-150, DOI: 10.2478/pesd-2014-0030.

Received: November 27, 2022
Accepted: August 24, 2023