INTERNATIONAL JOURNAL OF CONSERVATION SCIENCE

ISSN: 2067-533X Volume 13, Issue 1, January-March 2022: 3-14 www.ijcs.ro

A MULTI-ANALYTICAL INVESTIGATION OF AN ANCIENT EGYPTIAN PAINTED WOODEN COFFIN FROM THE LATE PERIOD

Mohamed MOUSTAFA[1*], Medhat ABDALLAH[2], Ahmed ABDRABOU[1], Hussein M. KAMAL[1]

[1] The Grand Egyptian Museum, Conservation Center, Giza, Egypt
[2] Directorate of Conservation, Saqqara Storerooms, Giza, Egypt

Abstract

The focus of this study is to apply multi-scientific analytical techniques to identify the painted layers, ground layer, and previous restoration interventions of an ancient Egyptian painted polychrome coffin from the late period. A combination of multispectral imaging, optical microscopy (OM), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and X-ray fluorescence (XRF) were utilized in a non-destructive and micro destructive technique to identify the painting materials and techniques and the condition of the object. There are three wooden species used in the coffin and identified as Ficus sycamores, Acacia albida, and Tamarix sp. Whereas, the identification of insects' species is included in this study. The primary results provide a strong suggestion of using cinnabar on the goddess Nephthys face, which is considered a rare pigment found in a late period collection.

Keywords: *Multispectral imaging; Acacia albida; Cinnabar; X-ray fluorescence; Insects*

Introduction

Wood has played an important role throughout human history. Whereas religion was very essential in daily life. Since the predynastic period (ca. 4500–3100 BC), ancient Egyptians were fashioning primitive vessels that were meant to preserve and protect the deceased.

These vessels are known as sarcophagi and were called the neb ankh, meaning possessor of life, by the Egyptians [1]. Polychrome wooden coffins were most popular during the second intermediate period (ca. 2300–1640 BC), specifically during the 18th Dynasty. These coffins were decorated with mineral pigments mixed with binders while sometimes utilizing gesso and varnish as well [2, 3].

The types of woods and pigments used in the creation of coffins were dependent on many factors, including the period, the social and economic status of the deceased, and the location in which the coffin was made.

The studied coffin (GEM No. 65490) dates back to the late period from Bani Sueif storage. The coffin consists of two pieces: lid and box. Both outsides of the coffin box are decorated with multicolored inscriptions in vertical registers. The wooden coffin was covered with a coarse white ground layer, then a fine painting layer with multi-colors of drawings. The coffin dimensions are about 183cm in length and 56cm in width. This article intends to apply a combination of multi analytical techniques to provide more information on the original

* Corresponding author: mohamed.moustafa223@yahoo.com

materials and previous restoration interventions. Moreover, mapping multispectral imaging technique (MSI) including infrared (IR) false-color with x-ray fluorescence (XRF) results as non-destructive techniques to identify the painted layers (Fig.1).

Fig. 1. General view of the coffin lid with color checker

Materials and methods

Scientific analytical techniques were used to determine with more information the original layers and added materials. Besides, explain the deterioration aspects, and provide a strategy of conservation for the coffin.

Visual assessment

Visual assessment was performed to determine the deterioration aspects of the polychrome coffin. A conservator's critical eye can also decide the most effective analytical techniques to be applied for identifying the materials of the coffin under study [4-6].

Optical microscope

A Zeiss Stereo DV 20 (stereomicroscope) equipped with an Axio Cam MRC5 was used to identify the insects' remains that were found inside the coffin.

Whereas, OPTIKA microscopy (Italy) equipped with an OPTIKA B 9 digital camera was used to identify the coffin wooden species. Fallen samples from the coffin base, dowels, and tenons were cut into thin sections as representative of the three principal anatomical directions: transverse (TS), tangential (LS), and radial (RLS). Identification of wooden species was carried out based on the anatomic features of wood anatomy atlases [7-10].

Multi-Spectral Imaging Technique (MSI)

This technique is applied to monitor the painted layers by using a certain range of wavelengths in the electromagnetic spectrum that includes and extends the human eye *capacities*. A multispectral imaging technique consists of two main factors: incoming radiation emitted by a radiation source and directed toward the object, which interacts with the incoming radiation; and recording the outgoing radiation from the surface layer as a result of the interaction between the incoming radiation, and the object [11].

Visible (VIS), visible-induced ultraviolet luminescence (UVL), visible-induced infrared luminescence (VIL), and infrared luminance (IR) figures were captured using a full spectrum digital camera (Nikon D90 DSLR - CMOS sensor) in a wavelength between 360 and 1100nm and fitted with a Nikon Nikkor 60mm f/1:2.8D AF lens.

The camera was used in a manual mode and was connected to a computer to provide a sharp focus in nonvisible modes (IR and UV) using live view mode. It has been calibrated using a color checker passport supported with its software to create a camera raw profile. The figures were shot in RAW format to allow for color adjustment using the camera profile, and white balanced [12].

Two photographic white light fluorescent sources were supplied excitation for visible imaging, and the camera lens was fitted with a B + W 486 bandpass filter (400–700nm). Two UV radiation sources (365nm) were supplied excitation for UIL imaging, and the camera lens was outfitted with a B +W 420 and B +W 486 bandpass filter (400–700nm).

The excitation of VIL imaging was supplied by two white LED light sources and the camera lens was fitted with a Schott RG 840 cut-on filter. This technique is very effective in identifying the bluish areas painted by Egyptian blue, it appears as bright white against a dark background [13, 14].

The excitation of IR reflected imaging was supplied by two LED IR radiation sources (900 nm) and the camera lens was fitted with a Schott RG840 cut-on filter [15].

IR false color figures (IRFC) are made by editing the VIS and IR figures using photoshop software. A copy of the VIS figure is separated into its red, green, and blue (RGB) components. The green channel replaces the blue channel, whereas the red channel replaces the green channel. Then, the IR figure constitutes the red channel of the edited VIS [16, 17].

X-ray diffraction (XRD)

The previous filler materials were analyzed by XRD using the XRD system PW3040-analytical equipment-PANalytical pro model, Cu target tube, and Ni filter at 40kV and 30mA; X'pert Highscore software was used to provide qualitative results of the previous restoration materials.

Fourier transform infrared spectroscopy (FTIR-KBR)

FTIR Spectrometer (IRPrestige-21, Shimadzu) analyzed powders of previous conservation interventions and remains from adhesives in the transmission range 4000 - 400cm^{-1}. Spectrum resolution of 4cm^{-1} was measured, and 20 scans were recorded per sample. The spectra of analyzed samples were compared with target samples at the FTIR laboratories [18-20].

X-ray fluorescence (XRF)

A portable system of Bruker Thermo Scientific Niton XL3t analyzer was used to identify painting ground layers and previous restoration materials on the studied coffin. This device includes an x-ray tube with Ag anode, 50kV and 0-200μA max, at mining mode, spot diameter 3mm, duration of exposure 60 seconds [6].

Results and discussion

Identification of wooden species

In ancient Egypt, it was very common to use native wood, such as acacia, tamarisk, and sycamore-fig [21]. The microscopic figure of thin wood sections proved that the wood samples obtained from the wooden base are acacia (*Acacia albida*; Fig. 2a-c), and sycamore fig (*Ficus sycamores L.*) (Fig. 3a-c).

Acacia is mentioned in ancient texts as having been obtained in the Sixth dynasty from Hat nub in middle Egypt and Wawat in Nubia and used for making boats and warships. In addition, Acacia wood was employed in Egypt not only for boat building but also for the masts [22], while sycamore fig was native in Egypt and was used to make coffins at least since the Fifth dynasty.

Wooden dowels and tenons were identified as tamarisk (*Tamarix sp.*; Fig. 4a-d). Tamarisk has medium bending, compression strength, moderate hardness, coarse and fibrous texture. Because of these characteristics, it was the preferred choice in ancient Egypt for making dowels over a wide chronological period [15].

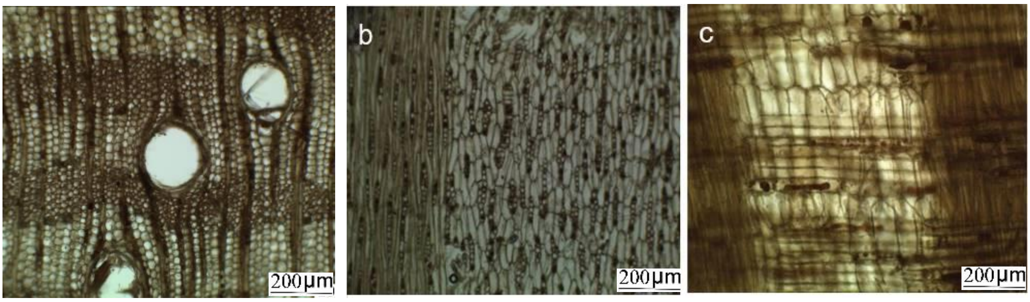

Fig. 2. (a) The anatomical characteristics of *Acacia albida* by OM in transmitted light: Transverse section (TS) showing growth ring boundaries indistinct or absent, wood diffuse-porous, vessel arrangement dendritic multiples of 2–5, parenchyma in wide confluent bands; (b) Tangential section (TLS) showing rays mainly uniseriate, sometimes with biseriate portions, width 1–3 cells, fibers in more or less tangential bands alternating with the parenchyma; (c) Radial section (RLS) showing inter vessel pits alternate, all ray cells procumbent, some rays with gummy contents

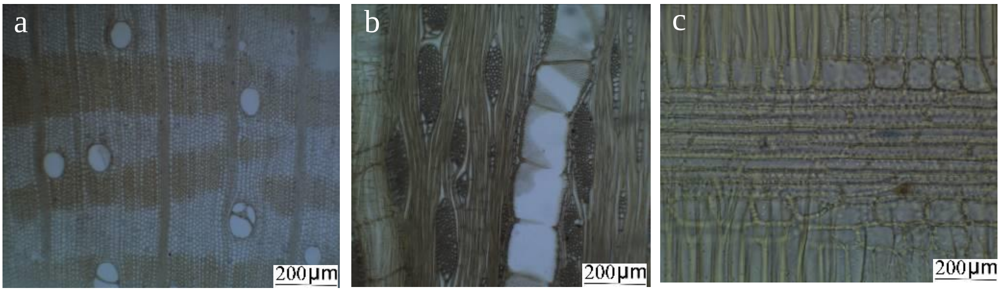

Fig. 3. (a) The anatomical characteristics of *Ficus sycomorus* by OM in transmitted light: Transverse section (TS) showing vessels solitary or in radial multiples of 2 to4 and axial parenchyma vasicentric in bands more than three cells wide; (b)Tangential section (TLS) showing rays of two distinct sizes, larger rays commonly 4 to 12 seriate; (c) Radial section (RLS) showing body ray cells procumbent with one to four rows of upright and square marginal cells

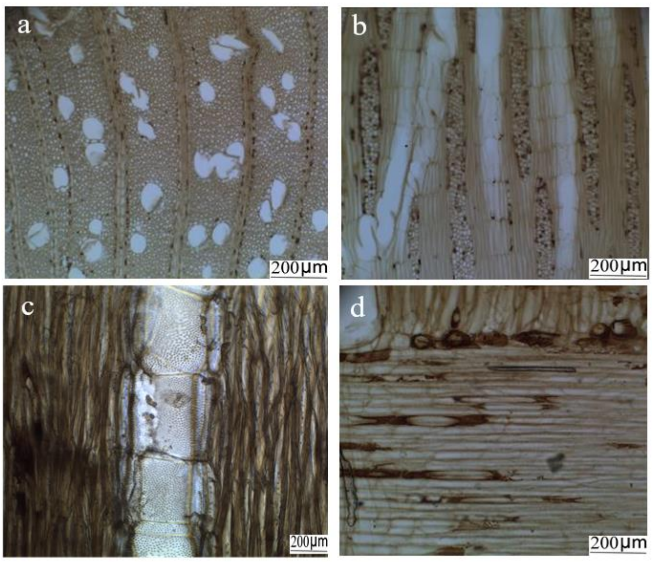

Fig. 4. (a) The anatomical characteristics of *Tamarix sp.* by OM in transmitted light: Transverse section (TS) demonstrating wood semi-ring-porous to diffuse, vessels solitary and in small clusters and axial parenchyma present in vasicentric or confluent distribution; (b) Tangential section (TLS) showing multiseriate rays commonly 5–20 cells in width; (c) Details of tangential section (TLS) showing simple perforation plates and inter vessel pits alternating; (d) Radial section (RLS) showing heterocellular rays with procumbent, square, and upright cells mixed throughout the ray.

Two insects' species and remains of insect molt were identified. The first one is spider beetle (*Gibbium psylloides*), depending on diagnostic morphology: The posterior border of the antennal fosse is prominently produced laterally. The pubescence of the head and first antennal segment differs as well: the setae on the top of the head near the antennal fosse are scale-like (Fig. 5a) [23]. The second insect is identified as black carpet beetle (*Attagenus unicolor*) based on diagnostic morphology: adult black carpet beetles range from 1/8 to 3/16 in. long (Fig. 5b). They have a shiny black and dark brown with brownish legs. Remains of a larva molt is identified as the larva of black carpet beetle full-sized larva can be as long as 5/16 in. and range from black to light brown (Fig. 5c). Larvae are shiny, smooth, and hard and stiff hairs cover their body [24].

Fig. 5. (a) Spider beetle; (b) Adult black carpet beetle; (c) Larva of black carpet beetle

Identification of the previous restoration interventions

The painted polychrome coffin was previously restored. XRD analysis of the filler materials indicated the presence of gypsum as the main component, which was common, used as a gap filler for loss compensation in the past few decades (Fig. 6). FTIR was used for identifying vegetable fibers and adhesive materials that were used as previous restoration interventions.

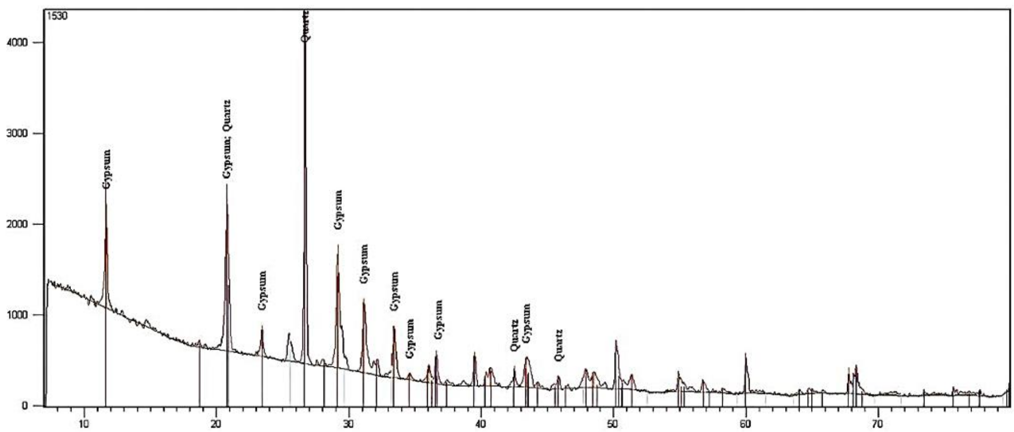

Fig. 6. XRD analysis of the filler material

The vegetable fibers were identified as linen by comparison with a controlled sample based on characteristic absorption bands: C-C stretching band 1627cm^{-1}, C-H bending bands 1429 and 1371cm^{-1}, and O-H stretching band 3404cm^{-1}. The spectra of cellulose bands particularly at 1373, 1338, 1319, 1261, and 1157cm^{-1}.

Besides, two intense bands with peaks at 2850 and 2918cm^{-1} are ascribed to C-H group deformation vibrations in methyl and methylene groups (CH_3, CH_2, CH_2-OH) of cellulose and lignin (Fig. 7) [25, 26].

Previous adhesive material was identified as polyvinyl acetate (PVA) by comparison with the controlled sample. IR spectrum of the PVA has a fingerprint characterized by several sharp and intense peaks. The most dominant band is related to the C=O stretching vibration associated with acetate groups with a molecular vibration at 1734cm^{-1} and complemented by two less intense peaks at 1431 and 1375cm^{-1}, due to the CH_3 asymmetrical and symmetrical bending vibration, respectively.

The second most intense peak was noticed at 1244cm^{-1}, according to the asymmetrical stretching mode of ester groups, supported by lower wavelengths of a double peak with the maximum at 1022cm^{-1} and the less intense one at 947cm^{-1} (Fig. 8) [27, 28].

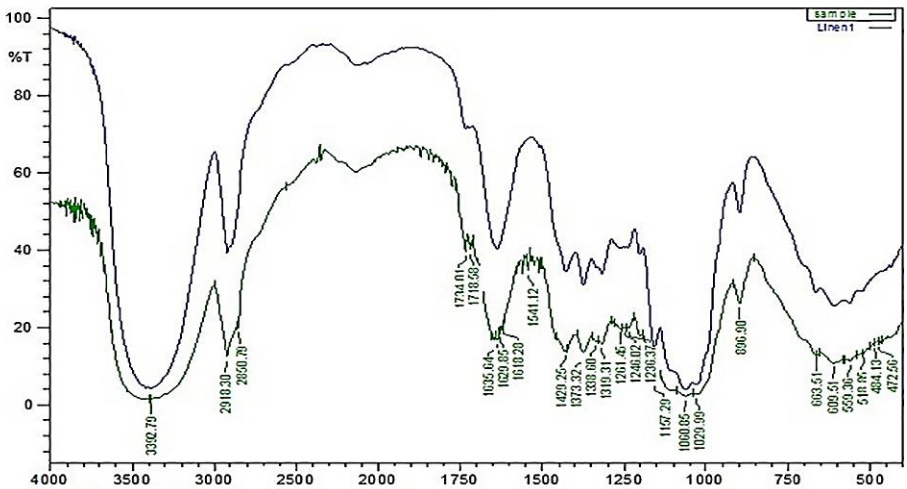

Fig. 7. FTIR spectrum of the vegetable fibers

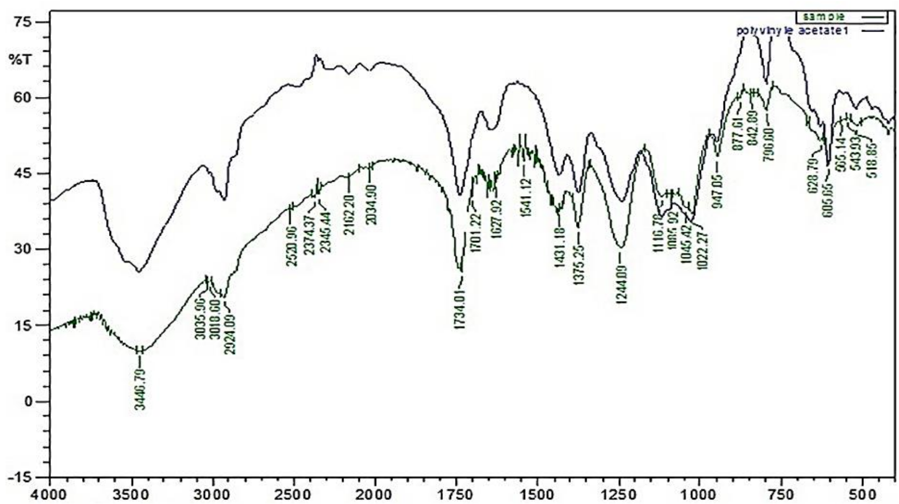

Fig. 8. FTIR spectrum of polyvinyl acetate

Investigation of the ground layer and painted layers

The ancient Egyptians were known for their creation of beautiful pigments using natural materials. At first, pigments were derived from naturally occurring sources that required little to no manipulation.

However, as time progressed, advancements in technology allowed the Egyptians to develop a larger range of colors with the introduction of methods such as heat and chemical reactions [29, 30]. The chromatic palette applied on this coffin includes blue, green, red, and yellow applied on the white ground layer (Fig. 9 a-b) (Table 1).

Fig. 9. (a)(b) Visible images of the Goddess Nephthys from the coffin base, and the Goddess Isis from the coffin lid with the spots location of the optical microscope images and XRF analysis

Table.1. XRF results of the ground layer and painted layers

Elements	**(1) Ground layer**	**(2) Green painted layer on the Isis wings**	**(3) Blue painted layer on the Horus tail**	**(4) Blue painted layer on the Nephthys body**	**(5) Light green painted layer on the Nephthys body**	**(6) Red painted layer on the Nephthys face**	**(7) Yellow painted layer on the Nephthys head**
As			0.314	0.682			0.965
Cu		0.922	1.170	3.169	0.686		
Fe		0.297	0.164	0.098	0.498		0.374
Hg						1.476	
Ca	31.300	13.597	4.805	3.295	12.858	18.394	17.848
K	0.163	0.243	0.763	0.590		0.161	0.264
Al		0.573		0.264		0.579	0.361
Si	2.101	4.996		0.692		3.237	2.391
Cl	0.486	0.465		0.381	0.414		0.292
S	0.152	2.334	1.332	0.918	1.572	2.333	3.787

Identification of the ground layer

XRF spectrum analysis of the ground layer revealed the presence of calcium (Ca), while sulfur (S) was absent. This result suggested that the ground layer is made of calcium carbonate ($CaCO_3$) (table1).

Blue painted layer

Two kinds of blue painted layers were identified in the painted coffin: Egyptian blue and azurite. The optical examination of the blue pictorial layer on the Horus tail shows crystal growth in the form of rectangular squares, and the pigment grains are coarse, which may indicate the presence of Egyptian blue [31]. In addition, grains of red pigment were noted with the bluish grains (Fig. 10a).

When this pigment is excited in the blue, green, or red range of the electromagnetic spectrum, it emits an intense and wide IR emission centered at around 910nm [32]. In the VIL figure, Egyptian blue emission shows as bright white, whereas, all other materials become dark gray or black [33].

In this context, the VIL figure (Fig. 10c) proved that the bluish painted layer appeared as bright white, whereas, all other materials appear dark. The luminance of Egyptian blue might be detected by the brightness of the bluish areas. In addition, the IR false color figure (Fig. 10d) revealed the presence of blue painted layers as red, which confirms the presence of Egyptian blue. XRF spectrum analysis of the blue-painted layer shows the presence of silica (Si), copper (Cu), and calcium (Ca) the main components of Egyptian blue (Table1).

The optical examination of the blue pictorial layer on the decorated body of Nephthys shows the pigment grains as fine, which may indicate the presence of azurite. Besides, some grains of yellow pigment were noted (Fig. 10b). IR false color shows the blue-painted layer as bluish, which means the Egyptian blue was absent in some areas.

The presence of blue painted layer as bluish in IR false color may be related to the presence of azurite (Fig. 10d). XRF spectrum analysis of the blue-painted layer indicated the presence of Cu, the main component of azurite $Cu_3(CO_3)_2(OH)_2$, while cobalt (Co) the main component of cobalt blue was absent, as well as arsenic (As) the main component of orpiment (As_2S_3) related to the yellowish ground painted layer (Table1).

It was noted the presence of light green painted layer with azurite on the decorative body of the goddess Nephthys on the outer base of the coffin (Fig. 9a). XRF results showed the presence of Cu and Ca, which refers to the presence of malachite as a green pigment (Table1). In some circumstances, azurite is degraded into green by increasing oxidation, causing the change in color from blue to green. It is most likely that a water molecule is added to two azurite molecules in the formula, which emits one of carbon dioxide and leaves three malachite molecules. Thus, this pigment may have been azurite and degraded to malachite as follows:

$$2Cu_3(CO_3)_2(OH)_2 + H_2O \longrightarrow 3Cu_2(CO_3)(OH)_2 + CO_2$$ [34].

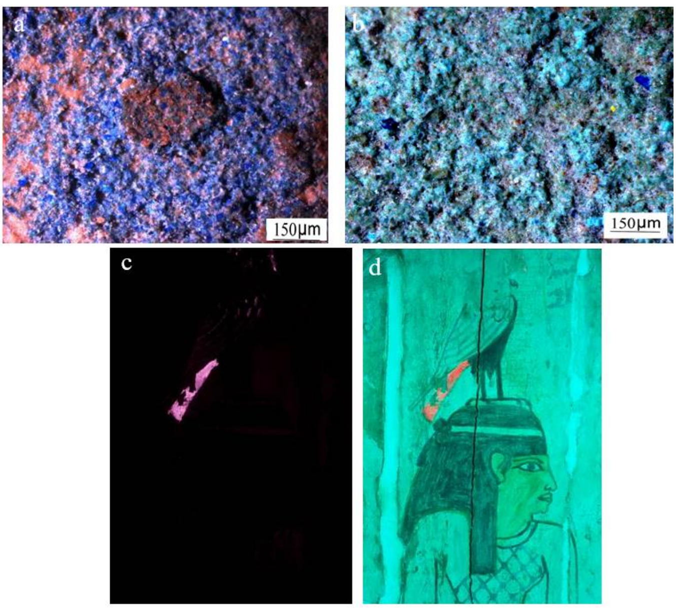

Fig. 10. (a) Egyptian blue under an optical microscope; (b) Azurite under an optical microscope; (c) VIL image; (d) IR false-color image

Green painted layer

The appearance of a green painted layer occurred around the first intermediate period and was used up to the middle kingdom (ca. 2300–1640 BC). Microscopic examination shows the pigment grains as fine sand (Fig. 11a). In addition, the green painted areas did not show any UV fluorescence (Fig. 11b). This might indicate the presence of copper-based pigments, which are known to quench the fluorescence of the surrounding media. Copper-based pigments are supported by the IR reflected figure (Fig. 11c), the green painted layers appear dark because of the strong absorption properties of these pigments in the near IR range.

False-color figure (Fig. 11d) shows that the greenish painted areas appear with a light blue hue, which provides a strong suggestion of using malachite ($Cu_2(CO_3)(OH)_2$) [35]. XRF results indicated the presence of Cu and potassium (K), which refers to the presence of malachite as a green painted layer. The absence of silica (Si) gives us an indication that the ancient Egyptian artisan did not use Egyptian green in this area (Table 1) [36].

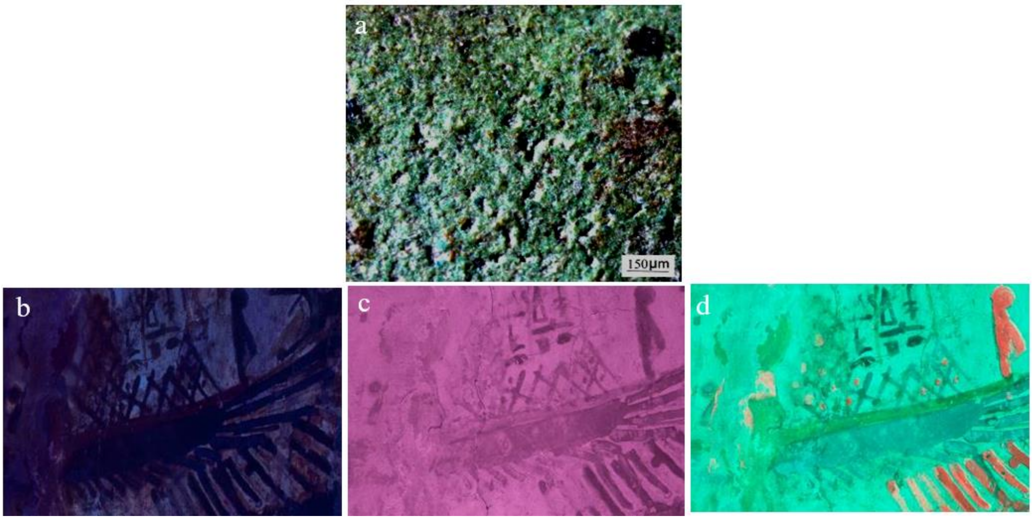

Fig. 11. (a) Malachite grains under an optical microscope; (b) UV image; (c) IRR image; (d) IR false-color image

Red painted layer

A combination of the non-destructive techniques provides a strong suggestion of using cinnabar on the reddish face of the goddess Nephthys. Cinnabar (HgS) provides an intense red, although there is no evidence of its usage before the late or Roman period (ca. 30 BCE–500 CE), according to Quirke in 1993, it has been detected as a pigment on a papyrus from the late period (747-332 BC), and its usage has been documented since the middle of the 12th Dynasty [37].

In 2011, Bonizzoni investigated a painted wooden coffin that dates back to the 26th Dynasty, about 664 to 525 BCE, it was made for Shepsesptah, as a priest of sachem, and in which cinnabar was detected in the reddish areas of the decorative flower elements, but examples are still very rare [38]. The microscopic examination shows the pigment grains as fine texture (Fig. 12a). The red-painted layer did not appear darker in the UVL figure. This may suggest the absence of iron-based pigment, which has strong quenching properties (Fig. 12c). XRF spectrum analysis of the red-painted layer shows the absence of iron (Fe) as the main element of hematite Fe_2O_3, whereas, the presence of mercury (Hg) and sulfur (S), the main components of cinnabar HgS (Table 1).

Yellow painted layer

A yellow-painted layer has been noted and identified as an orpiment. It is a historical pigment discovered on ancient Egyptian artifacts and paintings dating from the 31st to the 6th century BC. It was referenced in Greek and Roman literature; orpiment crystals are relatively rare since it normally forms masses and crusts.

The microscopic examination shows the pigment grains as coarse texture (Fig.12b). The UVL figure indicated the presence of a yellowish emission from luminescent material on the surface. This luminescence presumably relates to yellow painted areas made of arsenic-based pigments, which refers to orpiment since it gives yellow fluorescent properties (Fig. 12c) [39]. XRF spectrum analysis of the yellow-painted layer shows the presence of (As) and sulfur (S), the main components of orpiment (Table 1).

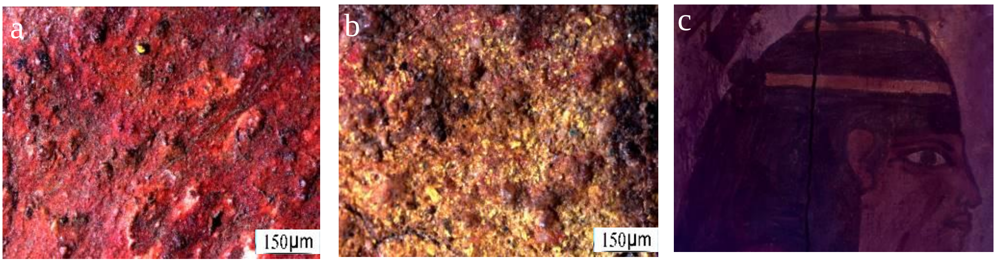

Fig. 12. (a) Cinnabar grains under an optical microscope; (b) Orpiment grains under an optical microscope; (c) UVL image

Conclusion

The studied anthropoid coffin is related to the late period, which was received from the Bani Sueif storage room in 2016, dimensions are 183cm in length and 56cm in width. This coffin is made of three wooden species: the planks are made of acacia (*Acacia albida)* and sycamore-fig *(Ficus sycamores)*, whereas, the dowels and tenons are made of tamarisk *(Tamarix sp.)*; it is not common to use acacia along with sycamore-fig for making coffins. However, these wooden species may have been available for the artisan in a workshop or related to the social class of the deceased. Insect remains were identified as spider beetle, adult black carpet beetle, and molt of the larva of black carpet beetle.

Two kinds of painted layers were noticed on the same line on the decorated body of Nephthys at the coffin outer base and identified as azurite and malachite. The contact area between the coffin base and the ground of the tomb provides a suggestion of the degradation of azurite painted layer to malachite based on increasing the humidity, which can cause oxidation of the bluish painted layers.

The chromatic palette used in this coffin was suggested as orpiment for the yellow-painted layer, Egyptian blue and azurite for the blue-painted layers, malachite for the green-painted layer, and cinnabar for the red-painted layer.

A combination of imaging and spectroscopic techniques allowed the identification of a remarkable number of painted layers without sampling. However, the complete identification required the use of other spectroscopic techniques, such as XRD and Raman spectroscopy.

Acknowledgments

The authors would like to thank all staff at GEM-CC, wood lab members; FTIR lab member Dina Hassan, XRD lab member Mr. Hassan Zidan, and XRF technician Negm Eldin Morshed for their help.

References

[1] D.B. Redford, **The Ancient Gods Speak: A Guide to Egyptian Religio**, Oxford University Press, NewYork**,** 2002.

[2] C. De Vartava, C. *Reviving, the lost Ancient Egyptian Art of Sarcophagus Making*, The **Heritage of Egypt**, **2**(2), 2003, pp. 3-11.
[3] P.T. Nicholson, I. Shaw, **Ancient Egyptian Materials and Technology**, Cambridge University Press, New York, 2009.
[4] G. Abdel-Maksoud, *Analytical techniques used for the evaluation of a 19th century quranic manuscript*, **Science Direct Journal, 44**(9), 2011, pp. 1606-1617.
[5] A. Lo Monaco, E. Mattei, C. Pelosi, and M. Santancini, *The scientific investigation for the study and conservation of the wooden model of S. Maria Della Consolazione's church (Todi, Italy)*, **Journal of Cultural Heritage, 14**(6), 2013, pp. 537-543.
[6] I.C.A. Sandu, C. Luca, I. Sandu, P. Atyim, *Research regarding the saft wood supports degradation evaluation in old painting, using preparation layers. I. Chemical composition and technical analysis,* **Revista de Chimie**, **52**(1-2), 2001, pp. 46-52.
[7] M. Abdallah, A. Abdrabou, and H. Kamal, *Investigation, preservation and restoration process of an ancient Egyptian wooden offering table*, **International Journal of Conservation Science, 7**, 2016, pp. 1047-1064.
[8] * * *, IAWA *List of microscopic features for hardwood identification*, **IAWA Bulletin n.s., 10**(3), 1989, pp. 219-332.
[9] R.A. Cristache, I.C.A. Sandu, A.M. Budu, V. Vasilache, I. Sandu, *Multi-analytical Study of an Ancient Icon on Wooden Panel*, **Revista de Chimie, 66**(3), 2015, pp. 348-352.
[10] I.C.A. Sandu, S. Bracci, I. Sandu, M. Lobefaro, *Integrated Analytical Study for the Authentication of Five Russian Icons (XVI-XVII centuries),* **Microscopy Research and Technique, 72**(10), 2009, pp. 755-765. DOI: 10.1002/jemt.20727.
[11] A. Aldrovandi, E. Buzzegoli, A. Keller, D. Kunzelman, *Investigation of painted surfaces with a reflected UV false colour technique*, **8th International Conference on Non-Destructive Investigations and Microanalysis for the Diagnostics and Conservation of the Cultural and Environmental Heritage**, Lecce (Italy), 2005, pp. 15-19.
[12] A. Cosentino, *Effects of different binders on technical photography and infrared reflectography of 54 historical pigments,* **International Journal of Conservation Science, 6**(3), 2015, pp. 287-298.
[13] G. Verri, D. Saunders, J. Ambers, T. Sweek, *Digital mapping of Egyptian blue conservation implications*, **Studies in Conservation, 55**(2), 2010, pp. 220-224.
[14] J. Dyer, G. Verri, J. Cupitt, **Multispectral Imaging in Reflectance and Photo-induced luminescence modes: A User Manual,** British Museum, London, 2013.
[15] J. Dyer, E.R.O. Connell, A. Simpson, *Polychromy in Roman Egypt: Aa study of a limestone sculpture of the Egyptian god Horus,* **The British Museum Technical Research Bulletin, 8**, 2014, pp. 93-103.
[16] A. Cosentino, *Practical notes on ultraviolet technical photography for art examination,* **Conservar Património, 21**, 2015, pp. 53-62.
[17] A. Abdrabou, M. Abdallah, H. Kamal, *Scientific investigation by technical photography, OM, ESEM, XRF, XRD and FTIR of an ancient Egyptian polychrome wooden coffin*, **Conservar Património, 26**, 2017, pp. 51-63.
[18] R.A. Cristache, I.C.A. Sandu, A.E. Simionescu, V. Vasilache, A.M. Budu, I. Sandu, *Multi-analytical Study of the Paint Layers Used in Authentication of Icon from XIXth Century,* **Revista de Chimie, 66**(7), 2015, pp. 1034-1037.
[19] I.C.A. Sandu, S. Bracci, I. Sandu, *Instrumental analyses used in the authentification of old paintings - I. Comparison between two icons of XIXth century,* **Revista de Chimie, 57**(8), 2006, pp. 796-802.
[20] I.C.A. Sandu, C. Luca, I. Sandu, V. Vasilache, M. Hayashi, *Authentication of the ancient easel paintings through materials identification from the polychrome layers - II. Analysis by means of the FT-IR spectrophotometry,* Revista **de Chimie, 59**(4), 2008, pp. 384-387.
[21] W.V. Davies, *Ancient Egyptian timber imports: an analysis of wooden coffins in the British Museum*, **Egypt, the Aegean, and the Levant: Interconnections in the Second**

Millennium BC (Editors: W.V . Davies and L. Schofield), British Museum Press, London, 1995, pp. 146-156.

[22] A. Lucas, J.R. Harris, *Ancient Egyptian Materials and Industries, Histories and Mysterious of man*, **London**, 1989, p.447-344.

[23] R. Gale, P. Gasson, N. Hepper, G killen, *Ancient Egyptian materials and technology,* **Cambridge: Cambridge University Press, 1**, 2000, pp. 334-371.

[24] X. Belles, *Identification and geographical distribution of Gibbium equinoctial Boieldieu and Gibbium psyllids (Czenpinski) Coleoptera: Ptinidae*, **Journal of Stored Products Research, Science Direct, 21**(3), 1985, pp. 151-152.

[25] D.H. Choe, *Carpet beetles, integrated pest management in the home, pest notes,* **Publication 7436, University of California, Agriculture and Natural Resources,** 2012, pp. 1-4.

[26] S.H.D. Hulleman, *Determination of crystallinity in native cellulose from higher plants with diffuse reflectance Fourier transform infrared spectroscopy*, **Carbohydrate Research, 261,** 1994, pp. 163-172.

[27] M. Moustafa, M. Abdallah, R. Magdy, A. Abdrabou, H. Kamal, *Analytical study and conservation process of scribe box from old kingdom*, **Scientific Culture Journal, 3**(3), 2017, pp. 13-24.

[28] W. Shuya, *Photochemical degradation study of polyvinyl acetate paints used in artworks by Py–GC/MS*, **Journal of Analytical and Applied Pyrolysis, 97,** 2012, pp. 158-163.

[29] P. Ronald, D. Amelia, S. Gentile, F. William, L. Huang, *Quantitative analysis of copolymers and blends of polyvinyl acetate (PVA) using Fourier transform infrared spectroscopy (FTIR) and elemental analysis*, **Journal of Chemical Education, 4**(2), 2016, pp. 25-31.

[30] N. Proietti, *Spectroscopy and microanalytical techniques for studying the materials and state of conservation of an ancient Egyptian wooden sarcophagus*, **Analytical Bioanalysis Chemistry, 399,** 2011, pp. 3117-3131.

[31] C. Calza, *XRF applications in archaeometry: Analysis of Marajoara public covers and pigments from the sarcophagus cartonnage of an Egyptian mummy*, **X-Ray Spectrometry**, **36**, 2007, pp. 348-354.

[32] A.C. Sparavigna, *Ancient technologies: the Egyptian sintered quartz ceramics*, **Philica, 142,** 2014, pp. 1-5.

[33] G. Accorsi, G. Verri, M. Bolognesi, N. Armaroli, C. Clementi, C. Miliani, A. Romani, *The exceptional near-infrared luminescence properties of cuprorivaite (Egyptian blue*), **Chemical Communications, 23,** 2009, pp. 3392-3394.

[34] G. Verri, T. Opper, T. Deviese, *The treu head: A case study in Roman sculptural polychromy*, **The British Museum Technical Research Bulletin, 4,** 2010, pp. 39-54.

[35] R.L. Frost., Z. Ding, J.T. Kloprogge, W.N. Martens, *Thermal stability of azurite and malachite in relation to the formation of medieval glass and glazes,* **Thermochimica Acta, 390**(1-2), 2002, pp. 133-144.

[36] A. Abdrabou, M. Abdallah, H. Kamal, *Investigation of an ancient Egyptian polychrome wooden statuette by imaging and spectroscopy,* **International Journal of Conservation Science**, 2018, pp. 39-54.

[37] D.A. Scott, *A review of ancient Egyptian pigments and cosmetics*, **Studies in Conservation, 61(4),** 2014, pp. 185-202.

[38] S.G.J. Quirke, **Owners of Funerary Papyri in the British Museum**, British Museum Press, British Museum Occasional Paper, 92, London, 1993.

[39] L. Bonizzoni, S. Bruni, V. Gugliemi, M. Milazzo, O. Neri, *Field and laboratory multi-technique analysis of pigments and organic painting media from an Egyptian coffin of 26th Dynasty,* **Archaeometry, 53**, 2011, pp. 121-230.

Received: February 12, 2021
Accepted: January 15, 2022