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ANALYTICAL STUDY AND CONSERVATION OF GILDED MUMMIFORM CARTONNAGE FROM THE GRECO-ROMAN PERIOD IN CAIRO MUSEUM

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ABSTRACT

The state of preservation of the Cartonnage collection stored in the basement of the Egyptian museum in Cairo, is very poor; it is suffering biodeterioration as a result of inappropriate storage.
The analytical techniques utilized in this study : optical microscopy (OM), Scanning Electron Microscopy (SEM) equipped with an energy dispersive X-ray detector (EDS), X-ray diffraction (XRD), and Fourier transform infrared spectroscopes (FTIR). These analytical techniques aim to specify the layer structure of the cartonnage (preparation layer, painted layer and gilded layer),they also identify the adhesives used to paste the layers of textile and in binding pigments and gilding.
The treatment plan started with consolidating the fragile parts, removing the cotton bandages which we used to maintain the shape of the mask. Japanese tissue adhered with Klucel G is used to support the mask. Lenin ruptures were fixed and consolidated using Chitosan 5%.

KEYWORDS: Cartonnage, pigments, storage, gilded, Linen, Consolidation; Ruptures, Refilling

1. INTRODUCTION

Study of the Egyptian religious doctrines and return of sprint to the body after death, and the role of this belief in the appearance of cartonnage as alternative from the deceased features through which the spirit "alba" can reach the body "ka" again if the mummy was damaged. In addition, the section examined the Greek affection by the Egyptian religious beliefs and intermingles of the Greco-Roman religion with the ancient Egyptian religion. As a result, the disgusting idea of death for the Greeks and the Romans changed and this convention of the Egyptian funeral collections items, which caused appearance and spread of Greek and roman cartonnage. In addition, the meaning of cartonnage was identified and different opinions of its definition which unanimously agree that the term cartonnage expresses "card that bears the features of the deceased and consists of plaster layers coloured shade that was applied to a piece or linen or papyrus stuck by sticker" and the beginning of its appearance and periods of its use.

Cartonnage is a composite materials made from layers of linen or papyrus, coated with gesso then paintings. It was used to make 'masks' (head or upper body covers), foot cases, shaped symbolic plaques and even full body covers which were attached to the mummy-wrapped body prior to burial (Basile and Natale, 2006; Rowe et al., 2010). During manufacture, moist layers of adhesive-soaked linen and gesso were moulded into a particular shape. After drying, the gesso surface was smoothed before application of paint or gold leaf. A further layer of gesso was often applied with a brush to the underside of the casing to give it further strength and rigidity (Susi Pancaldo, 2010; Amenta, 2007)

The most ancient gilded surface were made of pure or highly pure gold leaf, beaten out to form a leaf or as powder mixed with an organic binder (Wright, 1983). The sarcophagi of nobles often had gilding decoration outside. Gilding became popular during the new kingdom (1570- 1070 B.C).

The middle kingdom (2025-1700 BC) is considered the first period to use cartonnage , third intermediate period (1064-669 BC) and Ptolemaic and early roman periods (330 BC – 250 AD). Each period produced it own distinct style of cartonnage manufacture and decoration (Adams, 1996; Wright, 1983).

The cartonnage study is 185.5 cm long, 23-45 cm width, thickness 0.5- 1 mm. We observed that it's composed of multi layers of linen bandages, covered by preparation layer of gesso and covered by a polychrome tempera and gilded gesso, the inlaid eyes and eyebrows are made of coloured glass paste. This mask has gilt front and Egyptian-style funerary motifs and painted on the back of the head with blue colour and sides with red colour.

The state of preservation of the cartonnage is so poor when received and mostly distorted. It has areas of loses and distorted areas that were folded inside, there is areas of lacunae on the painted layer, gesso layer and the gilt as well. The lower part in the left side feet had been crushed and has missing parts, the linen has areas of loss and it lost its structural cohesion, micro crack in the painting layer especially in the very end of the right side (Fig. 1).

The main objective of the study cases to identify the layer structure and techniques, characterize painting and gilding materials used to decorate the cartonnage by using analytical techniques such as light optical microscopy (LOM), scanning electron microscopy (BSE−EDS), x-ray diffraction analysis (XRD), and Fourier transform infrared spectroscopes (FTIR). The obtained results helped later on to set up a reliable conservation plane of the study case.

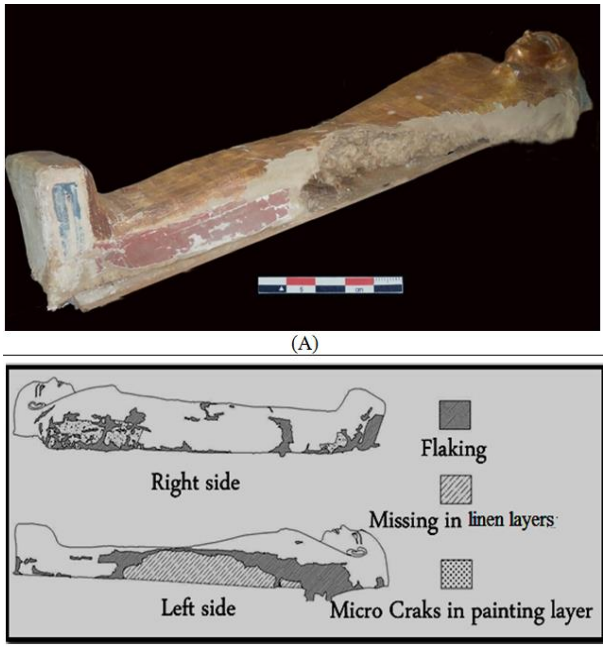


Figure 1.The main damage of cartonnage effected by rat and certain insects,which has led to lost a large part of it

2. MATERIALS AND METHODS

Representative samples were selected from parts that were already separated from the cartonnage to identify the constituents and degree of deterioration. These samples were representative of blue, red and gilded layers as well as the linen and preparation layers. Analytical methods for each material are given in Table 1.

Sample	Analytical methods
Blue pigment	USB microscope +XRD+EDS
Red pigment	USB microscope +XRD+EDS + FTIR
Gilded layer	USB microscope +XRD+ EDS+ FTIR
Preparing layer	EDS+ FTIR

2.1. Light optical microscopy

Samples were observed by a Wild M8 stereomicroscope, an Olympus BX51 optical microscope and recorded with a USB microscope. The stratigraphic sections were prepared by embedding the sample in a polyester resin, cold polymer sable with the addition of a catalyst, and then polished with a Strikers DAP-V machine by using Si–C paper discs with a decreasing granulometry (600, 1200, 2400 and 4000 grit size), until the cross section surface became smooth and specular (Lititzis and Polychroniadou, 2007). These preparation processes were applied at the Geology Department, Faculty of Science, and Cairo University (Afifi, 2011).

2.2. X-ray diffraction (XRD)

Red, blue, gilded layer pigments powders were investigated using a diffractometer (Philips PW 1840), operated at 40 kV and 25 m A, CuKa radiation and a receiving slit of 0.2 mm .The measurements were made at room temperature. Preparation of each sample consisted of grinding it in the dry form, by using a mortar and pestle to obtain a fine powder. The data were interpreted using the embedded software (Scott, 2008).

2.3. Dispersive x-ray analysis

Samples were investigated by Philips (XL30) microscopy, equipped with EDS micro analytical system to obtain the total element content qualitatively and quantitatively. It was useful for semi quantitative elemental analysis to make up for the deficiencies of XRD (Hanlan, 1975). In some cases, doubt arose about specific minerals that could not be readily identified by XRD (Perdikatsis, *et al*., 2000).

2.4. Fourier transform infrared Spectroscopy (FTIR)

FTIR spectra were obtained using a FT-IR Thermo Nicolet 760. The resolution is of: 4 cm1 (Region 4000 : 400 / Absolute threshold 0.002 /Sensitivity : 50). The sample preparation process consisted of grinding the sample to obtain fine stucco powder which was then mixed with KBr powder, with a sample/KBr ratio of 1:15. The FTIR quantitative analysis was done at the micro analytical center of Cairo University.

3. RESULTS AND DISCUSSION

3.1. Light Optical Microscopy

It was clear from data Fig. 2 that optical photomicrograph obtained on the polished cross-sections of the studied painted and gilded layer. LOM examination showed the rough morphology of the blue surface. The pigment surface is inhomogeneous in thickness, most probably due to inadequate preparation of the paint layers. From the optical analysis, the investigation of the blue pigment sample showed the pale blue pigment in form of a thin layer with some dark grains of cuprorivaite applied on a thin medium of plaster (gesso), there were also dark blue spots in the coarse grains due to the manufacture of pigment.

The blue colors appeared to have faded to a very weak in many areas showed inhomogeneous composition of the sample (Fig. 2A) which have different phases (dark blue, light blue), the thickness of the color is between 0.2 to 0.4 mm. The investigation of the red pigment sample shows thick layer of the paint layer with dark grains embedded in the layer (Fig. 2B), the thickness of the color is between 0.1 to 0.3 mm.

The investigation of the gild sample shows the canary hue of the pigment applied in form of a single layer on the plaster (Fig. 2C), the thickness of gold leaf is about 0.05 to 0.10 mm.

The results of the light optical microscope show that there is progressive damage in the linen. Fibre identification proved that the fibres are from linen.

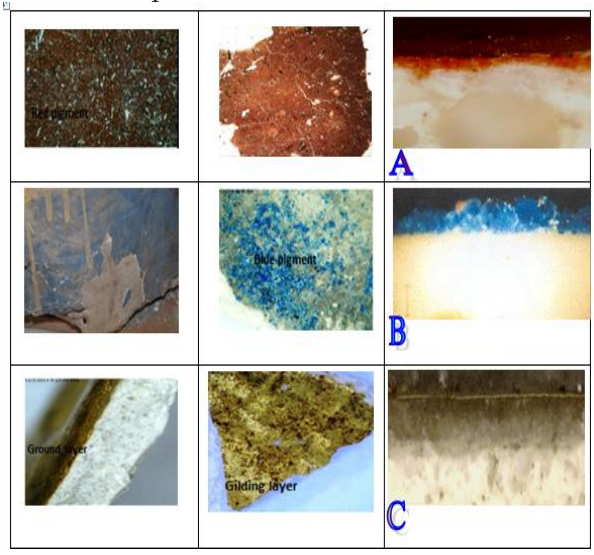


Figure 2. LOM photomicrograph of the paint layer of cartonnage A. red pigment ,B. blue pigment, C. gilded layer

Figure 3.The morphology of fibres under USB microscope, proved that the fibres from linen and the mainly deterioration by insect.

3.2.X-ray diffraction (XRD)

It was clear from XRD data of red pigment (Fig. 4) indicated that the red pigment is hematite (Fe_2O_3). Results indicate that blue pigment is Egyptian blue. (Ca Cu Si_4 O_{10}) (Fig. 5). XRD data of the gild sample (Fig. 6) indicated that the gilding layer is gold leaf.

3.3. Microstructure and microanalysis (BSE−EDS)

The BSE micrographs obtained for the ground layers, the EDS microanalysis obtained on the sample shows the peaks of calcium (86.38%), silicon (1.88%), and iron (6.08%) are present (Fig.7) .

The BSE image obtained on a polished cross-section of the red pigment shows clearly the brighter skeletal crystals, probably of hematite (Fe_2O_3), the EDS microanalysis obtained on the sample (spot analysis) shows the peaks of iron (59.41%), silicon (3.95 %), calcium (1.49 %) and copper (13.34 %) are present (Fig. 8).

The BSE image obtained on a polished cross-section of the blue pigment shows clearly the brighter skeletal crystals, probably of *cuprorivaite* ($CuCaSi_4O_{10}$). The EDS microanalysis obtained on the sample (spot analysis) shows the peaks of silicon (3 .41%), calcium (58.37%) and copper (0 .41%) are present, whose atomic percentage ratio are in agreement with the chemical formula of *cuprorivaite*, (Fig. 9).

The BSE microanalysis obtained of the gilding layer sample shows the peaks of gold (73.82%) silicon (2.17 %), calcium (8.79 %) and copper (0.50* %) are present (Fig. 10).

While iron, potassium, sodium, chlorine, aluminum, magnesium and sulfur were also measured in all samples (Siska Genbrugge; 2010).

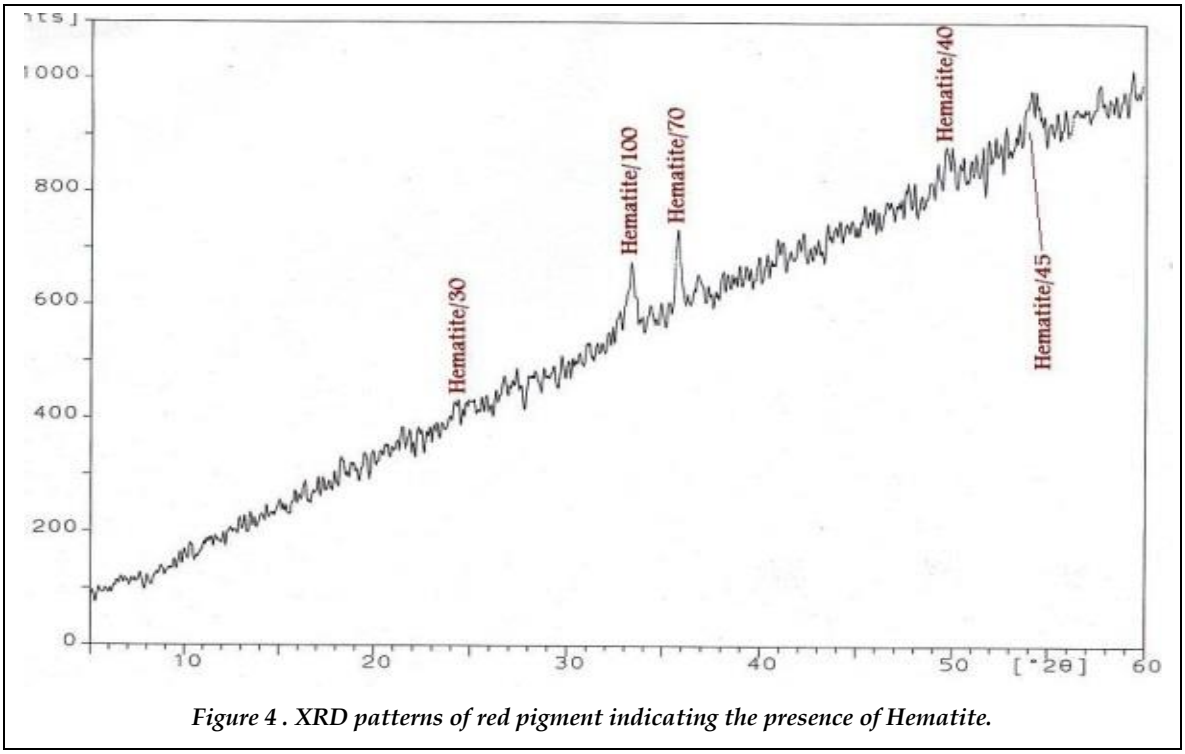


Figure 4 . XRD patterns of red pigment indicating the presence of Hematite.

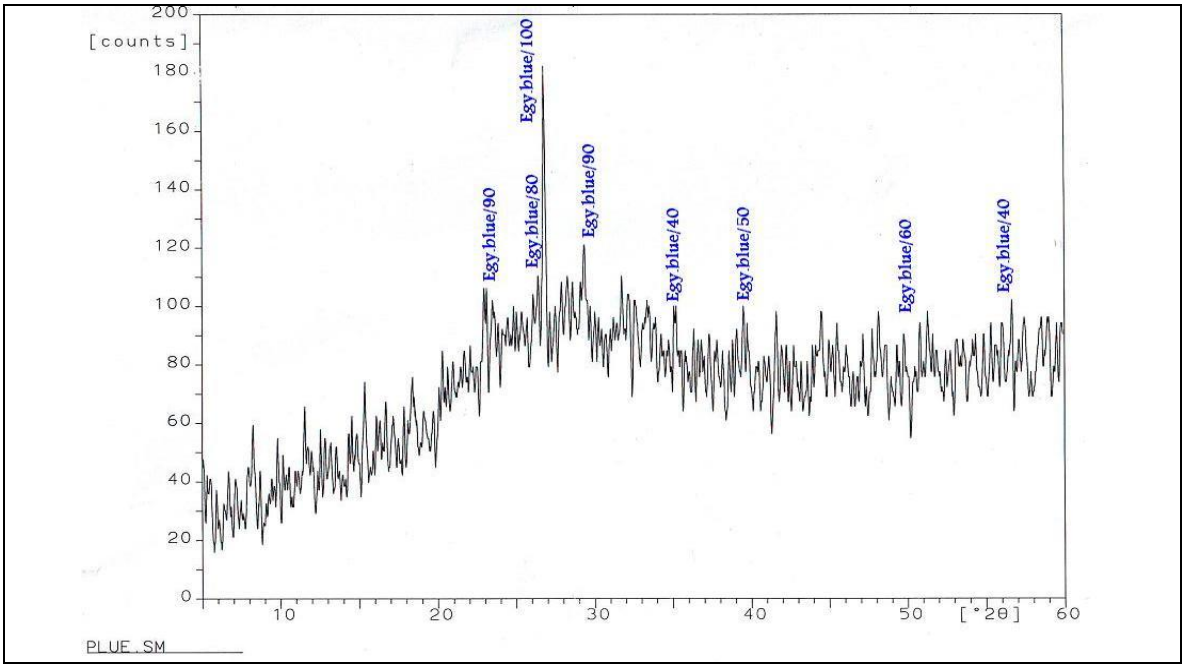


Figure 5 . XRD patterns of blue pigment indicating the presence of Egyptian Blue

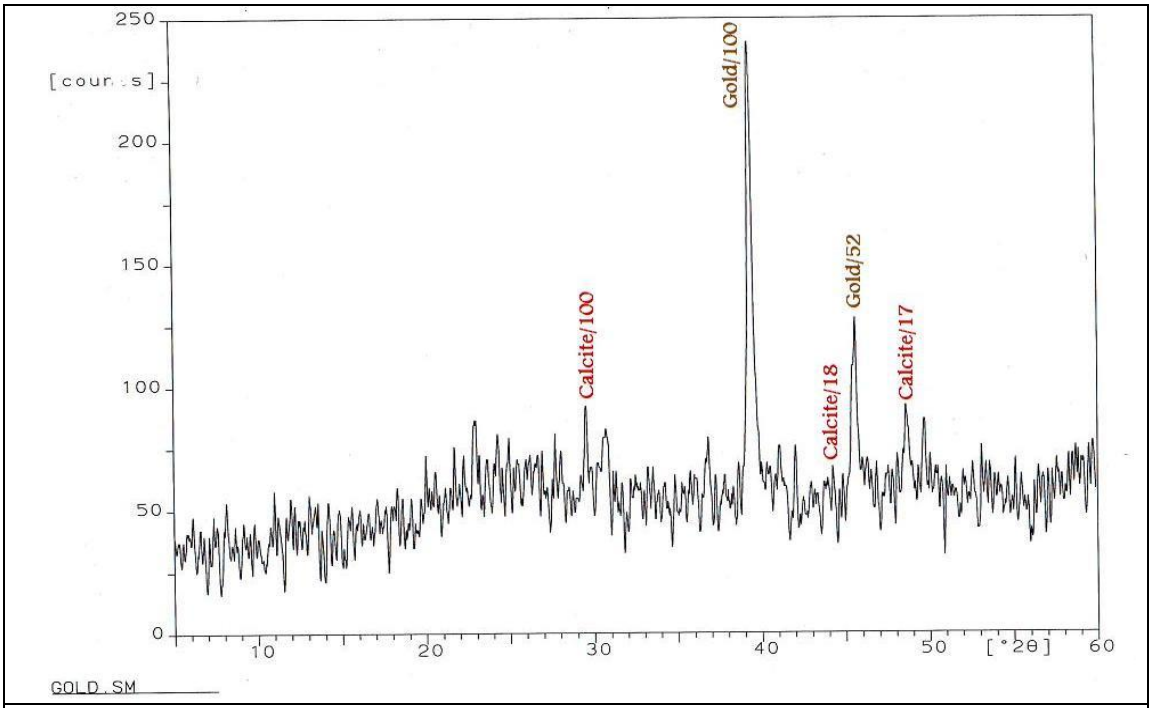
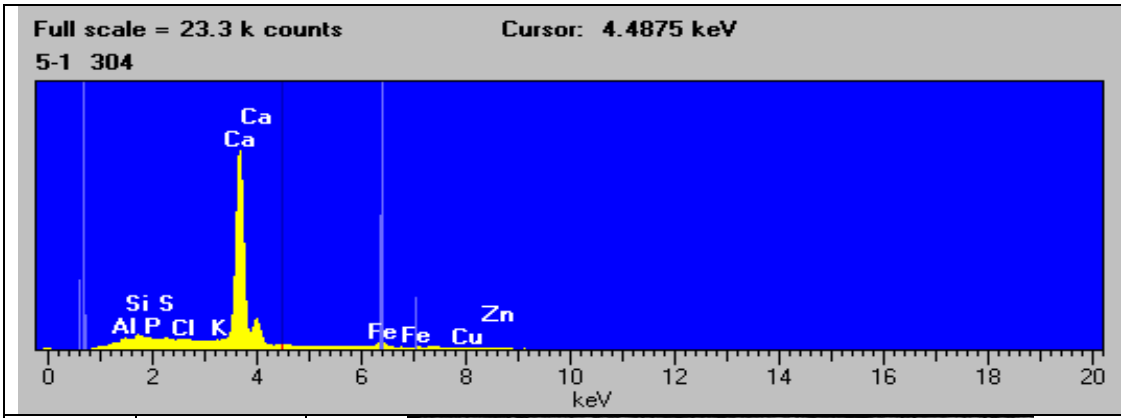


Figure 6. XRD patterns of the gilding layer indicating the presence of Gold and Calcite



Elm	Elm %
Mg	0.11
Al	0,87
Si	1.88
P	0.26
S	0.38
Cl	0.85
K	0.85
Ca	86.38
Fe	6.08
Cu	1.48
Zn	1.17
Total	**100.00**

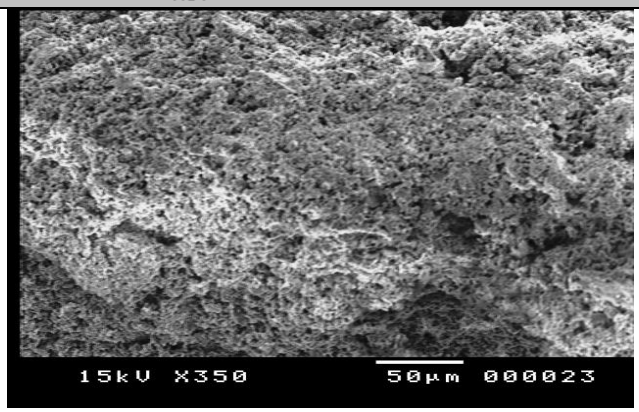
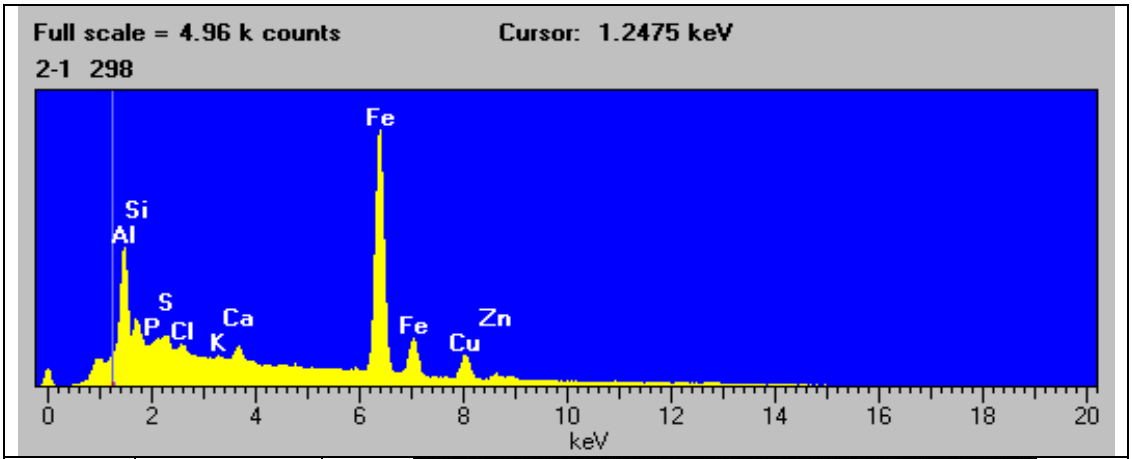


Figure 7. EDX analysis for the ground layer



Elm	Elm %
Al	17.82
Si	3.95
P	0.23
S	0.63
Cl	1.04
K	0.42
Ca	1.49
Fe	7.08
Cu	13.34
Zn	1.72
Total	**100.00**

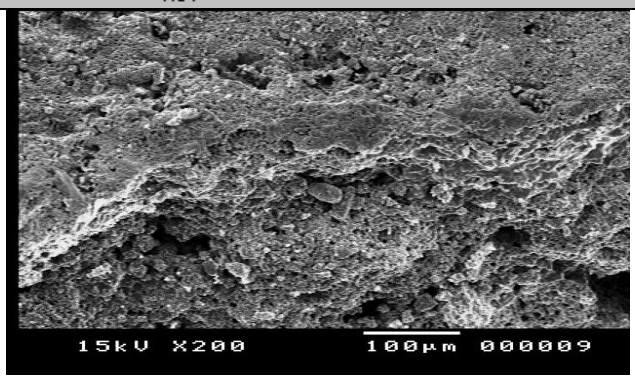
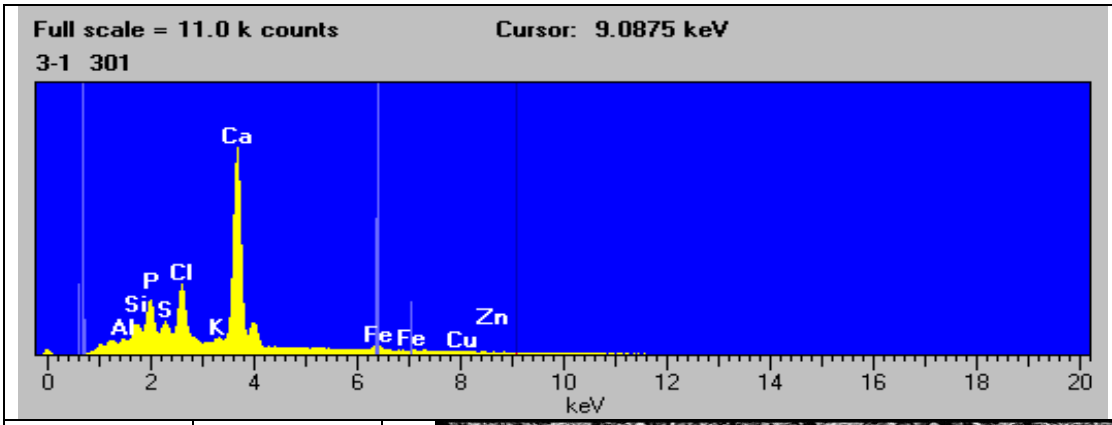


Figure 8. EDX analysis for the red pigment



Elm	Elm %
Mg	2.44
Al	0.92
Si	3.41
P	8.87
S	3.86
Cl	13.41
K	1.33
Ca	58.73
Fe	4.03
Cu	0.41
Zn	0.40
Total	**100.00**

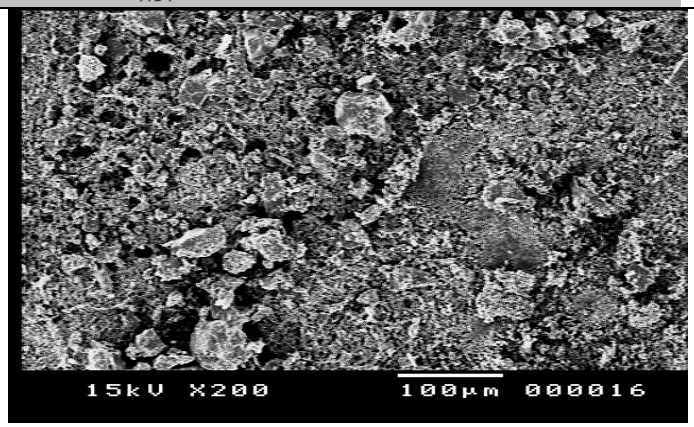
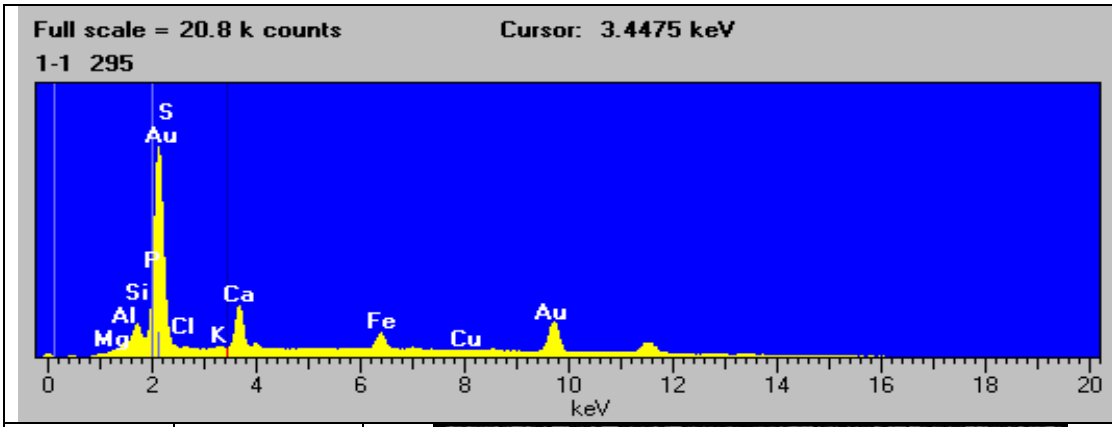


Figure 9. EDX analysis for the blue pigment



Elm	Elm %
Mg	0.11
Al	0,99
Si	2.17
P	4.87
S	0.57
Cl	0.64
K	0.41
Ca	8.79
Fe	7.08
Cu	0.50
Au	73.82
Total	**100.00**

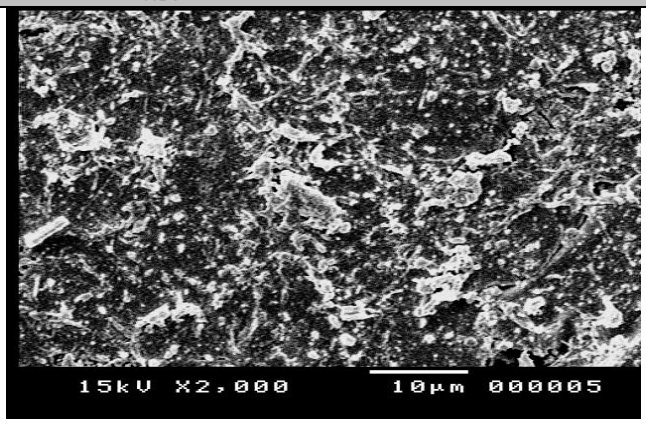


Figure 10. EDX analysis for the gilding layer

3.4. Fourier transforms infrared Spectroscopy (FTIR)

According to (Derrick, Stulik, & Landry, 1999) where it was stated that the animal glue appears when the following functional groups:
3400-3200 cm^{-1} N-H stretching band
3100-2800 cm^{-1} C-H stretching bands
1660-1600 cm^{-1} C=O stretching band
1565-1500 cm^{-1} C-N-H bending band
1480-1300 cm^{-1} C-H bending band

Comparing these functional groups that have emerged in the three archaeological samples it is clear that a great similarity between the two occurred which confirms that the mediator used in ground colored layer of animal glue (Fig. 11).

- The first sample of ground layer appeared N-H group at 3307.32, 3421.1, C-H group also appeared at 2923.56 - 2853.17 and appeared group C = O at 1671.02, 1598.7 and C-N-H group appeared at 1559.17 and the C-H group appeared at 1295.93, 1325.82, 1457.92.

- Second sample special red N-H group appeared at 3307.32 as C-H group appeared at 2853.17 and appeared group C = O at 1671.02, 1599.66, 1637.27 and C-N-H group appeared at 1560.13 and the C-H group appeared at 1295.93, 1325.82, 1422.24, 1462.74.

- The third sample painted golden yellow N-H group appeared at 3307.32, 3421.1, C-H group also appeared at 2923.56 and appeared group C = O at 1671.02, 1599.66 and C-N-H group appeared at 1560.13 and the C-H group appeared at 1295.93, 1325.82, 1409.71, 1462.74.

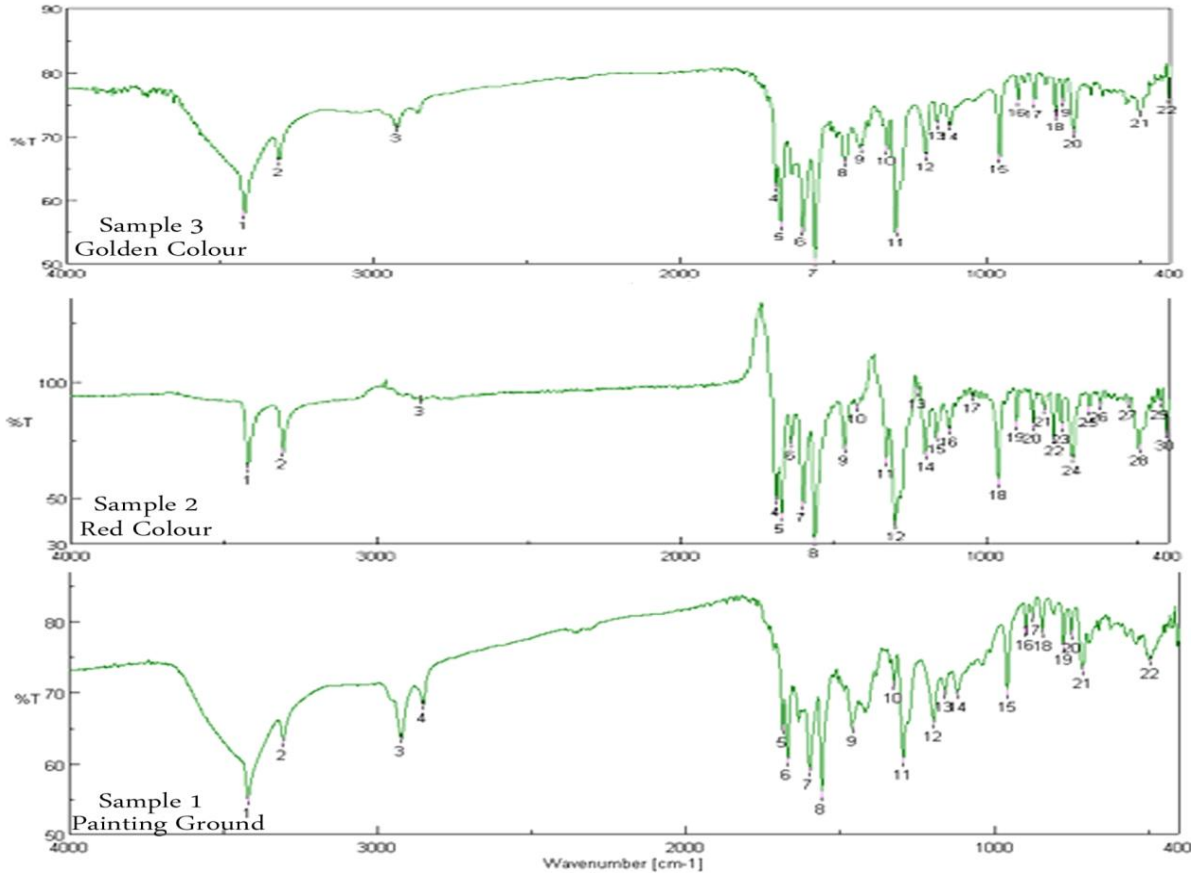


Figure 11. FTIR pattern of samples from cartonnage

4. CONSERVATION PROCESS

The main reason that caused the major damage of the cartonnage is rats and insects. Basically, the storage area of the basement lack of pest management to avoid infestation of stored objects that led to causing more damage and threaten to lose objects. The cartonnage has breaks, disjoints and micro cracks in the ground layer, painting and gilded layers as well, that resulted in losing the painted layer and parts of decoration.

Initially, the treatment of the cartonnage started by mechanical and chemical cleaning to remove dust, accumulated dirt and deposits, rejoining by adhering detached areas and separated parts of decorations, detachment of gilded layer were fixed

locally by consolidation injection using Paraloid B72, increasing the mechanical strength for linen. Consolidation of the fragile parts were carried out as follows (Figs. 12, 13, 14):

- Paraloid B72 3%: 5% was used to fix separated peels.
- Surface cleaning was performed using Ethyl Alcohol and distilled water 1:1
- Removal of the stuffed cotton and old bandages.
- Strengthening the surface of the cartonnage facing by applying Japanese tissue stripes glued with Klucel G 5% in Ethyl Alcohol.
- Pasting ruptures in layers of linen and ground layer, using Chitosan 5% in Ethyl Alcohol.

Concerning the reason behind the making of a new support, when we first received the cartonnage, it was stuffed with cotton to preserve its shape. Later on, the cotton was covered with dust and due to the insufficient storage in combination with other factors such as original structure of cartonnage, temperature and relative humidity, and biological threats.

Studies have proved that foam layer does not dissolve or degrade or change over time in any relatively permanent preservation conditions and the effects of display in museums and storage. Additionally, it does not interact with each other or with the effect of material in a destructive or destructive when applied now or the future. It can be removed when needed without causing any damage.

The mold was prepared using liquid foam covered with insulating layer of linen glued with Paraloid B72 10% to carry the mask and the shape of the mask during conservation . Tissue layers used to preserve the decorative layer of cartonnage was removed using ethyl alcohol. Then, the separated pieces of the paint layer was fixed into place. This was followed by final consolidation of the surface of cartonnage by Paraloid B72 dissolved in acetone 2.5%.

5. CONCLUSION

The results of the analysis of the state of preservation of the Cartonnage collection stored in the basement of the Egyptian museum in Cairo, after performing investigation on this case study, indicates that textile support consists of 11-15 layer of linen, ground layer consists of calcium carbonate, blue pigment is identified as Egyptian blue, red pigment is identified as hematite. The gilded layer is a gold leaf. Results identified the adhesive/binder used paste the layers of linen, pigments and gilded layer as animal glue.

Figure 12 The main damage of the cartonnage

Figure 13 Steps of conservation of the cartonnage

Figure 14 Cartonnage after conservation process

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