

Strategy for Preservation of Two Romanian Archaeological Wrapped Mummies in Siywa Excavation, Egypt

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Abstract

Two historical mummies dating back to the Roman era, discovered in EL-Salam area in Siywa tombs, their length reached to 170cm, preserved in Hall No.6 of the museum store in Siywa. Both of them wrapped in linen rolls but one of them provided with Cartonage layer (gesso layer of 2cm) were chosen to the study. The mummies showed different aspects of deterioration types. This study aimsto describe these aspects of deterioration; explain the mechanisms of deterioration resulting from investigations through applying different analyses processes (visual assessment, microbiological investigation, scanning electron microscope (SEM/SEM&EDS), Fourier transform infrared spectroscopy (FTIR), X-Ray florescence (XRF), Stereo Microscope (SM)). Finally,apply appropriate restoration and conservationprocedures to the mummies. Theconservation techniques used were Sterilization procedures; Mechanical and chemical Cleaning processes; Completion of the missing parts of the Cartonage (Jesso/ gypsum layer); Consolidation, Unfolding and mechanical supporting of the weaken parts of linen rolls; The treatment of the Cartonage layer cracks and fragments of it; and Storage and Display conditions.The results of investigations revealed that the mummies suffered from a degradation of amino acids as well as oxidation and hydrolysismechanisms.The mechanical andchemical cleaning used removed the surface dust and dirt without damage to thecomponents of the mummies.In general, allthe conservation processes of the mummies revealed its aesthetic value again.

Keywords: Mummy; Linen; Cartonage; Visual Assessment; Sterilization; Consolidation; Unfolding.

1. Introduction

The mummies discovered by the Egyptian excavation mission under the chairmanship of Dr. Abdul Aziz Al-Dumeiri in the Ouj oasis in 2010 which far away from Siwa oasis about 160 km. It was an abandoned oasis with the rock tombs which dating back to roman era and have not any inscriptions, drawings or wall paintings but contained the mummies of the study and other skeletons. Mummification is considered one of the most important matters in the history of ancient Egyptian civilization. The artificial mummification process started in the Fourth Dynasty during the Old Kingdom reached its peak in the New Kingdom (Abdelrahman Elamin, 2011).

Ancient Egyptian civilization was distinguished by a clearly defined belief in a human existence which continued after death, but this individual immortality was considered to be dependent in part on the preservation of the body in as lifelike a form as possible. In recent years, Egyptian mummies have been taken into consideration of scientific studies (David, 2001). Cartonage is one of the most important archaeological materials that are found on the mummies and including it from there, colors, scenes, texts and the writings of ancient which can be revealed through them for many of the facts, historical information and secrets (Teeter, 1994).

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The conservation of mummies is a politically and socially sensitive issue (Cassman & Odegaard, 2004). The preservation of a mummy after study involves: (1) Identifying the type of mummification process used and the state of deterioration; (2) Selecting an appropriate method of diagnosis; (3) Individualized restoration; and (4) Recommending storage conditions, including environmental and biological protection. Finally, storage conditions should show the respect that each human body deserves, taking into account the laws and beliefs of each nation (Lombardi, 2001).

Deterioration in mummies is caused by several factors, including environmental conditions, physical damage, biological damage or damage caused by previous conservation attempts. Sometimes, these factors occur in isolation, but they can also be present in combination (David, 2001). Insects are considered one of the most serious factors causing damage to Egyptian mummies. Panagiotakopulu (2001) reported that mummies, both human and animal, were highly susceptible to insect attack. The presence of insects depends on three factors (climate, food and competition with other living organisms) (Hill, 1985).

The growth of microorganisms in organic materials such as mummies is dependent on the presence of moisture, although, other factors such as temperature should be taken into consideration to understand the bio-deterioration mechanism. High temperatures from internal case lighting and windows can also cause the mummified skin to stiffen and become more susceptible to cracking and chemical breakdown. The chemical destruction of mummified tissue can also occur through exposure to air pollution, often high in large cities and industrial areas (Valentin, 1996).

2. Materials and Methods

The authors applied different restoration and conservation procedures on two historical mummies dating back to the Roman era, discovered in EL-Salam area in Siywa tombs, their length reached to 170cm, preserved in Hall No.6 of the museum store in Siywa. Both of them wrapped in linen rolls but one of them provided with Cartonnage layer (gesso layer of 2cm).

Documentation procedures essentially mean assessing levels of damage. The survey was intended to serve two closely linked purposes:

- A historic record to determine the historical value of the historical mummies
- A condition record to clarify the condition of the historical mummies in order to put an appropriate plan and conservation procedure to deal with the damage that is found.

There are a lot of deterioration aspects found in the two historical mummies that can appear in the Visual Assessment.

2.1. Visual Assessment (The condition survey of the two historical mummy's deterioration aspects)

All the deterioration aspects and treatment procedures of the historical mummies were recorded using a high-resolution digital camera image to create realistic photographic documentation of the aspects of deterioration. The visual observation was used to follow the changes of historical mummies to explain the deterioration forms and to record all the procedures of restoration and conservation procedures. This method is very effective because the causes and mechanism of deterioration may be easily identifiable (Abdel-Maksoud, 2011). The two historical mummies of the study contain several materials that can be divided into: mummy body, layers of linen, covered with decorated plaster and lying on a coffin. With the critical eye observation of the two historical mummies from the museum store in Siywa, it was found:

The First mummy:

It is a mummy wrapped in torn linen rolls which colored with dark brown stains especially in different places of head and legs parts and other separate linen parts. Also there is collapse and complete loss in the back part of the backbone of the mummy. As well as the complete change in the color of linen, prevalence of weakness and tear in the linen textile which resulted in dissociation of the rolls from each other. Many fungal and insect infections are spread in different parts of the linen in the head parts and other different parts of the mummy.



Fig.1. the first mummy before restoration and conservation procedures which the deterioration aspects appeared.

The second mummy:

It is mummy covered with colored Cartonnage layer suffer from different lose parts at the feet and different parts of the mummy body. A large part of the Cartonnage is also lost in the chest area which made the hands of the mummy appeared in the Uzairian form. Also there is splitting in the linen textile in the parts around the neck and head parts. There are classifications of dust, clay and salts on the head and face parts. There is a great loss in Cartonnage color layer. Also there are micro cracks in the Cartonnage gesso layer. There are a broken parts found in small pieces beside the mummy. Some cracks found in the skull and general weakness in the bones of skull and face.



Fig.2. the second mummy with the Cartonnage (gesso layer) before restoration and conservation procedures which the deterioration aspects appeared.

2.2. Isolation and identification of fungi(collection of samples swabs)

Sterile cotton swabs wiped from different infected parts of the mummies especially in the contaminated area and saved in dry, sterile, polypropylene bags, kept in ice during transportation, then stored in the refrigerator (4°C) till the isolation of microorganisms. Or Isolation was made directly in the laboratory after wiping process. Samples were determined by serial dilution and plating on the media used (Harley, 1993). The fungi were isolated by wiping the swabs on culture medium of potato-dextrose agar (PDA) then incubated at 26± 2°C for 1–2 weeks. Fungal colonies were identified according to (Raper and Fennell, 1995; Barnett and Hunter, 1972; Watanabe, 2002; Domschet *et al.*, 1980; Stevens, 1981).

2.3. Fourier Transform Infrared Spectroscopy (FTIR)

Fourier transform infrared attenuated total reflection (FTIR-ATR) has been extensively used to investigate absorption and reactions on surfaces. This method of analysis has been used in accordance with Infra-red spectra were obtained using a FTIR spectroscopy (JASCO-ATR-FT/IR-6100). This method of analysis gives information on the composition of the material and at the same time gives an indication of the behavior of the protein materials degradation (Abdel-Maksoud, 2013). Attenuated total reflection (ATR-FTIR) was used as significant advantage of ATR technique is that the archaeological samples require no preparation, thereby minimizing possible damage. Infrared spectra were obtained using a Fourier transform infrared spectroscopy (JASCO-FT/IR-6100) in Laser Technology Unit (LTU), Center of Excellence for Advanced Sciences (CEAS), National Research Center (NRC), Dokki, Giza, Egypt. This method of analysis has been used in accordance with Jadoul *et al.*, 1996; Pouliot *et al.*, 1999; Xie *et al.*, 2002; Velkova&Lafleur, 2002; Liao *et al.*, 2006; Dias *et al.*, 2008; Russeau *et al.*, 2009. Analyses with FTIR were performed to identify the chemical composition of some fragments taken from linen and hair samples to investigate absorption and reactions on surfaces of historical Egyptian mummies.

2.4. Investigation of the surface morphology by Scanning Electron Microscope (SEM)

A scanning electron microscope was used for the investigation of the surface morphology of the historical linen rolls. The fine gold coating was used. All samples were conditioned under the standard atmospheric conditions for 24 hours at temperature of 25°C and relative humidity 65% (Havlíková *et al.*, 2009). All samples were photographed by SEM at the Scanning Electron Microscope Laboratory of Faculty of Science, Cairo University, Giza, Egypt.

2.5. Investigation of the surface morphology of the painted layers by Scanning Electron Microscope Examination and Energy Dispersive Spectrometry (SEM&EDS)

SEM&EDS was used for examining the surface morphology of the painted layers used in the separated pieces, in addition to the appearance of deterioration spots. Two small samples were taken from the cartoonage examined by using an Inspect S50 (FEI Image size: 1000 x 1000Mag:128.686327077748xHV:5.0kV).

2.6. Investigation of cartoonage layer by X-Ray fluorescence (XRF)

Three small samples were taken from the cartoonage and examined by IR fluorescence (IRF) using Instrument Type VERTEX 70, IR fluorescence (IRF).

2.7. Investigation of the surface morphology of textile by Stereo Microscope

Stereo Microscope was used to investigate the surface morphology and cartoonage layer to identify the condition of the cartoonage by using a ZEISS device, Stemi 2000-C.

3. Treatment and conservation procedures

3.1. Sterilization procedures:

Sterilization was started using a light spraying technique, and that was by using compressor provided with paradie chlorobenzene dissolved in ethyl alcohol (1%), the process can be repeated for several times, especially in the contaminated areas (around the neck area of the head as well as in chest area in the second mummy) with the fungal infestations. Then it should be left till dry and the odor of the sterilization materials gone. This infection was result of the tears in the linen textile which appeared due to the loss of Cartonage layer which led to the necessity of sterilization.



Fig.3. the historical mummies' sterilization: sterilization process of the linen rolls in the first mummy and the neck area in the second area

3.2. Mechanical and chemical Cleaning processes:

Mechanical and chemical cleaning processes for all Components of the mummy (wrappings, bandages hair and etc.) were applied in accordance with Gansicke et al., 2003 and Farrell et al., 2006. Mechanical cleaning process was done by different means of tools e.g. scalpel, spatula and other metal tools. Also hand blower can be used to get rid of the block dust/clay and stains in the linen rolls in the first mummy and the Cartonnage colors and skull area in the second mummy, some organic solvents were also used in cleaning steps for linen rolls especially the brown stains in different places.



Fig.4. the historical mummies' mechanical cleaning process of the linen rolls in the first mummy and the Cartonnage colors and skull area in the second mummy with some organic solvents

3.3. Completion of the missing parts of the Cartonnage (Jesso/ gypsum layer):

The completion process was carried out using the gypsum plaster provided with the diluted primal AC33 treated with the appropriate fungicide as well and suitable color oxides. The completion steps carried out gradually from the small pieces into the large areas till the dryness process completed, then the sanding and softening works completed.



Fig.5. the historical second mummy completion process using the gypsum plaster

3.4. Consolidation, Unfolding and mechanical supporting of the weakened parts of linen rolls:

Consolidation is considered one of the most important processes in our case study. Conventional stitching techniques cannot be used with linen wrapping because the needle and sewing thread may break the dry and fragile linen threads. It was noticed that linen rolls were folded and suffer from dryness as some of them turned into untwisted blocks with internal ruptures. Flattening, crease removal and unfolding and humidification process was done with ethyl alcohol: water (2:1 %). Also the consolidation process done to the folded linen rolls directly by using spraying technique with primal AC33 dissolved in water provided with pesticide till it could be completely flattened in accordance with Abdel-Kareem (2000).

Also repairing tears and mechanical supporting of the weakened parts steps used for consolidation process for the torn parts of the linen rolls which applied by using modern linen pieces treated and dyed with oxides provided by fungicide, which applied in all torn parts of the historical linen.

Unfortunately, the back linen part of the mummy backbone become very weak and turned into powder. So treated and dyed linen the same color of the historical linen was used for mechanical supporting process which fixed with the weak and torn parts of mummy backbone. Consolidation materials used for that step e.g. primal or Bareloid B-72 (2%).

Consolidation works and lining the weakened parts applied to the mummy linen rolls with primal AC33 diluted in distilled water (10%) provided with pesticide (mentioned before). So the weakened parts consolidated in three stages. The linen rolls stabilized together after the unfolded process. Then using B-72 dissolved in ethyl alcohol (2%) with spraying technique by compressor. Finally, the drying process to get rid of excess moisture in linen rolls.



Fig.6. the historical mummies consolidation, unfolding and mechanical supporting of the weakened parts

3.5. The treatment of the Cartonnage layer cracks and fragments of it:

The second mummy suffers from some cracks in the Cartonnage layer that resulted in some fragments and powder. It was necessary for consolidation process which applied by injection technique with primal AC33 diluted with water (10%) treated with antifungal mentioned before. The fragmented pieces also were treated and fixed again to its original places and the Cartonnage colors fixed also in the feet area and some other different places over the mummy.



Fig.7. the historical mummies treatment of Cartonnage layer cracks and fragments

3.6. Storage and Display conditions:

There is no absolute rule for the display of mummies. There are guidelines, but also an ongoing debate. It was indicated that many museums now have policies on the display of mummies: All such displays should be designed so that the mummies are accompanied by an explanatory interpretation that places them in an historic context. Display of archaeological remains for aesthetic or artistic purposes alone will not be permitted. Where human remains are displayed in the museum, there will be a notice outside the relevant display space alerting visitors to the presence of human remains.

Conservation procedures applied for the two historical mummies in the museum store in Siwa. The tightly closed wooden box was prepared from the museum store Administration. The box was sterilized from inside and outside. Also the modern linen textile treated with antifungal materials was placed in the Box floor, then a polyethylene layer was also placed and finally, the wrapped mummy with the linen rolls placed inside that box. The free spaces in the box were supported with the compact sponge (thickness 10cm) covered with tissue paper in order to prevent the bad effect of this sponge on the linen rolls. Finally, the mummy was delivered inside that box to the Custodian of the museum store in Siwa and preserved in hall no.7.



Fig.8. the historical mummies after restoration and conservation procedures which preserved in the prepared box in hall no.7 in the museum store of Siwa

4. Results and Discussion

4.1. Fungi identification of the two historical mummies

The fungal species were identified and characterized based on their morphological characters and microscopic analysis by using taxonomic guides and standard. The following morphological characteristics were evaluated: colony growth (length and width), presence or absence of aerial mycelium, colony color, presence of wrinkles - furrows, and pigment production (Apinis, 1963; Rohilla, 2012). Isolation and identification of micro-organisms are very important for the restoration and conservation treatments of the historical manuscripts; they give an idea of the microbiological deterioration which helps to determine the most appropriate methods for prevention, inhibition and removal of these micro-organisms (Abdel-Maksoud, 2011). Valentin (2001) stated that among the types of fungi found in Spanish museums, archives and libraries are *Aspergillus niger*, *Aspergillus flavus*, *Aspergillus fumigatus*, *Penicillium chrysogenum*, *Rhizopus nigricans*. Valentin (2003) reported that *Penicillium* and *Aspergillus* strains are harmful to textiles because they have a high level of cellulolytic activity and grow in materials with a moisture content of 7- 8%. David (2008) mentioned that fungi of various types are often seen in ancient tissues as a result of poor storage of the specimen.

The most dominant fungi isolated from the mummies studied. The identified fungi belong to two genera, *Ascomycotina* and *Zygomycotina*. Infestations of fungi, particularly *Rhizopus sp.*, caused the white spots found on the linen bandages. The identified fungi were: *Aspergillus niger*, *Aspergillus sulphureus*, *Aspergillus versicolor*, *Aspergillus sydowii*, *Penicillium chrysogenum*, *Penicillium islandicum*, *Alternaria alternata*.

4.2. Fourier Transform Infrared Spectroscopy (FTIR):

Chemical composition of the binder of the paint layers samples of cartonnage in the second historical mummy was determined by FT-IR analyses. The FT-IR spectrum of the binding media was similar with the ones of made with animal glue. The results of FTIR analysis were compared with reference spectra with well-known organic adhesives. The sample spectrum was compared with spectra of Arabic gum, animal glue and yellow and yolk egg. FTIR analysis shows that the residue of the bonding material is animal glue.

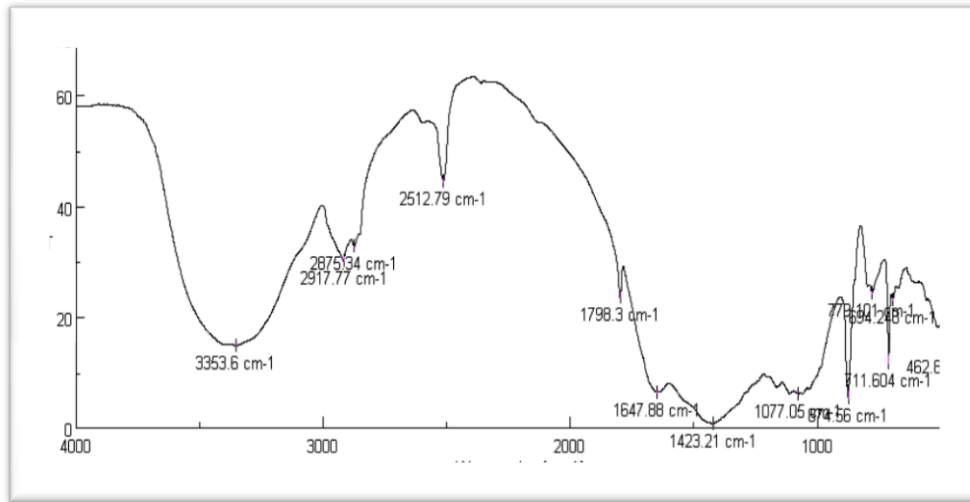


Fig.9. FTIR spectra of paint layers samples of cartonnages shows that the residue of the bonding material is animal glue

Hair fibers analyzed by ATR-FTIR According to Espinoza *et al.* (2008), the region (1200 to 1000 cm⁻¹) is associated with vibrations of the sulphur-oxygen groups of keratin. The peptide bond is the most abundant bond within a keratin protein (Panayiotou, 2004).

The degradation in the archaeological sample compared to the control sample was recorded. The results proved the presence of sulphur-oxygen groups in the two samples and observed keratin degradation of archaeological hair sample. Oxidation in the region between 1400 and 900 cm⁻¹ of the amino acid cystine to cysteic acid can occur in hair, resulting in an increase of the S=O stretching absorbance.

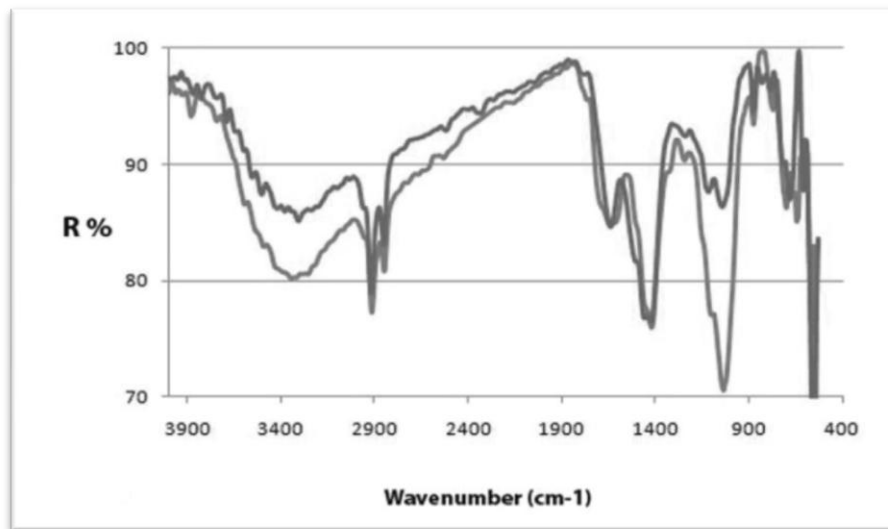


Fig.10. FTIR spectra of the hair sample of the historical mummy shows the degradation of keratin

4.3. Investigation of the surface morphology of the historical mummies by Scanning Electron Microscope (SEM):

Investigation of the linen rolls of the wrapped historical mummies showed that the linen fibers which identified from different parts of the rolls were damaged. The fibers are extremely roughened, deteriorated, broken with transverse cracking and longitudinal splitting characterized by small scratches, small slits and holes. Furthermore, one can see the dust, dirt that covered the fibers.

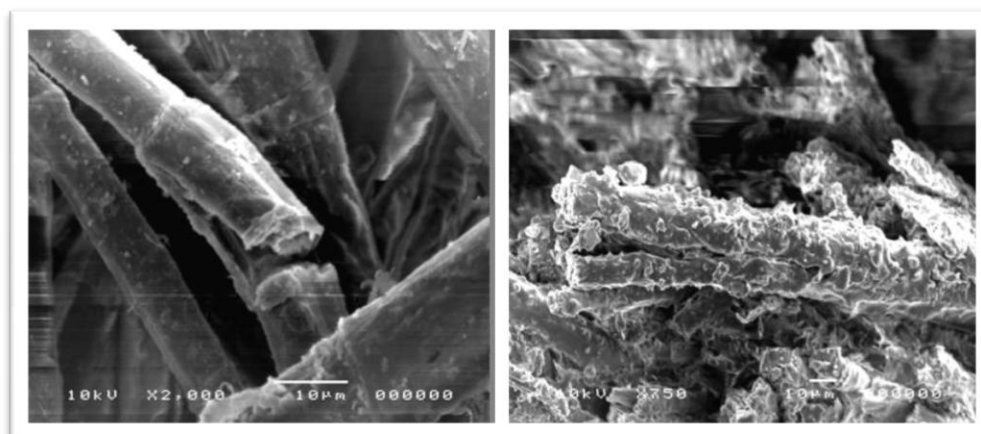


Fig.11. SEM images that show degradation aspects in linen fibers in the wrapped rolls of the historical mummies

4.4. Investigation of the surface morphology of the painted layers by Scanning Electron Microscope Examination and Energy Dispersive Spectrometry (SEM&EDS):

The preliminary observation of the cartoonage revealed that black paint layer had been directly applied on a white ground layer. The black paint was applied to decorate the cartoonage. SEM&EDS examination for the white ground layer (Gesso) and the painted surface of the cartoonage by using an Inspect S50 (FEI Image size: 1000 x 1000Mag:128.686327077748xHV:5.0kV. The examination shows coarse morphology and inhomogeneous composition of the black color, it was made of Graphite (Coral) and it appears in light areas on the surface the ground layer. In almost every analysis of Egyptian pigments, black has proven to be carbon.

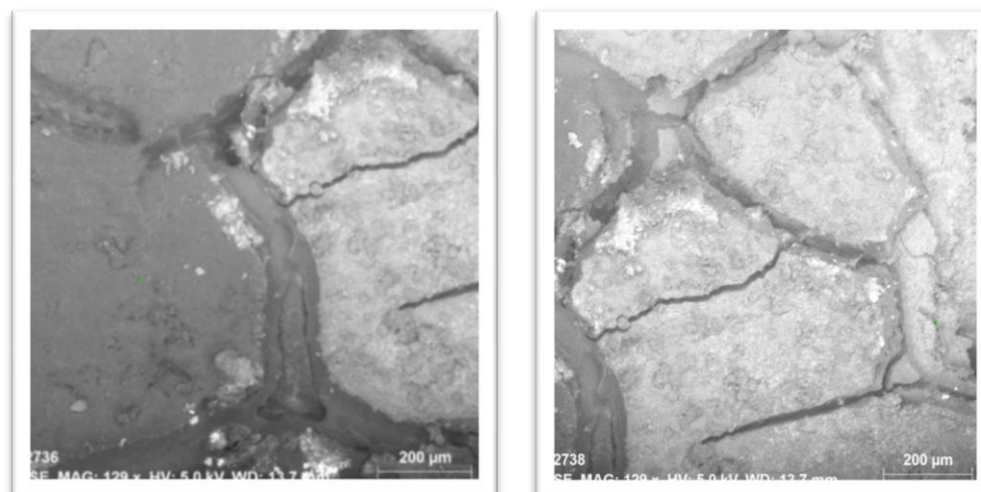


Fig.12. SEM&EDS images that show examining the surface morphology of the painted layers in addition to the appearance of deterioration spots, Image size: 1000 x 1000Mag:128.686327077748xHV:5.0kV

4.5. Investigation of cartoonage layer by X-Ray fluorescence (XRF)

The samples were taken from the cartoonage and examined by (XRF) showed that the ground layer of cartoonage was a mixture of calcite (CaCO_3) as main component and quartz (SiO_2).

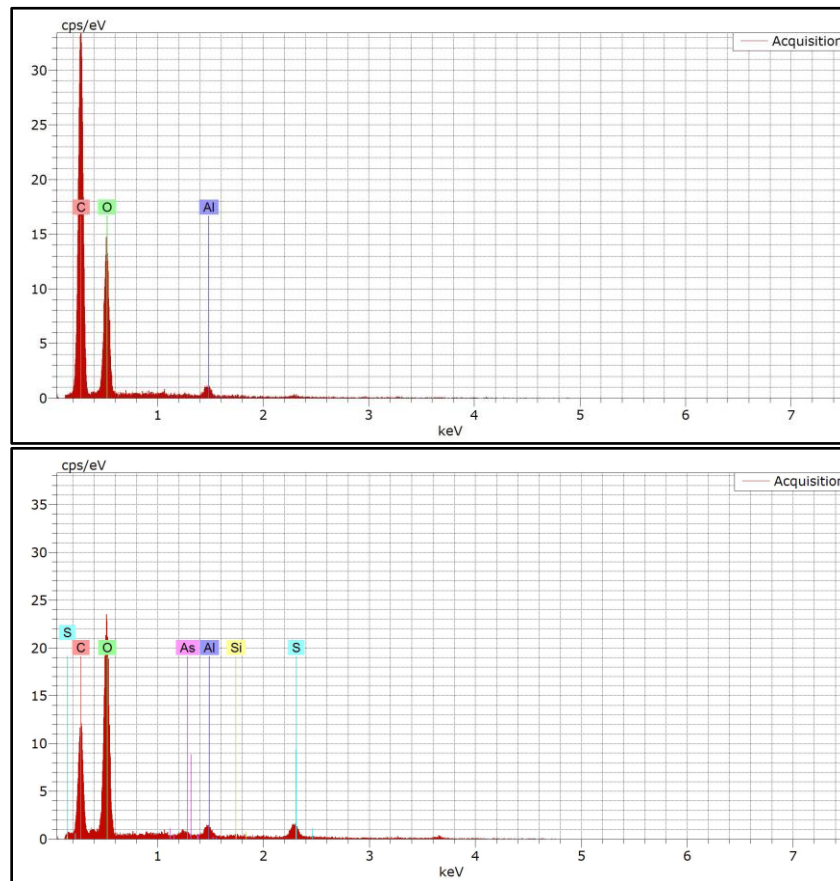
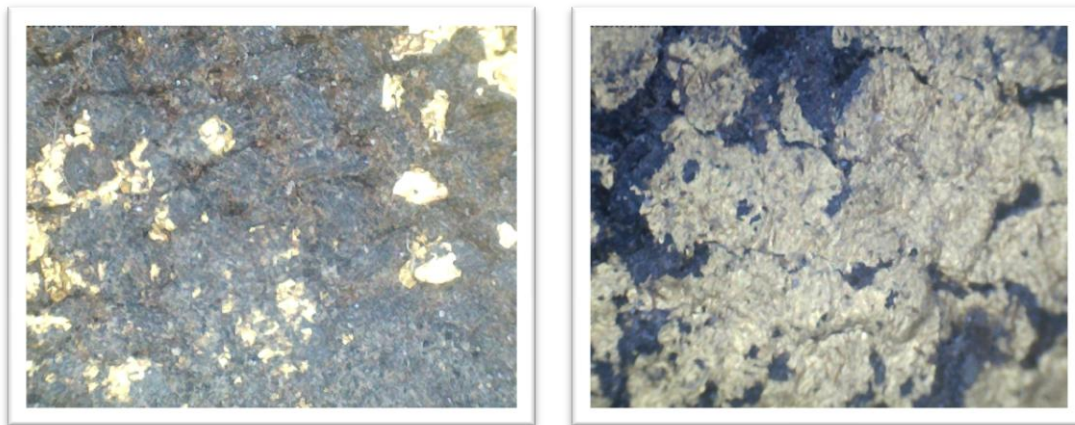


Fig.13.samples of cartoonage layer examined by IR fluorescence

4.6. Investigation of cartoonage layer and surface morphology of textile by Stereo Microscope

The samples were taken from the cartoonage layer and surface showed that the preliminary observation of the cartoonage revealed that black paint layer had been directly applied on a white ground layer. The black paint was applied to decorate the cartoonage. The examination shows coarse morphology and inhomogeneous composition of the black color, it was made of Graphite (Coral) and it appears in light areas on the surface the ground layer. In almost every analysis of Egyptian pigments, black has proven to be carbon. Also the textile surface is suffered from many aspects of deterioration factors.



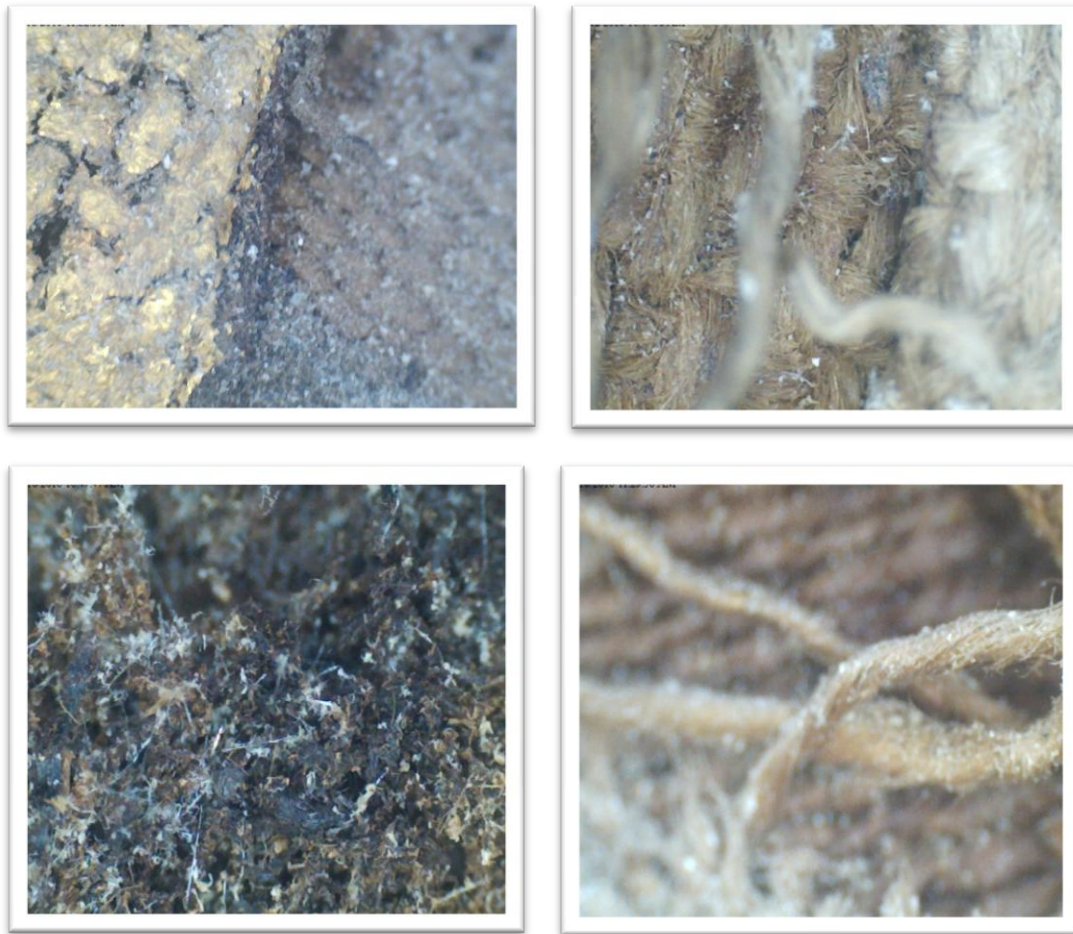


Fig.14. Stereo Microscope images that show examining the surface morphology of the painted layers of cartonnage and the surface morphology of the textile in addition to the appearance of deterioration spots, Image size:1000 x1000Mag:128.686327077748xHV:5.0kV

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