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PHYSIOCHEMICAL DIAGNOSTIC STUDY OF THE CONSERVATION STATE OF MOHAMED ALI PASHA PAINTED PORTRAIT (NATIONAL MILITARY MUSEUM, CAIRO)

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ABSTRACT

This research is the outcome of an integrated diagnostic study that has been performed to assess the conservation state of the oil painted portrait of Mohamed Ali Pasha at the National Military Museum, Citadel of Saladin (Cairo) in preparation for conservation interventions. Documentation methods, micro-stratigraphic examination and chemical studies were conducted to characterize the painting materials, technique and the physiochemical changes that occurred on. The painting was imaged by Multi-spectral imaging (MSI) and samples were collected from representative areas. Cross-sections from the previous conservation interventions added to the original painting structure, varnish, pigments, medium, ground layer, canvas support and wooden stretcher were studied by the means of stereomicroscopy (SM), scanning electron microscope coupled with dispersive energy of X-ray spectrometer (SEM-EDS), Attenuated total reflection-Fourier transform infrared spectroscopy (ATR- FTIR), Gas chromatography-mass spectroscopy (GC-MS), and X-ray diffraction (XRD). The studies resulted in the characterization of the deterioration phenomena that occurred to the original painting materials of linen canvas support, the ground layer of barite, calcite, hydrocerussite, zinc oxide and the followed oil painted layer. Discoloured dammar varnish and non-systematic previous conservation intervention affected the appearance of the painted layer of burnt sienna, green earth, red ochre, and ultramarine with the mixtures of lead-based pigments. It was concluded that the painting was incompatibly conserved more than once with destructive consequences to the painting aligned with chemical changes occurring to the paint medium and the varnish.

KEYWORDS: Multispectral imaging; Conservation state; Cross-sections; SEM-EDS; XRD; ATR- FTIR; Physiochemical changes

1. INTRODUCTION

Mohamed Ali pasha portrait was dedicated to the National Military Museum at Saladin Citadel in Cairo by Hassan Shaarway Bey in December 1949. The painting was painted by Esperón who signed his name with the date of the painting of 1897 at the far left of the bottom of the painting. The painting depicts Mohamed Ali Pasha. He sits in the eastern sitting with the three-quarters position on the throne couch. It was mentioned that "Thomas Brigstocke" was the first one who painted Mohamed Ali Pasha with this position and was displayed at the royal academy in 1849_ the year of Mohamed Ali's death, and then the painters from the 19th and 20th centuries transferred this painting from him (fig 1-B) (Ameen, 2012). Little is known about the life and work of Esperón but his other paintings indicated some characteristics of the technical painting school he belongs to. It is worth mentioning that Esperón added a kind of vitality to his paintings by using rich details techniques with vivid painting materials. He was also used to express the third dimension by cascading the painting elements (Rees, 2021). Some preserved portraits at the Egyptian museums are attributed to Esperón. Abbas Helmy I portrait is preserved at El- Manial palace with a date of 1853. A portrait of Khedive Ismail is preserved at El-Manial palace and dated 1860. Prince Ibrahim El-hamy's portrait is preserved at the Jewellery museum in Alexandria and is dated 1876. From Esperóns' paintings dates, it can be assumed that he came to Egypt in the second half of the 19th century (Ameen, 2012). Mohamed Ali Pasha painted portrait is applied on canvas of 140 cm in width and 200 cm in height. The painting has a rectangular wooden frame of 189 cm in width and 248 cm in height. The frame is decorated with gilded ornaments in the form of opened flowers and surrounded by two branches of plants. In the middle of the lower side of the frame, there is a small plate of copper that inscribes the dedication information to the museum.

Figure 1. A) Mohamed Ali Pasha painting at the National military museum with elucidation to the painter signature, Year of painting with Indian numerals and a copper plate of the painting dedication & B) Mohamed Ali painting of Thomas Brigstocke at the Royal Academy

The preliminary investigation of Mohamed Ali pasha painting presents the existence of structural (Young, 2014) and aesthetic problems associated with the previously non-systematic conservation interventions (Alawneh et al., 2018; Beskhyroun et al., 2019) and the uncontrolled environmental conditions (Bacci et al., 2008; Kabbani, 1997). The painting has been incompatibly conserved several times; this mainly appears with the different fabric patch varieties in the back of the painting (fig 2A). Uneven application of retouching shows a significant aesthetic problem (Johnason, 2014), especially in the part of Mohamed Ali's right shoe. The painted layer also suffers from extensive damage that is ranging from dirt accumulation, varnish discolouration, retouches, wrinkling, cracking, mechanical pressure from the heavily fixed verse patches, flaking to missing, cutting off parts, and paints liquefaction from the recently painted museum walls on the reverse side of the frame. This work aims to evaluate the conservation state of Mohamed Ali's painting at the National Military Museum at Citadel of Saladin (Cairo) in preparation for conducting scientific conservation interventions. The research included the documentary, stratigraphic and chemical studies with the aim of tracking the causes of the mechanical and chemical changes that occurred to the painted layer of the painting.

Figure 2. A) The verse of the painting with differently fixed fabric patch varieties, B) the mechanical pressure of the verse patch on the painted layer, C) asymmetric retouches, D) cut off of the painting layers, E) wrinkles of paints, F) Paints liquefaction, dirt accumulation and G) heavily uneven retouches

2. MATERIALS AND METHODS

2.1 Sampling

The visual investigation showed that the new addition of the whole painting layers from the support to the painted layer at the lower right side aligned with the multiplicity of the fixed patches on each other on the verse of the painting. Two samples were collected from these areas and prepared as cross-sections. The cross-sections were embedded in a transparent epoxy resin (EpoFix _ Struers A/S). The surfaces of cross-sections were polished and ground by a rotating grinder using different grades of silicon carbide grinding papers. Further (6 samples) were collected from the representative areas (fig 3.) of the painting to characterize the painting materials; varnish, pigments (red, sky blue, green, brown, light green), binding media, ground layers, the painting support (canvas and wooden stretcher) and a reverse fixed patch.

Figure 3. Samples locations for technical analysis

2.2 Methods

2.2.1 Multi-Spectral Imaging

To investigate the conservation state of the painting and the distribution of paints, a multispectral imaging system (Pelagotti et al., 2008; El-Rifai et al, 2016; Abdellah et al., 2020) has been used which operates in the range between 380 - 1100 nm in the visible (VIS), near-ultraviolet (UVA) and near-infrared (NIR) using a modified Fuji Film S5 DSLR camera. The multispectral images were collected and processed in the following modes: Visible (VIS), and Infrared CCD. Reflected (IRR), Infrared False Colours (IRFC), Infrared Transmission (IRT), and Ultraviolet Fluorescence (UVF). The system employs a Schneider IR/UV Block filter, B+W IR filter 093 (1% transmission at 800nm to 88% at 900nm) and B+W UVA filter 403 (320 - 385nm) in addition to 18W UV Fluorescent Black Light, IR and VIS LED lights.

2.2.2 Microscopy

Microscopic examinations of samples taken from the painting were performed using Carl Zeiss c-2000 stereomicroscope (Germany) and Zeiss sigma scanning electron microscope coupled with dispersive x-ray spectrophotometer (SEM-EDS) to achieve elemental analysis with in-class geometry of Zeiss sigma 500. Zeiss Gemini in-lens detects secondary (SE) and backscattering (BSE) modes with EHT 3.00 kV and vacuum pressure of 1.01e-09 mbar. SEM-EDS was performed at the Faculty of Science, Fayoum University.

2.2.3 Attenuated Total Reflection-Fourier Transform Infrared Spectroscopy (ATR- FTIR)

For characterization of the varnish, the binding medium, and the organic material used as an adhesive of the ground layer, FTIR spectra were collected from FTIR- VERTEX 80/80 V Bruker. Non-destructive analyses were carried out with a platinum single reflection diamond ATR module with a resolution of 4 cm^{-1} in the range of 4000-400 cm^{-1}. The analyses were conducted at the National Centre For Researches, Dokky, Giza.

2.2.4 Gas Chromatography-Mass Spectroscopy (GC/MS)

To specify and confirm the type of used paint medium, GC/MS was carried out by using a Perkin Elmer Auto System XL equipped with a Flame ionization detector(FID) was used under the following conditions: Fused silica capillary column ZB-5 (60 m x 0.32 mm i.d), the Oven temperature was maintained initially at 150◦C and programmed from 150 to 240◦ C at rate 3◦C/min, then mentioned at 240◦C for 15 min, injector temp230◦c, detector temp 250◦c, Carrier gas; Helium, Flow rate 1ml/min, sample size 2µl, split 1:10. The sample was analysed in the oils and fats department, National Centre for researches, Cairo, and prepared in two main steps; extraction of the fatty material in the sample by using a mixture of chloroform and methanol 2:1 in Suksit equipment for 16 hours and evaporating the solvent by the Rotary evaporator then the sample will be ready for preparation the methyl esters of the fatty acids in the sample by adding Benzene, Methanol and concentrated sulphuric acid 10:84:4 % in the order to conduct the Methylation process in temperature from 80 to 90 ^{o} c for an hour to finally put the prepared methyl ester in the Gas chromatography equipment in very high temperature to transform the methyl ester to gas in the separation column to separate the fatty acids with low molecular weights firstly and the fatty acids with high molecular weights (Abdelatif, 2008). The analyses were performed at the oils and fats department of the National Centre For Researches, Dokky, Giza.

2.2.5 X-Ray Diffraction analysis (XRD)

X-ray diffraction analysis was carried out to characterize the chemical compositions of the inorganic pigments as olive green, red, dark brown, yellow, light green, and the ground layer of the paintings by using X'Pert PRO X pert PRO system with a monochromator, Cu radiation (λ= 1.542 A) at 50 kV, 40 mA and scanning speed 0.02 /sec were used. The reflection peaks between 2θ=2^{o} and 60^{o} corresponding spacing (d, A) and relative intensities (I /I^{o}) were obtained. The diffraction charts and relative intensities are obtained and compared with ICDD files. The analyses were conducted in the general authority for mineral resources, Cairo.

3. RESULTS AND DISCUSSION

3.1 Technical documentation

The conservation state of the painting was conducted with the assistance of a multispectral imaging system. The painting was examined under visible light, raking light, ultraviolet fluorescence, infrared reflectance, infrared transmission, and infrared false colour. Several deterioration phenomena have visually appeared on the oil painting of Mohamed Ali by visible light imaging. Some of these deteriorations are mainly due to the previously incompatible conservation interventions. The current painted appearance shows an aesthetic problem in some areas due to the uneven application of retouches. Also, re-drawing motifs at the lower decoration tape represent a difference from the original part (fig 4. F). The stress from the back fabric patches that appears near Mohamed Ali's face and wrinkles at the part of Mohamed Ali s' shoes (fig 2. B&E) are due to the heavy application of glue layers for patch fixation on the verse side. This is besides the other phenomena of brittleness, cracking, losing parts, varnish discolouration and dirt accumulation are also found in the painting (fig 4. E & F).

Ultraviolet fluorescence imaging yielded preliminary information about the protective varnish. The varnish layer showed yellowish blue fluorescence colour when illuminated by ultraviolet light. This could indicate the presence of natural resin. The varnish fluorescence did not appear in some areas due to the accumulation of dirt on the surface (Cosentino, 2015 a). It also showed the retouched areas from the previous conservation interventions with darker tonality than the original part. The ultraviolet image of the verse side of the painting represented the multiplicity of fabric patch varieties which refers to that the painting was conserved several times (fig 5. F).

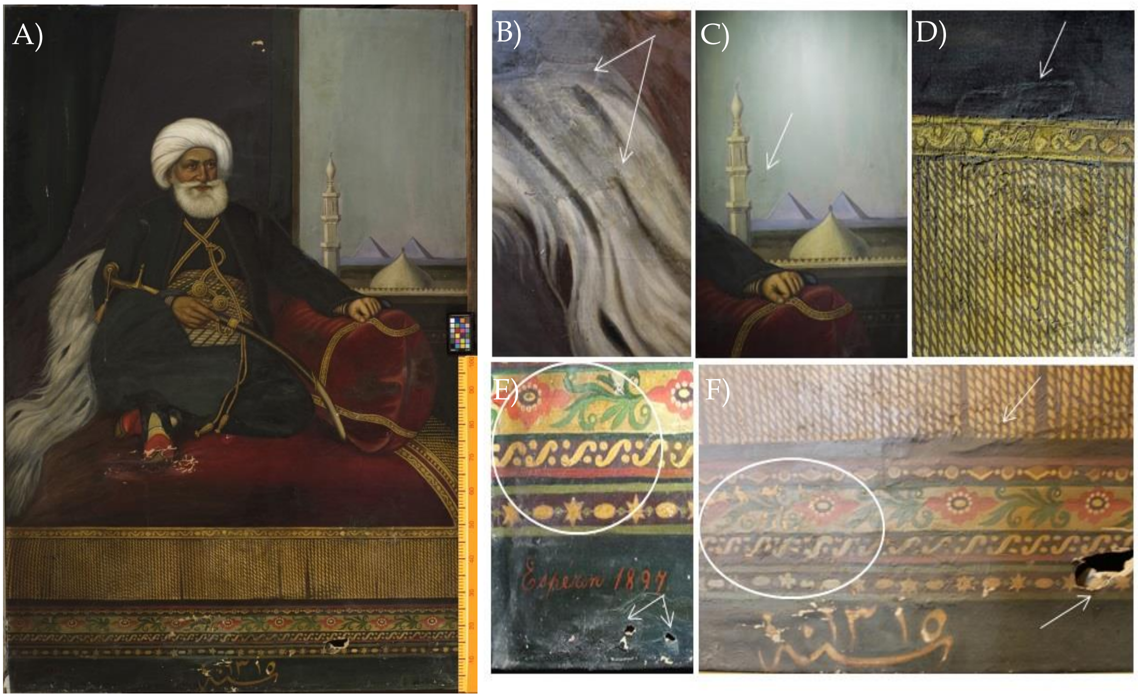

Figure 4. High-resolution visible-light image of the full painting A, illustration of the deterioration phenomena of the paint layer B, C, D irregularities of retouched areas, E discolouration of varnish, F dissimilarity of re-drawn motifs with original, losses, cracking and brittleness of the painted layer

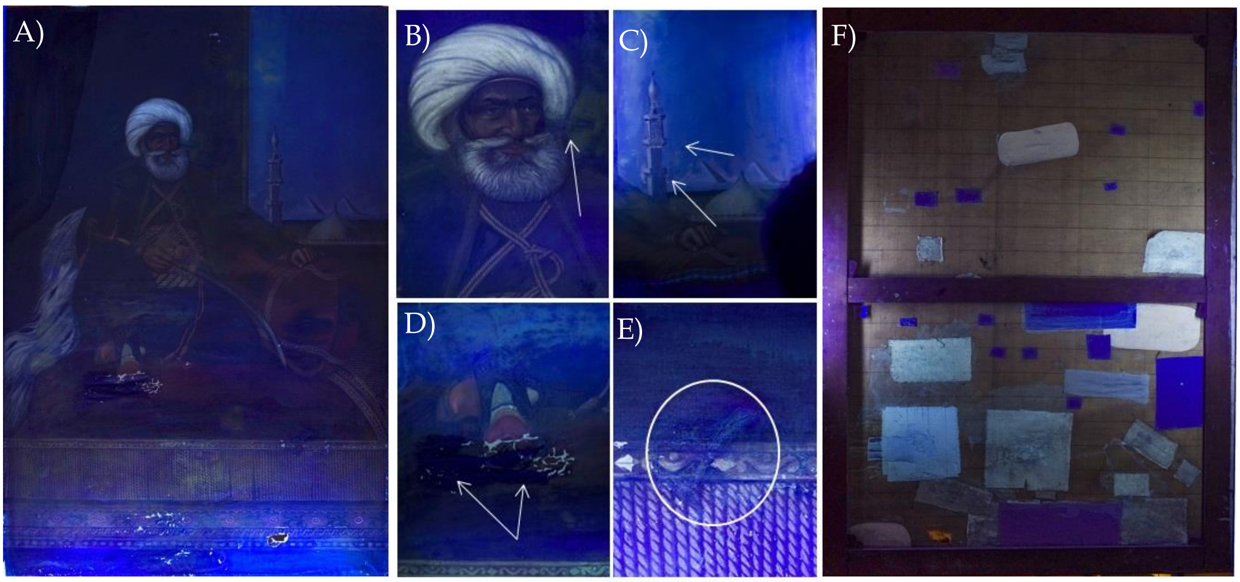

Figure 5. The ultraviolet fluorescence image of A) the full painting, B, C, D, and E illustration the fluorescence of the varnish and retouched areas & F shows the verso of the painting

Raking light images were performed on some parts of the painting due to its large size through which the surface irregularities of the painting became extremely observable. These irregularities were mainly due to the ingenuity of Esperón in drawing prominent motifs (Miriello et al, 2021), wrinkling, the pressure of the verse patches, and the incompatibly uneven application of retouches (fig 6. B &C). Infrared false colour imaging is sometimes used for initially determining some pigments (Elkhaial & El Hadidi, 2022). For Mohamed Ali's painting (fig 6. F), the reddish shadow at the sky blue background and pyramids suggested the existence of ultramarine and the yellowish shadow at the red couch, pillow, and Mohamed Ali s' shoes suggested the existence of red lead (Soltan, 2010). Infrared reflected imaging did not detect under-drawing. The darker retouched parts were markedly observable than the originally painted layer in the infrared reflected image.

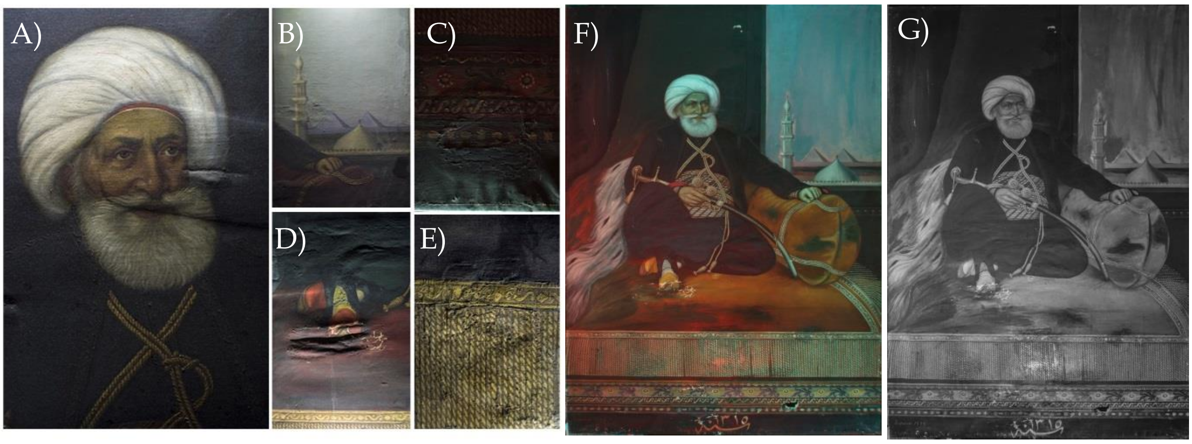

Figure 6. The raking light images of the painting through which A) shows the effect of the verse patch pressure on the front painted surface, B), C) uneven retouches, D) wrinkling, E) the prominent motifs, F) Infrared false-colour image & G) Infrared reflected image of the full painting

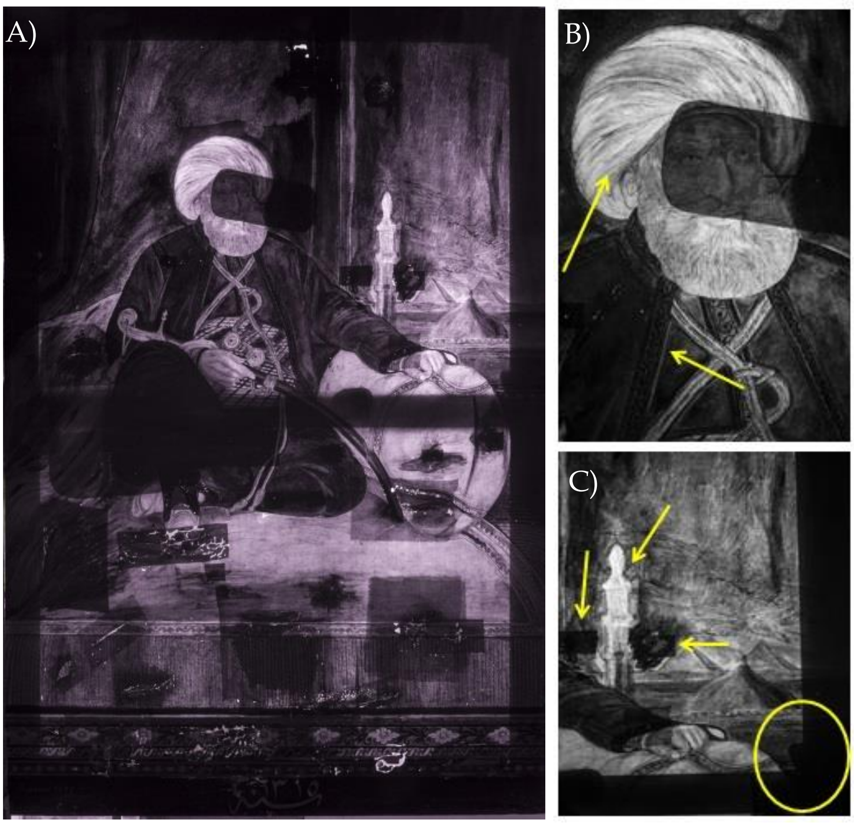

Figure 7. The infrared transmitted images of Mohamed Ali's painting: the full painting (A), the information from IRT image (B) presents the reflection of the white pigment on Mohamed Ali's turban & (C) the upper part of the minaret with clarification of stretcher members, wedges and the verso fabric patches

Infrared transmitted image is used to study paintings on translucent support such as canvas to provide a better reading of the under-drawing and underpainting. In this case, the lighting can be effectively shielded and no infrared light is diffused in the examination room then the camera faces the front of the painting to provide sharper drawing lines. It is also effective for highly reflective pigments such as lead white and Titanium white as their hiding powers are rarely affected by infrared light to be strongly reflected with no producing a contrast with the ground and the under-drawing (Cosentino., 2015 b). Infrared transmitted images of Mohamed Ali's painting markedly showed the verso fabric patches and the 5 members of the wooden stretcher with the joint wedges of the 19th century (Laaksovirta, 2020) appeared in the infrared transmitted image. It also presented the drawing lines as sharper than a pencil drawing with the details of motifs. The reflection of the white pigment from Mohamed Ali's turban and the upper part of the minaret (fig 7. B& C) suggested that the white pigment could be lead white as Titanium white was not provided as a pigment since this date of the painting (Mohie, 2002). The spectral images did not show retouching in this area.

3.2 Technical analysis

3.2.1 Cross-sections

3.2.1.1 Original stratigraphic structure with the verse sized patches

The first cross-section represents the original stratigraphic structure of the painting with two heavily fixed patches with thick layers of glue on the back of the canvas support (sample no.1). Stereomicroscope image mag x 3.2, backscattering and secondary electron images of SEM mag x 150 showed that the sample is composed of eight successive layers (fig 8.). The first layer from the bottom represents the canvas of the outer patch that is heavily fixed with a thick layer of glue (layer 2) that is followed by another fixed patch (layer 3) with another thick layer of glue (layer 4) to the original canvas support (layer 5). The original canvas support is followed by the ground layer (layer 6), brown paint (layer 7), and finally the varnish layer (layer 8). EDS analysis of the ground layer showed that the dominant elements are Ca, Ba, Zn, Pb and a negligible ratio of Ti that is could be from the adjacent ground layer added during the previous conservation intervention. The dominant elements of the brown paint are Al, Si, Ca, Fe, Ba, S, Zn, and K which suggest that the brown paint could be burnt sienna.

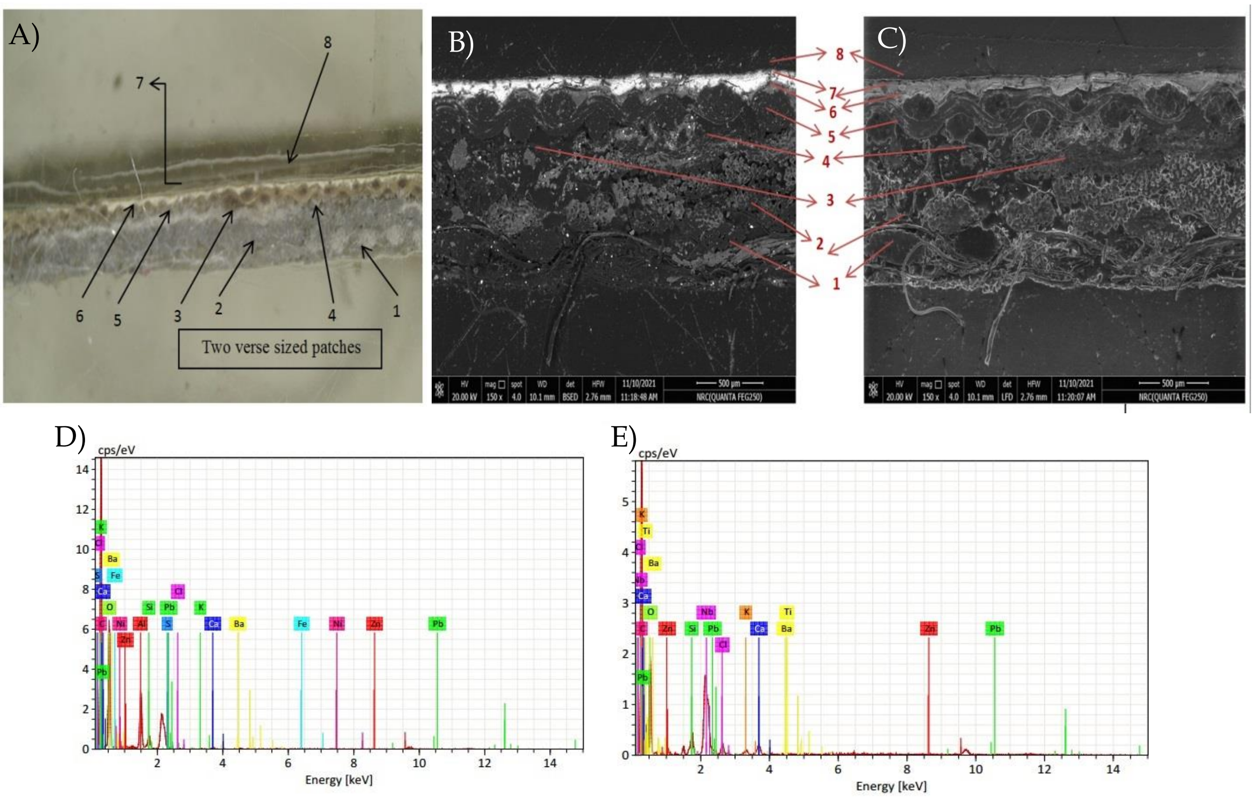

Figure 8. The original stratigraphic structure with the verse sized patches, A) stereomicroscope image mag x3.2, B), C) secondary electron and backscattering images mag x150, D) & E) EDS analyses of brown paint and ground layer respectively

3.2.1.2 New stratigraphic structure

The second cross-section represents a new stratigraphic structure that was added to the lower decorative ribbon during the previous conservation intervention (sample no.2). The microscopic investigation showed that the sample is formed by three successive layers. The first layer from the bottom represents the canvas support followed by the ground layer and the green painted layer with no observation of the addition of varnish coating (fig 9). EDS analysis of the ground layer confirmed that the dominant elements are Ti and Zn suggesting that the ground layer added during the previous conservation intervention was mainly composed of titanium dioxide and zinc oxide. EDS analysis of the olive green paint detected the elements of Mg, Al, Na, Fe, Si, K, Ca, Ba, Ti, and Zn with a negligible ratio of Pb. The detected elements of the green painted layer suggest that the green pigment could be green earth from the type of glauconite.

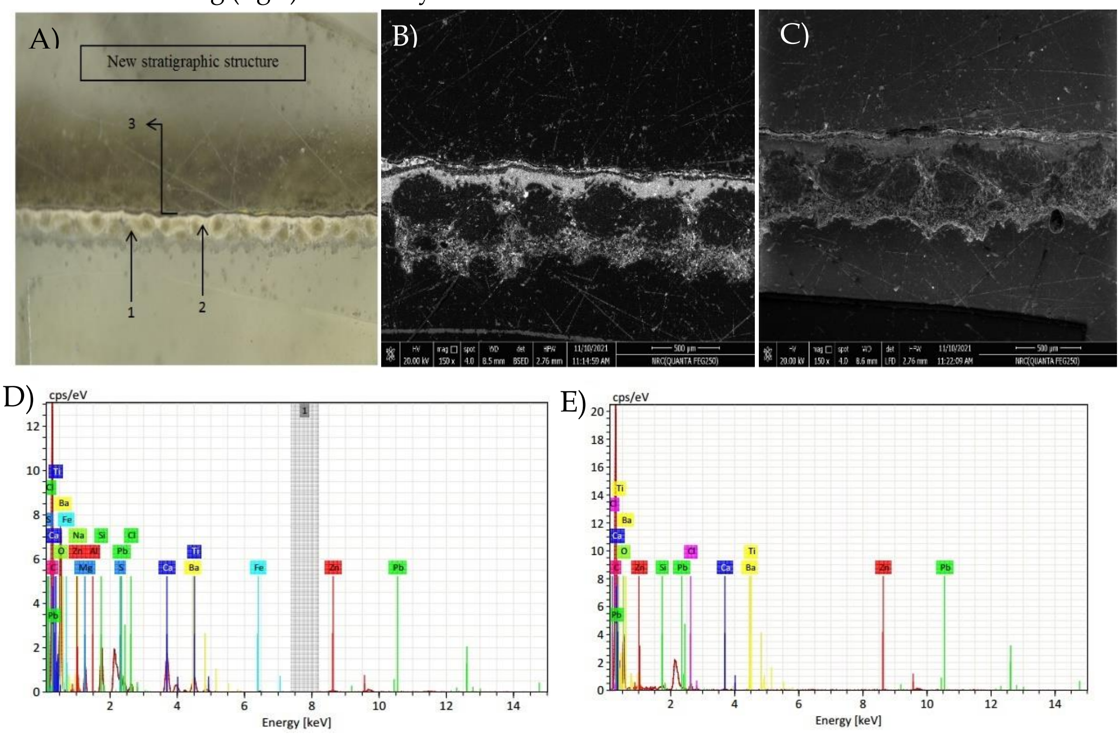

Figure 9. The new stratigraphic structure examinations a) stereomicroscope image mag x3, b) backscattering image mag x300, c) secondary electron image mag x 150, d) &e) EDS analyses of the olive green paint and ground layer respectively.

3.2.2 Varnish layer

The ATR- FTIR analysis of the varnish layer showed the disappearance of many characteristic bands via ageing processes over time as photo-, thermal, or/and bio-degradation. The auto-oxidative process through radical chain reactions is the main recognized degradation pathway (Popescu et al., 2012; Ciofini et al., 2015). FTIR spectra in the transmission revealed the presence of the C-H stretching band at 2918 cm^{-1} which is a characteristic of tri-terpenoid resins and not affected by ageing. The characteristic band of the varnish carbonyl group appears as a shoulder in 1716. 23 cm^{-1}, shifted to the slightly higher wavenumber, related to the formation of new intermolecular interactions as hydrogen bonds and new functional groups with growing a shoulder at the peak of 3270 and 3393 cm^{-1} related to new carboxylic acid groups (Ciofini et al., 2015). The band at 1657 cm^{-1} is assigned to stretching vibrations of C=C from *cis* –C=C– groups. The band at 1436 cm^{-1} includes the information on the C-H bending vibration of methyl and methylene groups and 1315 cm^{-1} is assigned to C-H bending vibration that gives the structural information on the hydrocarbon skeletons in the dammar resin (fig 10). The C-O stretching vibration is assigned at 1014 cm^{-1}. The band of 951 cm^{-1} indicated the deformation vibration of *trans* and *cis* C-H groups (Popescu et al., 2012).

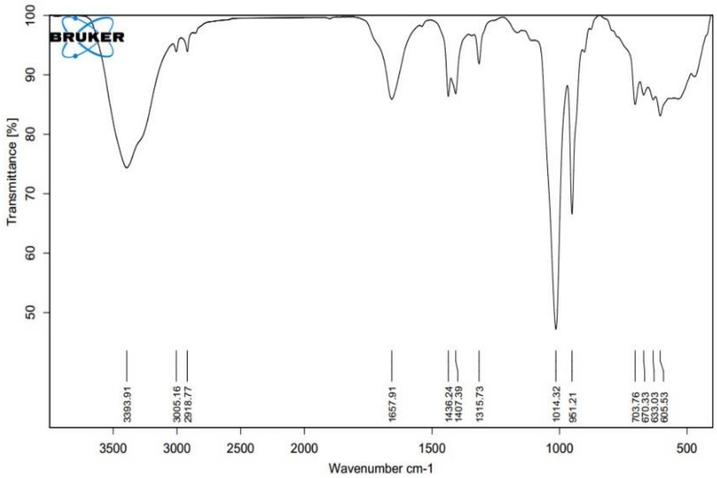

Figure 10. The peaks of ATR- FTIR spectrum of dammar varnish

3.2.3 **Binding** *medium & ground layer*

The inspection of FTIR spectra collected from the powdered black paint (sample no.3) in transmission mode demonstrated the presence of organic and inorganic materials. The spectrum reveals the presence of drying oil in which the peaks of ester were recorded at a broad stretching band centred around 1713 cm^{-1}. This band may result from hydrolysis of oil ester group to carboxylic ones. The hydrolysis of the oil ester group could come from the aqueous sizing from the patch fixed on the verse of the collected black paint. The band at 3398 cm^{-1} is assigned to both the O-H stretching band and the - N-H stretching band of animal glue from the ground layer. N-H peaks on the broader bonded O-H band. Asymmetric and symmetric C-H stretching bands of aliphatic groups of animal glue and fatty acids of oil are generally found at 2917 and 2849 cm^{-1}. The band of 1794 cm^{-1} is assigned to a very weak band of C=O of carbonate from the ground layer (Alawneh et al., 2018). The region of the carbonyl stretching band (amide I) of animal glue appeared at 1641 cm^{-1}. The combination of the C-N stretching band and N-H bending band (amide II) of animal glue is characterized at 1537 cm^{-1} (Al Khasawneh & Elserogy, 2019). The broadband at 1397 cm^{-1} is due to the combination of the C-H bending vibration of animal glue, oil, and CO_3^{-2} stretching band from the ground materials (Abdellah et al., 2020). The bands of 1174, 1114, and 984 cm-1 are respectively due to the C–O stretching of animal glue, oil, and asymmetric SO_4^{-2} stretching band of sulfate from the ground. The band of 1069 cm^{-1} is ascribed to carbon black. The O-C-O bending band of the carbonate group is found at 871 cm^{-1}. The band of 711 cm^{-1} is ascribed to the C-H bending band of the oil fatty acids (Afifi et al, 2020). The bands of 680, 634, and 607 cm^{-1} are respectively due to the SO_4^{-2} bending band from the white materials of the ground layer. To specify the variety of the drying oil, further analysis of gas chromatography-mass spectroscopy (GC/MS) was performed. GC/ MS is considered to be a fundamental tool for analysing the lipidic binders by comparing the fatty acid compositions that do not undergo modification during the ageing process. Palmitic and stearic acids ratio is one of the most widely used approaches for characterization the drying oils. The typical ratio of linseed oil is 1.9+/- 0.5 (Manzano et al, 2011). To this end, the GC/MS of the black paint Sample confirmed that the ratio between palmitic to stearic is 26.05/11.96 = 2.17 which is the typical ratio of linseed oil (fig 10. B). The ground layer of the painting has been collected from the taking margins (sample no.4). The Stereomicroscope image elucidates the direct application of the white materials on the sized canvas. The ground layer is suffering from microcracks that appear in secondary electron images. Inhomogeneity of the ground materials refers to the multiplicity of the used white materials. The mineralogical composition of the ground layer by XRD indicated the presence of barite $BaSO_4$ at the rate of 44.60%, calcite with the percentage of 30.68%, basic lead carbonate 'hydrocerussite' $PbCO_3.Pb(OH)_2$ in the percentage of 12.49% and zinc oxide ZnO in the rate of 12.21%.

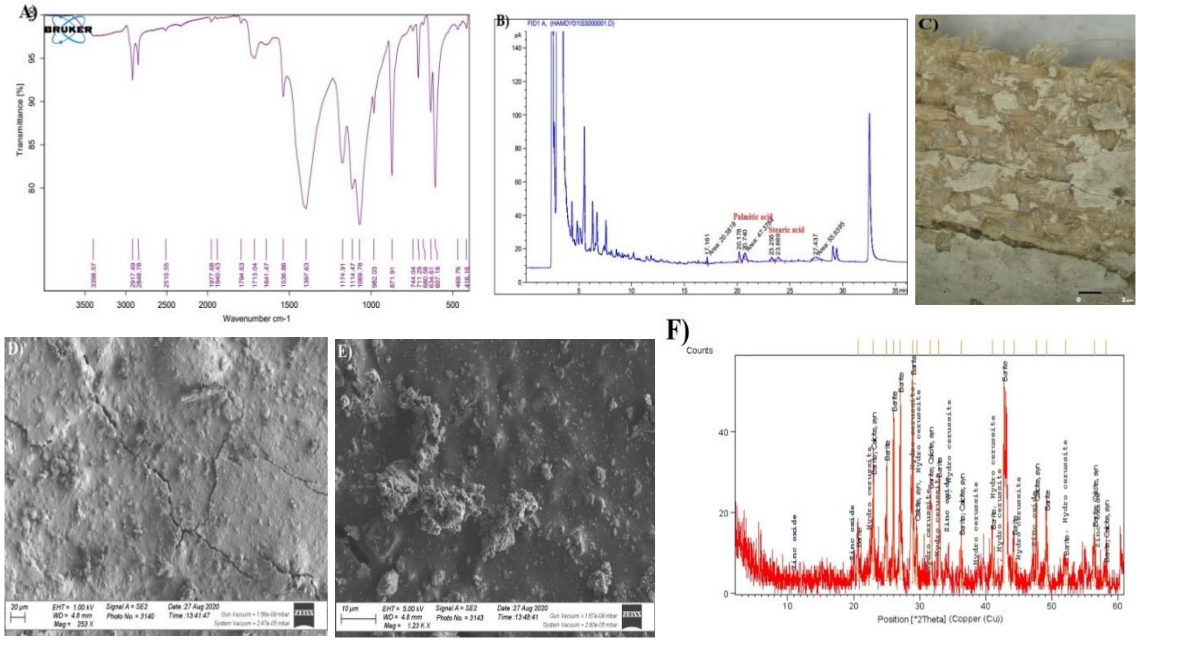

Figure 11. ATR- FTIR spectra of the powdered black paint A), GC-MS chromatogram of the binding medium B), C) stereomicroscope image mag x 3.2 of the ground layer on canvas support, D), E) secondary electron images of the ground layer, and F) XRD pattern of the ground layer.

3.2.4 Pigments

- ***Red***

The microscopic examination of red paint (sample no. 5) with a stereomicroscope showed the micro-cracks of the paint with the attempts of the previous conservation interventions to fix these cracks with the existence of dirt on the paint surface. Secondary electron images showed the effects of the consolidation materials on the surface of the paint that inhibited investigation of the appearance of the particles on the paint surface (Fig 12 A.B.C). EDS analysis of the red paint indicated the presence of the elements of Na, Mg, Si, Fe, Pb, Ca, Zn, and Al. The mineralogical analysis of XRD showed that red is mainly composed of lead red Pb_3O_4, hematite Fe_2O_3, and barite $BaSO_4$. The results of the red paint analysis indicated that it is a mixture of lead red and hematite. The presence of barite is ascribed to the ground layer.

- ***Sky Blue***

The microscopic examination of the surface of the sky blue paint (sample no.6) showed the accumulation of dirt on the discoloured varnish. Secondary electron images of the sky blue paint showed the ground materials appeared from the painted surface this is most probably due to the inadequate preparation of the paint. EDS analysis confirmed that the dominant elements are Na, Si, Al, Si, Mg, Fe, S, Pb, and a small percentage of Zn (fig 12. E). The elemental analysis of the sky blue paint suggests that the paint could be a mixture of ultramarine and lead white. The presence of Fe could be due to the contamination of the painter's palette by the adjacent brown paint.

- ***Green & light green***

The microscopic investigation of the green and light green sample (sample no.7) by the stereomicroscope image showed that the paint is cracked. The discolouration of varnish and the accumulation of dirt markedly appear on the painted surface (fig 12. F). The secondary electron images of SEM elucidated the cracks of the sample. Inhomogeneity of the light green particles suggested the paint mixture while the green paint showed consistency of the paint particles. EDS analysis of the green paint confirmed that the dominant elements are Mg, Al, K, Si, Fe, Na and a small percentage of Pb from the underlying layer. EDS analysis of the green paint suggests that green earth could be used. It should be mentioned that the element of Au that appeared in the elemental analysis is due to the coating of the sample with gold. EDS analysis of the light green indicated that the dominant elements are Mg, Al, K, Si, Fe, Na and a high percentage of Pb. The mineralogical composition of the light green paint referred to the presence of calcite $CaCO_3$, barite $BaSO_4$, basic lead carbonate $PbCO_3.Pb(OH)_2$ and green earth 'glauconite type' (Na, K)(Fe, Al, $Mg)_2(Si_4O_{10})(OH)_2$. The results collected from the light green paint confirmed that it is a mixture of basic lead carbonate and glauconite. The presence of calcite and barite are ascribed to the ground layer.

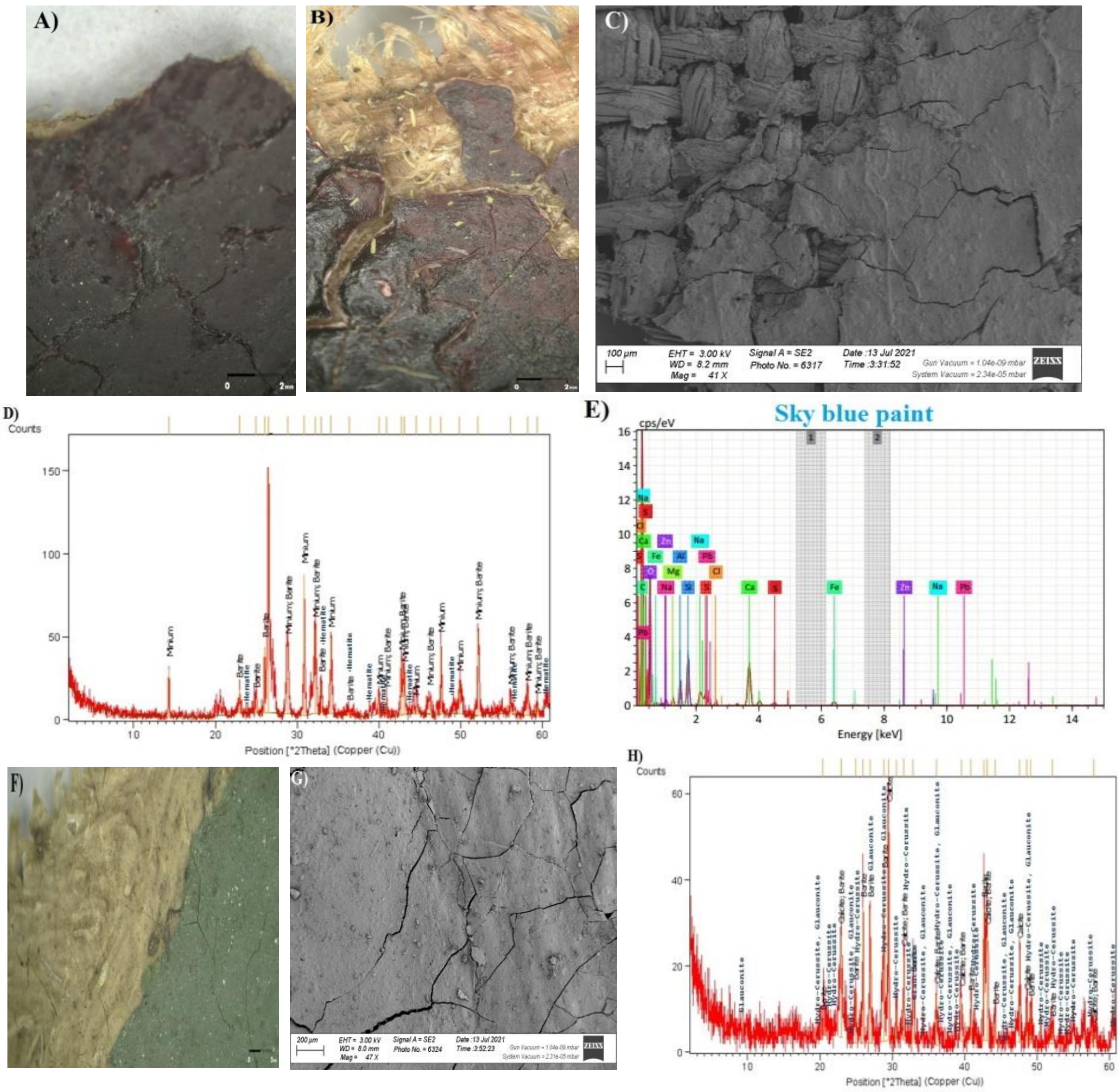

Figure 12. Microscopic examination of red paint A), B) stereomicroscope images mag x 3.2, C) Secondary electron image mag x 40, D) XRD pattern of red pigment, E) EDS analysis of sky blue paint, F) stereomicroscope image mag x3.2 of green and light green paint, G) Secondary electron image mag x 47 of green and light green paint & H) XRD pattern of light green pigment

3.2.5 Support

- ***Canvas, stretcher and fixed patches***

The original canvas support sample was taken from the taking margins (sample no.8). The microscopic examination of the original canvas support showed that it is made of natural fibres of linen. The fibres showed yellowing due to the natural degradation (Mahmoud et al, 2021). The SEM image of the canvas elucidated the linen fibres with traces from the ground layer. There are traces of glue and ground materials on the surface of the support (Fig 13. B& F). The glue was used during the previous conservation interventions to heavily fix the original canvas support to the wooden stretcher. To count the threads per cm, the sample was soaked in distilled warm water to dissolve the glue and separate the fibres from each other (Laaksovirta, 2020). The original canvas support has a thread count in the range of 33 to 35 per cm. The current stretcher represents the original stretcher of the painting. It is in good condition. The microscopic investigation suggested that it is made of coniferous trees. The pinewood is characterized by its pits from pinoid type in the cross-field (Mac-Gillavry, 2004). The fringes of the stretcher are suffering from the accumulation of the extra addition of the animal glue. Extra animal glue was applied during the conservation interventions to fix the canvas to the stretcher. Stereomicroscope images of the studied heavily fixed patches from the previous conservation interventions showed that it is from cotton fibres with a heavy application of glue (fig13.E).

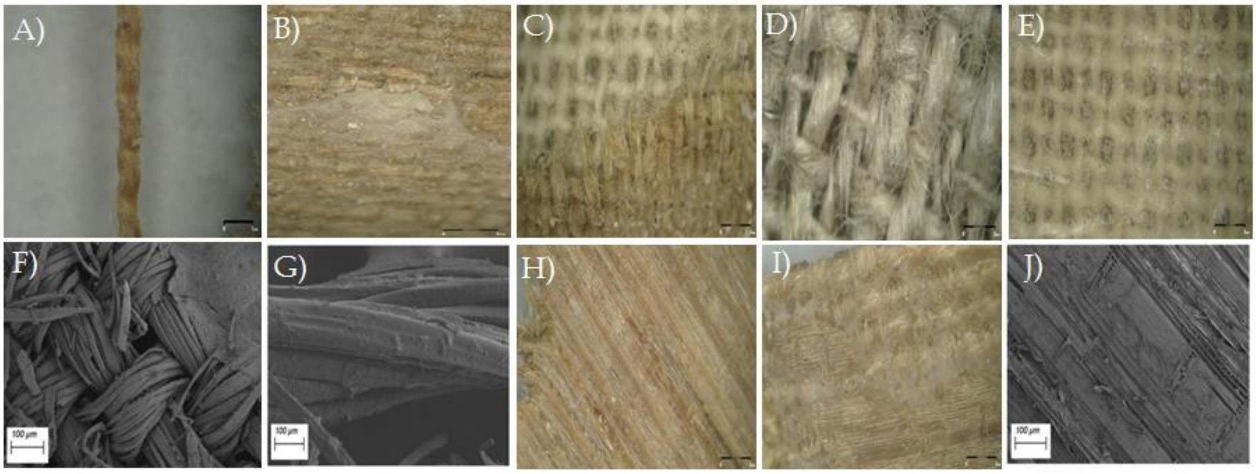

Figure 13. The microscopic examination of stereomicroscope images mag x3.2 of A) the original fibre linen, B) the original canvas support with a heavy application of glue from the previous interventions, C) the patch fixed behind the original canvas, D) the cotton fibres of the fixed patch, E) the heavy application of glue on the fixed patch, F), G) secondary electron image of the original linen canvas, H) stereomicroscope image mag x3.2 of the wooden stretcher, I) the heavy application of the glue on the wooden stretcher and J) secondary electron image clarifies the type of the pinewood mag x65.

4. CONCLUSION

The technical documentation and the technical analysis of Mohamed Ali pasha painting showed that the painting was incompatibly conserved several times with evidently chemical change effect on the oil medium and the protective varnish aligned with physical change that finally caused cracking of the painted layer. The micro-stratigraphic structure of Mohamed Ali Pasha portrait is composed of four successive layers; canvas support, ground layer, painted layer and final protective varnish. The previously non-systematic conservation interventions showed the additions of two heavily fixed patches with thick layers of glue to the original painting structure. The new stratigraphic structure that was added during the previous interventions showed the difference in the chemical components of the ground layer confirming that the interventions were not based on a scientific approach. The dammar varnish and oil medium of linseed oil showed hydrolysis as a result of the aqueous sizing from the patch fixed on the verse of the painting. The chemical compositions of the ground layer indicated the presence of inorganic and organic materials; barite, calcite, hydrocerussite and zinc that were bonded with animal glue. Burnt sienna, green earth, a mixture of red lead and hematite, ultramarine and green earth mixed with lead white were characterized as brown, green, red, sky blue and light green paints respectively. The varieties of the heavily applied patches with thick layers of glue caused heavily mechanical pressure on the painted layer with the existing cracks and micro-cracks on the painted layer aligned with the existence of heavily wrinkling at the part of Mohamed Ali's shoes. Uneven and asymmetric application of retouches distorted some areas of the painted layer. The accumulation of dirt and discolouration of the varnish via ageing played a role in the aesthetic value of the painting. The painting requires urgent conservation to eliminate further deterioration of the painted layer with restoring its aesthetic value.

AUTHORS CONTRIBUTION

Conceptualization, S.B.; methodology, S.B. and I.R.; software, S.B. and I.R.; validation, S.B. and A.S.; formal analysis, S.D. and S.B.; investigation S.D. and S.B.; resources, S.B. and S.D.; data curation, G.M., A.S. and S.D.; writing—original draft preparation, S.B.; writing—review and editing, G.M. and A.S.; visualization, S.B. and A.S.; supervision, G.M., A.S. and S.D.; project administration, , G.M., A.S. and S.D.; funding acquisition, S.B. All authors have read and agreed to the published version of the manuscript.

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REFERENCES

Abdelatif, Y.E. (2008). *Scientific research of treatment of the different factors of deterioration effects on oil painting components applied on chosen samples*, Master thesis, Conservation Department, Faculty of Archaeology, Cairo University.

Alawneh, F., Elserogy, A., and Al Dawood, R.S. (2018) The Conservation of the Byzantine icon from Georgios church, Jordan, Annales d'Universite 'Valahia' Targoviste, Section d'Archeologie et d'Histoire, Vol. Tome XX, pp. 53-69.

Alawneh, F., Elserogy, A., and Almasri, E. (2018) Using interdiscplinary studies and analyses in the conservation of Greco-Roman cartooage, Conservation Science in Cultural Heritage, Vol. 18, 219-238, DOI ;10.6092/issn.1973-9494/v18-n1-2018.

Abdellah, M., Abdrabou, A., and Kamal, H.M. (2020) Multi scientific analytical approach of Greco-Roman palette applied on a wooden model Naos; Case study, *Mediterranean Archaeology and Archaeometry*, Vol. 20 (2), 45-65, DOI: 10.5281/zenodo.3746942.

Afifi, H.A.M., Etman, M.A., Abdrabbo, H.A.M., and Kamal, H.M. (2020) Typological study and non-destructive analytical approaches used for dating a polychrome gilded wooden statuette at the Grand Egyptian Museum, *Scientific Culture*, Vol. 6 (3), pp. 69-83, DOI: 10.5281/zenodo.4007568.

Al khasawneh, S. and Elserogy, A. (2019) conservation and restoration of church icon from baptism museum, Jordan: case study, *Mediterranean Archaeology and Archaeometry*, Vol. 19(1), pp. 85-91, DOI: 10.5281/zenodo.2585977.

Ameen, N.Z. (2012) *Portraits in Egypt in the nineteenth century; Artistic and archaeological study*, Master thesis, Helwan University, Faculty of Arts, Department of Archaeology and Civilization.

Bacci, M., Cucci, C., Mencaglia, A.A., and Mignani, A.G. (2008) Innovative sensors for environmental monitoring in museums, *Sensors*, Vol. 8, pp. 1984-2005.

Beskyroun, S., Mahgoub, G., El- Rifai, I., Mahgoub, H., Osticioli, I., Nevin, A., and El-naggar, A. (2019) Study of the painted dome of the church of Archangel Gabriel, Cairo., *Egyptian Journal of Archaeological and Restoration Studies*, Vol. 9(2), pp. 129-140.

Ciofini, D., Striova, J., Camaiti, M., and Siano, S. (2015) Photo-oxidative kinetics of solvent and oil based terpenoid - varnishes, *Polymer degradation and stability*, pp. 1-28, DOI: 10.1016/j.polymdegradstab.2015.11.002.

Cosentino, A. (2015a) Effect of different binders on technical photography and infrared reflectography of 54 historical pigments, *International Journal of Conservation Science,* Vol. 6(3), pp. 287-298.

Cosentino, A., (2015b) Infrared technical photography for art examination, *e-preservation science*, Vol. 13, 1-6.

Elkhial, M.M., El Hadidi, N.M.N. (2022) multi-instrumental investigation and analysis of a unique ancient Egyptian wooden obelisk (New Kingdom) at the Grand Egyptian Museum, *Scientific culture*, Vol. 8 (1), pp. 1-14, DOI: 10.5281/zenodo.5717160.

El-Rifai, I, H. Mahgoub, and Ide-Ektessabi, A. (2016). Multi-spectral Imaging System (IWN) for the Digitization and Investigation of Cultural Heritage, Digital Heritage Progress in Cultural Heritage: Documentation, Preservation, and Protection, *Proceedings of the 6th International Conference, EuroMed2016*, Nicosia, Cyprus, Springer International Publishing, LNCS 10058, pp. 232-240, DOI: 10.1007/978-3-319-48496-9_19.

Johnason, E. (2014) *A detailed conservation report of heavily retouched painting from the Otto Valstad collection*, Master thesis in painting conservation, Institute of Archaeology, Conservation and History, University of Oslo.

Kabbani, R.M., (1997) In the classroom conservation: a collaboration between art and science, *Chemical Educator*, Vol. 1(2), pp. 1-18

Laaksovirta, E. (2020) Materials study, Conservation and plan for restoration of a 17th-century oil painting on canvas "Judith and Her Maidservant" in the Helsinki Art Museum, Master thesis, Metropolia University of Applied Sciences.

MacGillavry, J.N.B. (2004) Wood of the west house, Akrotiri, Santorini (Greece), *Palaeohistoria*, Vol. 45, pp. 95-120.

Mahmoud H.M., Hassan, R.A.A., Soliman, M.M.A., Roshdy, N.Sh., Ahmed, M.A., and Abdelfattah, M. (2021) Saving the mummy's shell; an interdisciplinary approach for analysis and restoration of cartonnage mummy case from El-Lahun excavations, Middle Egypt, *Mediterranean Archaeology and Archaeometry* Vol. 21(1), pp. 185-203, DOI: 10.5281/zenodo.4394072.

Manzano, E., Rodriguez-Simon. L.R., Navas, N., Checa-Moreno,R., Romero_Gamez, M., and Capitan-Vallvey, L.F.(2011) Study of the GC-MS determination of the Palmitic-Stearic acid ratio for characterization of drying oil in painting; La Encarnacion by Alonso Cano as a case study, *Talanta,* Vol. 84, pp. 1148-1154.

Miriello, D., De Luca, R., Bloise, A., Niceforo, G., Martin-Ramos, J.D., Martellone, A., De Nigris, B., and Osanna, M., Chiari, G. (2021) Pigments mapping on two mural paintings of the "house of garden" in Pompeii (Campania, Italy), *Mediterranean Archaeology and Archaeometry* Vol. 21(1), pp. 257-271 DOI: 10.5281/zenodo.4574643.

Mohie, M.A. (2002) *The scientific approach to study technology, conservation and restoration of oil paintings*, Dar- El Hany for printing and publishing

Pelagotti, A., Del Mastio, A., Derosa, A., and Piva, A. (2008) Multispectral imaging of paintings, *IEEE signal processing magazine*, Vol. 25(4), pp. 27-36.

Popescu, C.M., Vasile, C., Simionescu, B.C. (2012) Spectral characterization of natural resins used in conservation, *Revue Roumaine de Chimie*, Vol. 57(4-5), 495-499.

Rees, P. (2021) G. Esperon (19^{th} century) Dancing figures in an interior, Bonhams available at https://www.bonhams.com/auctions/26827/lot/38/ accessed on 22^{nd} May 2022 at 1:01 A.M.

Soltan, M.A., (2010) *A report of the condition, technical examination and conservation treatment, including scientific and art historical research of 'Sir Henry Fletcher' 17^{th}-century oil on canvas of unknown artist and an investigation into materials and techniques for historical lining*, Master thesis, North Umbria University.

Young, Ch. (2014) The painted surface and interface. In: The conservation of panel painting and related objects, *Research agenda 2014-2020, The Getty Foundation*, Rijks Museum.