

DOI: 10.5281/zenodo.3956807

AN ANALYTICAL STUDY OF A MURAL WITH COLORFUL GEOMETRIC DECORATION, COPTIC MUSEUM, CAIRO, EGYPT: A CASE STUDY

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Received: 26/06/2020

Accepted: 31/07/2020

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ABSTRACT

In the present study, a comprehensive investigation has been undertaken into an Egyptian Coptic fresco with geometric decoration and the reasons for its damage. It dates back to the 6th century AD and was initially located in the Saint Apollo monastery south Egypt in Asyut, and currently it is found at the Coptic Museum, Cairo. The analytical instruments used for investigation were portable digital microscope, Fourier transforms infrared coupled with attenuated total reflectance FTIR-ATR, scanning electron microscopy with EDX, X-ray diffraction and Optical microscope.

The results indicated that the painting was executed in a true fresco technique, which prepared on mud brick support with ground consisting of gypsum with a small percentage of lime, hematite used as red color and carbon used as black color.

KEYWORDS: Geometric mural paintings, Saint Apollo, Portable digital microscope, SEM-EDX, FTIR, X-ray diffraction, Microbiology

1. INTRODUCTION

Mural is one of the oldest forms of art and this is what the prehistoric caves refer to, to embody drawings that the primitive man thought of its ability to protect him, express itself or simulate his daily activities to his religious or political beliefs with colours from natural mineral oxides of iron and magnesium, white clay and black from charcoal and burnt bones (Liritzis et al., 2019) and was the oldest example of painting found on the walls of the Tomb such as Al-Koum Al-ahmar tomb, which dates back to the late pre-history (Ali, 1995).

The mural supports were different depending on the nature of the region and the building materials available, the most common was clay bricks, it was used more than 6,000 years ago (Abd El-Hafez, 2018). The oldest building blocks returned to the pre-history era and continued until ancient Egyptian times and continued until the Coptic era, especially in the monasteries of Upper Egypt as a good heat insulator and a suitable building material (Sallam, 2016).

As for the mural techniques, the walls, after being dried, are painted on them either using the tempera method, in which the color medium is used (Ali, 1995), or in fresco method which is a method carried out on the layer of construction mostly is (lime) which is still soft without the use of a color mediator, in that case, a union of carbon dioxide with the layer of lime (hydroxide calcium) has been used in Egypt and in Europe because it is more stable and color-preserving (Salama, 2019).

Coptic murals appeared in the area of Karmoz and in the tombs of the Bajawat which dating back to the fourth century and was the beginning of Coptic art, but for the topics that appeared in this period, a new type appeared, namely the geometric decorative formations of circles, squares and triangles that filled large areas and is a new art model that appeared in the fourth century, a new style that is content with symbolism and expression in the simplest ways and this style fits the state of ascetic and austerity reached by the Christian. This has been in the Bajawat since the early 4th century (Abo El-Yamin, 2013), St. Jeremiah in Saqqara (Salama, 2019), in the Red Monastery of Sohag (Bolman, 2006), and also in St. Apollo monastery, Bawit, Asyut (Clédat, 1904). Most of the layers of the murals were damaged due to poor preservation and in order to the harsh weather conditions due to the high temperature (40:48.4°C) (Climate-charts.com 2020) in the summer and the low temperature to (5°C) in the winter, the wind erosion and day sun light, which dried the paintings so the salts polymerized so it's became bigger producing an interior compression causing the detachments of paint layers (Sallam 2016; Salama 2016).

The aim of this research is a case study of the mural, to identify the components of the mural, and the layers of preparation and colors, and to identify the mural technique and to identify the various aspects of damage and microbiological damage to access the information necessary for the conservation of the mural.



Figure 1. Location of Bawit (Google Maps 2020).



Figure 2. Part of ruins of Bawit (After IFAO 2020).



Figure 3. A photo shows St. Apollo his companion Abbot Phib (After Clédat 1904).

1.1. BAWIT

It is an archaeological site located 80 kilometers north of Asyut, near the village of Dashlout, 28 kilometers south of El Ashmunin in Egypt (Basem 2015) (Fig. 1). It covers an area of 40 hectares and houses a cemetery and the ruins of the Monastery of

St. Apollo (Fig. 2). The monastery that was built on this site was the work of a monk known as Apollo, who was living between 316 and 395 AD. Apollo, taken by the desire for monastic life, went, accompanied by his friend Abbot Phib to a monastery (whose name is not revealed to us). Both of them practiced their new life by competing in austerity. Abbot Phib

died very early (Phib, may be from Phebos Apollo?), and Apollo left the monastery to retire to the mountain of Ablug, after forty years of solitude in the desert, became abbot of more than five hundred monks at Hermopolis (Santiebeati 2020). There is at present evidence for six different monasteries named after St. Apollo in the following places: Aphrodito, Bala'izah, Bawit, Titkoo, Memphis and Jeme. The monastery at Bawit may date back to the fourth century (Clackson 1996) and reached its peak during the seventh century AD when there were up to five thousand monks and at the Arab conquest of Egypt the number decreased slowly until the tenth or eleventh centuries and apparently no monks remained to stop the desert sands covering most of the abandoned buildings (Clédat 1904).

Excavations in this monastery were carried out by the French during the first part of the twentieth century. In his memoirs, Clédat (1904) mentioned the commencement of excavation in the winter of 1901-1902 and continued until 1903-1904. This work revealed two churches called the northern church and the southern church and a group of other buildings and the monastery was enormous, where its length extended about three kilometers, having a lot of rooms and small churches, were protected with a fence, and when the southern church was liberated from the sand, on the threshold of the entrance was the view of the archangels Gabriel and Michael and the founding saints of the monastery (St. Apollo and his companion Abbot Phib) (Fig. 3) (Clédat, 1904).

It seems that the church was built during the sixth century on an earlier edifice from the fourth century and while the second structure presents all the characteristics of a basilica church, with a nave, two side aisles, a sanctuary with a niche, and the entrance on its south and north sides. At one time, there were decorations carved in stone and wood and painted friezes with geometrical, vegetable and

figurative motifs that ran along the interior and exterior walls of the building. The nearby north church seems to date from the eighth century, and like the southern church, appears to be a transformation of a previous building, and for some reason the archaeological work of the monastery was stopped around 1913 and since then little research has been done and even earlier work lacks written documents, photographs (Walters 2002). In 1976, a number of murals were discovered on the site during excavations, and no report detailing this discovery has been made.

Valuable objects of the monastery of St. Apollo is widely scattered; in Europe, there are objects in the Louvre in Paris and in the museum of Late Antique and Byzantine Art of Berlin. The Coptic Museum in Cairo possesses a large collection of stone and wooden sculptures, as well as, wall paintings from Bawit. The greater part of the collection is situated in the lower floor of the New Wing (Hall 3 and 4) (Gabra, 2002).

1.2. GEOMETRIC SYMBOLS AND THEIR IMPORTANCE IN COPTIC ART

The Coptic artist excelled in blending the geometric elements and executing them on the way of the simulation of mosaics and departed from those abstract geometric formations and filled large areas and the geometric decorations were an auxiliary element of the botanical and animal drawings, and were complex compositions, some of which tried to form a cross and others symbolized different Christian ideas and these decorative elements inspired by Pharaohs, Greek or Roman elements and used crossed and interlocking lines and defined shapes with strong clear lines and these decorations were circular, triangle or square and also used symbolic expression in the simplest way (Mahmoud 2017), (Fig. 4) (Maspero, 1943).

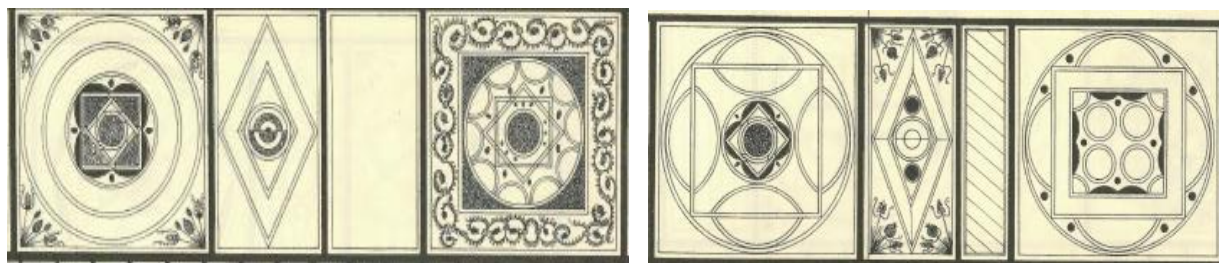


Figure 4. Some forms of geometric decoration in Coptic art after (Maspero 1943 P. XVIII)

These are used in either the interior or the exterior of the church building and can be interpreted to imbue certain meanings and symbolize different theological concepts. They are employed in ornamentation or architectural elements or even on the scale of

the spaces and sub-spaces of the church building in both the exterior and interior. This category of signs is a derivative from the category of meaning in architecture of crypto-numerological, as the projected meaning of the shape comes mostly from the num-

ber of its sides. Examples of employing certain geometric shapes or forms to give significance are as follows:

Triangle: was commonly used in tombs as a symbol of the Holy Trinity.

Cube: The altar is in almost a cubic shape, this connotes tomb of Jesus Christ, in addition to its acquaintance with the tombs of martyrs in reference to the verse from the Holy Bible: "I saw under the Altar, the souls of them that were slain for the word of God, and for the testimony which they held" (Rev. 6: 9).

Hexagon: according to the Coptic ritual, the baptized person experiences the death in the baptismal font when he is submerged in the baptismal water for three times, and then practices rebirth when he is out. Lord Jesus Christ was crucified on the sixth day and died on the Cross. According to the Holy Bible verses that read as: "Know ye not, that so many of us as were baptized into Jesus Christ were baptized into his death? Therefore we are buried with him by baptism into death: that like as Christ was raised up from the dead by the glory of the Father, even so we also should walk in newness of life." (Roman 6:3-4).

Octagon: some basins (Laqqan) or baptismal fonts have an octagonal plan, thus signifying regeneration and rebirth. So, it is a concept of co-resurrection with Lord Jesus Christ, who died and stayed in the grave for three days, and then, rose victoriously from the dead on the eighth day. Also, some domes covering the sanctuary area of some churches are supported on octagonal drums, perhaps this can be interpreted as eternity.

Circle: though the circle is a shape, but unlike the previous polygons, we may not assume that its symbolic meaning is a derivative of certain number, unless we assume that it has an infinite number of sides, thus is symbolized infinity in terms of numerology. Hence, in terms of Christian symbolism, it signifies "God" eternal and everlasting, as the circle has no beginning and no end. An example may be the circular upper window in the eastward wall over the main apse which is existing in some Coptic churches, signifying Jesus as "I am the light of the world" (John 8:12) (Guirguis, 2020).

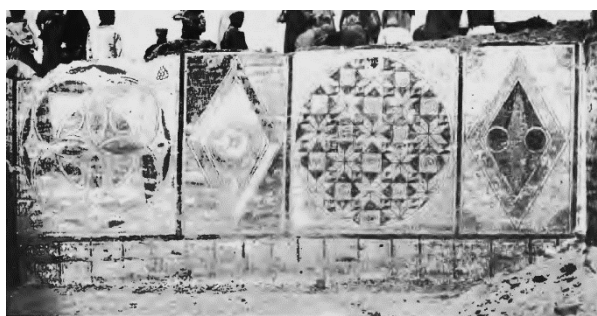


Figure 5. Room No 6. East wall geometric decorations right part of the niche, from the 2nd to the 6th panel (going from right to left) (after Maspero 1943 P. XVI).



Figure 6. Room 6. Left part of the niche, from 1st to 5th panel (after Maspero 1943 P. XVI).



Figure 7. The mural contains a circle occupying the entire square and within this circle the artist painted four overlapping circles and a central circle to be at the point of its capture the form of a cross and surrounded by those circles fair circles to be the general form of the cross, from the Monastery of St. Apollo at Bawit, displayed in the Coptic Museum in Cairo, No. 8437 - photo by the researcher MY.



Figure 8. A geometric mural that contains a large circle in square, in which there are a number of small circles and small squares, from the Monastery of St. Apollo at Bawit, displayed in the Coptic Museum in Cairo, No. 8438- photo by the researcher MY.



Figure 9. Interlaced squares with speckled green and pink backgrounds, conserved square showing uncleaned wall (left and right), and conserved cornice forming the bottom frame of a niche (above). Lower register, north lobe, sanctuary, Red Monastery Church, Sohag (after Bolman 2006 P. 16).



Figure 10. The geometric mural contains a circle in the middle of the square, and within it are 5 small circles that form a cross, the Monastery of St. Jeremiah at Saqqara, displayed in the National Museum of Egyptian Civilization, dating back to the fourth century AD (after Salama 2020).

The monastery of St. Apollo in Bawit is distinguished by the presence of some murals with geometric motifs that were decorating the lower part of the walls (Maspero 1943) (figure 5, 6). There are also some of the models of geometric murals from some of the archaeological monasteries dating from the 4th to the 6th century AD (Figs. 7, 8, 9, 10).

1.3. SYMBOLISM OF NUMBERS IN COPTIC ART

The Holy Bible mentions a lot of numbers, some can be understood in a literal sense and others have to be deciphered in a symbolic sense. According to the nature of the subject of interpreting symbols, there is no constant fixed interpretation as they are learned by convention, but these are the most commonly agreed upon meanings for numbers within this esoteric group.

One: symbolizes unity or oneness of God as per the verses in the scriptures, "I and my Father are one." (*John 10:30 & John 17:11*).

Two: Jesus sent his disciples in pairs. Sometimes the icons of the disciples are placed each two together "And he called unto him the twelve and began to send them forth by two and two; and gave them power over unclean spirits;" (*Mark 6:7*).

Three: usually refers to the Holy Trinity; The Father, the Son, and The Holy Spirit. "For there are three that bear record in heaven, the Father, the Word, and the Holy Ghost: and these three are one." (*1 John 5:7*).

Four: this symbolizes the four evangelists; Matthew, Mark, Luke, and John, who wrote the four gospels of the New Testament. Sometimes, it may signify the four cardinal directions, which means the

entire world. This means basically material or earthly completeness.

Five: it symbolizes the five Passions (wounds) of the Lord Jesus Christ; holes from the nails in each of the two wrists, the hole from the nail in His feet, the side which was pierced by the spear, and finally, the crown of thorns. We can see it in the five holes in the holy bread.

Six: most of the time signifies imperfection, as it falls shorter than the perfect number of seven.

Seven: appears in both the Old Testament and the New Testament. It is usually the number of perfection, according to the book of Genesis; God created the universe in six days and rested on the seventh day after He saw what He created is good. Saint Paul lists the gifts of the Spirit, which are seven in number. The book of life is sealed with seven seals. In the apocalypse, "the seven churches of Asia" were addressed (*Revelation 1:4*). Furthermore, we find it in many ecclesial subjects as the seven sacraments of the church, and the seven ranks of priesthood.

Eight: it is the number of regeneration or resurrection as Christ rose from the dead on the first day of the next week (i.e. Eighth day) (*Matthew 28:1*).

Nine: is an amplification of number three.

Ten: sometimes it signifies completeness. It is exemplified in the Ten Commandments to Moses, the ten plagues on Egypt.

Twelve: this number usually signifies the twelve disciples in the New Testament and the twelve tribes of Israel in the Old Testament. Sometimes its meaning it derived from the multiplication of three by four and combining their meanings, thus, this vibrant sets another meaning; sanction of the Holy

Trinity on the four corners of the universe; i.e. on the whole world (Guirguis 2020; Abdel Kader 2012).

2. MATERIALS AND METHODS

2.1. The examined mural

This mural is from the Coptic Museum and is from the ruins of the monastery of St. Apollo Bawit in Asyut. These rare murals must be preserved and tried to be displayed in a good way to commemorate the monastery of Apollo that has disappeared.

This mural is recorded in a registration number (8439), in the Coptic Museum, Cairo (Fig. 11), with dimensions of about 180 cm x 180 cm, about 4 cm thickness. It dates back to the 6th century and was discovered by Clédat in Bawit and the entire painting was moved and in the same hall there are other geometric murals -the most sophisticated of all those preserved in Egypt (Gabra, 2007) which were decorating the lower walls of the monastery and were transferred to the museum to preserve them from any damage.

The description of the mural, is a square, with a dark red background, a circle in its center with a perimeter decorated with inside 10 halves of circles colored in red and dark green, in the middle of which is an eight-cornered star and in the middle, small red circle and surrounded by black dots and decorated with green floral patterns on the four sides. Symbolism of painting in art and belief: The eight stars consist of two squares representing the four geographical aspects and the second represents the four evangelists; Matthew, Mark, Luke, and John, because the eight stars of the two squares symbolize the spread of the Gospels in the whole world and the circle in the middle represents an end, this represents that God has no beginning and no end and he used to run the universe from eternity to eternity (the only eternal God). The ten halves of circles: No. 10 represents the perfection of righteousness and happiness when the creature attaches to God and also indicates God's pleasure in the Ten Commandments, as the number ten represents the ten virgins and refers to humanity in its entirety (Guirguis 2020). The plant decorations were either in the form of bunches of grapes (grapevine) which are a symbol of the blood of Jesus Christ, or in the form of palm fronds as a symbol of the celebration of Jesus Christ as he entered Jerusalem as king, or perhaps it was for a decorative purpose to fill the void

on the main theme or to decorate the background to highlight the subject itself (Sharafeldean 2019).



Figure 11. The studied Coptic fresco geometric painting - photo by the researcher MY.

2.2. Sampling

The sample No.1 was taken from the original site of the monastery of St. Apollo at Bawit in Asyut to identify the type of the mural's support - case study. The necessary checks and analyzes were done to learn more information, including the digital microscope and the scanning electronic microscope equipped with the EDX unit and X-ray Diffraction. Sample No.2, during the mechanical cleaning process with a soft mattress, a small part of the mural was dropped, not more than a few millimeters, and was examined to identify the properties of the mural.

2.3. Analytical techniques

2.3.1. Visual examination

The visual examination is the first procedure that is done of the mural, as it is examined visually to see and determine its condition and what it is, as well as the amount of damage it has, whether cracks, gaps, sediments and air suspensions. It was found that there are cracks and gaps between large, small and accurate, as well as some air deposits of dust and soot and other previous conservations. The appearance of mural painting layers of a gap in the mural when has been examined by a portable electronic microscope (Fig. 12) which contains the support layer-mud brick- then preparation rough layer after that preparation fine layer, finally the paint layer.

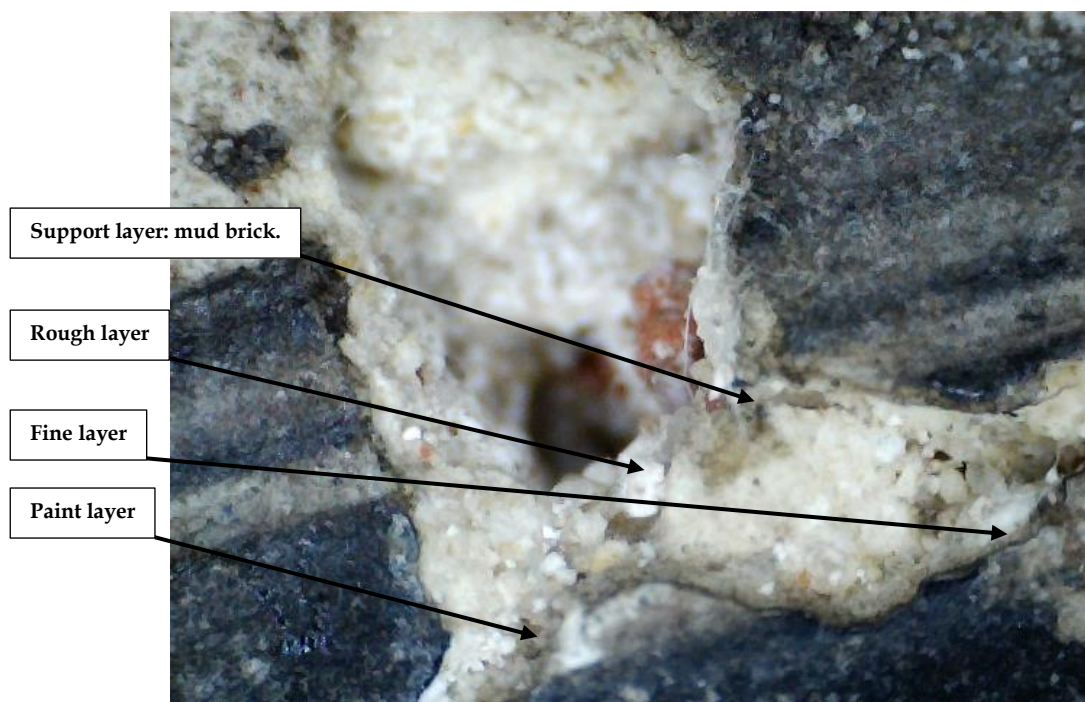


Figure 12. The mural painting structure layers, Loss of strength and granular disintegration due to chemical mineralogical physical changes.

2.3.2. Portable Digital Microscope (PDM)

This examination was applied directly on the mural in the museum without taking any samples. The Coptic mural was examined with a portable digital microscope (USB Digital Microscope, model: Olymous), with the following technical specification: image sensor 1.3 Mega pixels, magnification factor 10~1000 times, photo capture resolution 640×480,320×240 and LED illumination light resource adjustable by control wheel.

2.3.3. Fourier Transform Infrared (ATR-FTIR)

Sample fragments were analyzed by Fourier transform infrared spectroscopy - attenuated total reflectance (FT-IR-ATR), using (Nicolet 380) FT-IR spectrometer equipped with a detector using an ATR crystal, which represents added scans (at 2mm s⁻¹) in a spectral region ranging from 4000 to 500 cm⁻¹, with 4 cm⁻¹ resolution. The solid method was used in preparing the samples, as solid tablets were made from the samples and potassium bromide with concentration 0.002 %. The analysis was done at the Institute of Measurement and Calibration -El Haram - Giza.

2.3.4. Scanning Electron Microscope with EDX

The Sample was examined using SEM Model quanta 250 FEG (Field Emission Gun) - FEI Company, Netherlands, attached to the EDX Unit (Energy Dispersive X-ray Analyses), with accelerating voltage 30 K.V., magnification 14x up to 1,000,000 and

resolutions for Gun.1n, without coating of the samples with a highly conductive thin film of gold. The Scanning Electron Microscopy (SEM). EDX was done at the Egyptian Mineral Resources Authority, central laboratory sector, Giza, Egypt.

2.3.5. X-ray Diffraction

Type of X-ray diffraction analyzer used: Philips analytical x-ray b.v. Diffractometer-PW 1480-Netherland, operated at 35 KV, Electrode used: Tube anode: Cu., Wavelength: Wavelength alpha1 (a): 1.54056 -alpha2 (a): 2.54439, Generator current: 20 mA. We used X-ray laboratory - Department of conservation - Faculty of Archeology - Cairo University, The analysis software used (Match2 + PDF4 2015) to make intense estimates, measure angles, and make comparisons, Purpose of use: to identify crystalline inorganic compounds.

The measurements were made at room temperature. Preparation of the sample consisted of grinding the dry sample on one direction, by using a mortar and pestle to obtain a fine powder. The X-Ray Powder Diffraction (XRPD) analysis was done at XRD Unit in the faculty of archaeology, Cairo University.

3. RESULTS AND DISCUSSION

3.1. Portable Digital Microscope (PDM)

Sample (1): The morphology of the sample was studied and the manifestations of damage to the structure of the mural support. When the support is

built of several different materials such as mud bricks that were widely used in building Coptic monasteries and churches, it is more susceptible to damage and does not bear the harmful effects of various damage factors because it consists of a mixture.

It contains organic and inorganic components and is characterized by heterogeneity in its properties (Fig. 13), which exposes them to severe damage, cracks and losses that lead to damage to the mural applied to it (Abd El-Hafez 2018).

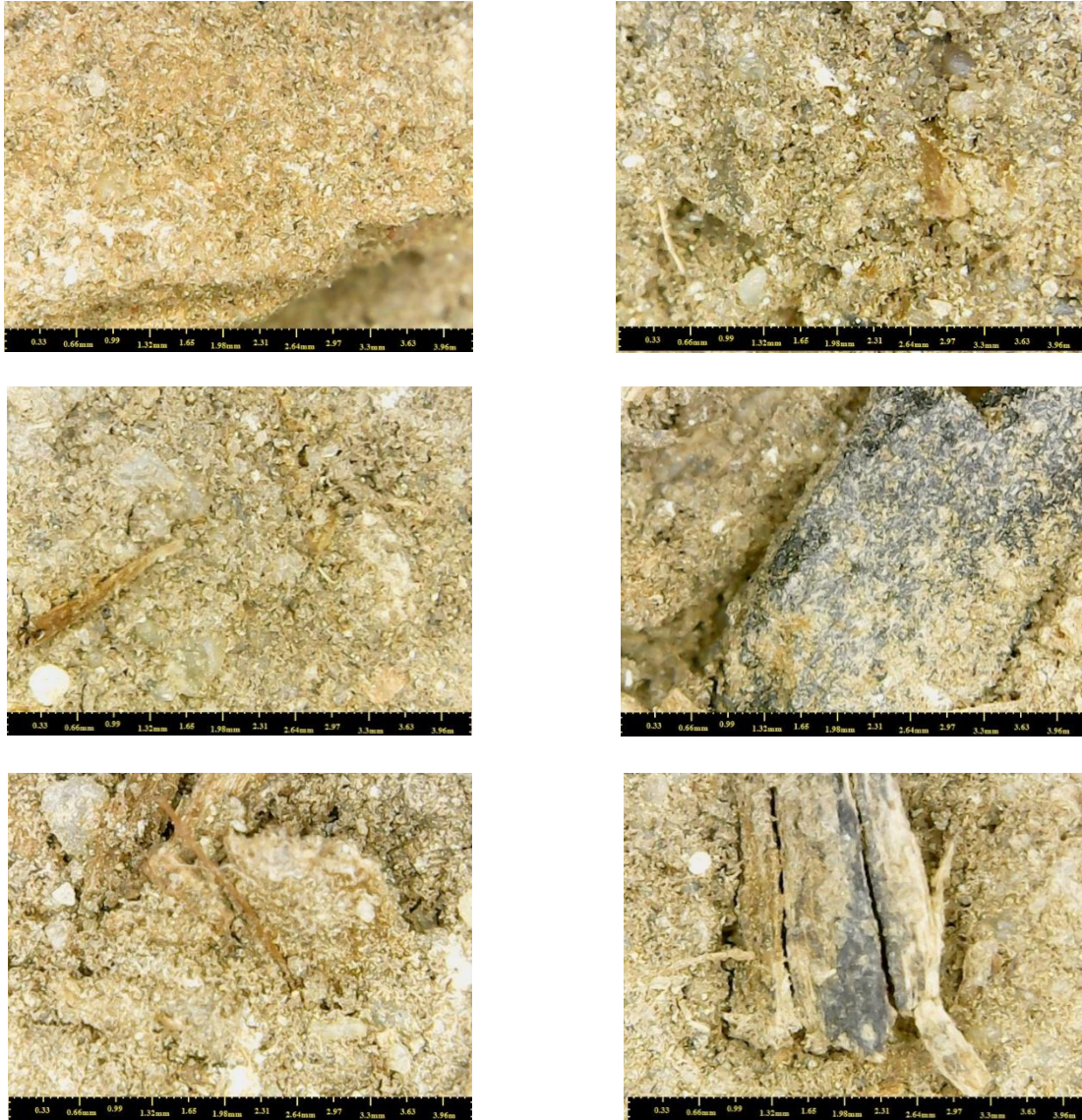


Figure 13 The mud brick is mixed with an organic and nonorganic materials to improve its properties, such as hay, strew and solid nonorganic material (magnification factor 1000 times).

Sample (2): After examining Coptic mural of Saint Apollo monastery investigation of the samples revealed that there are a lot of cracks, losses, previous

conservation processes, losses in the color layer, fading in the colors and small holes (Fig. 14 A-H).

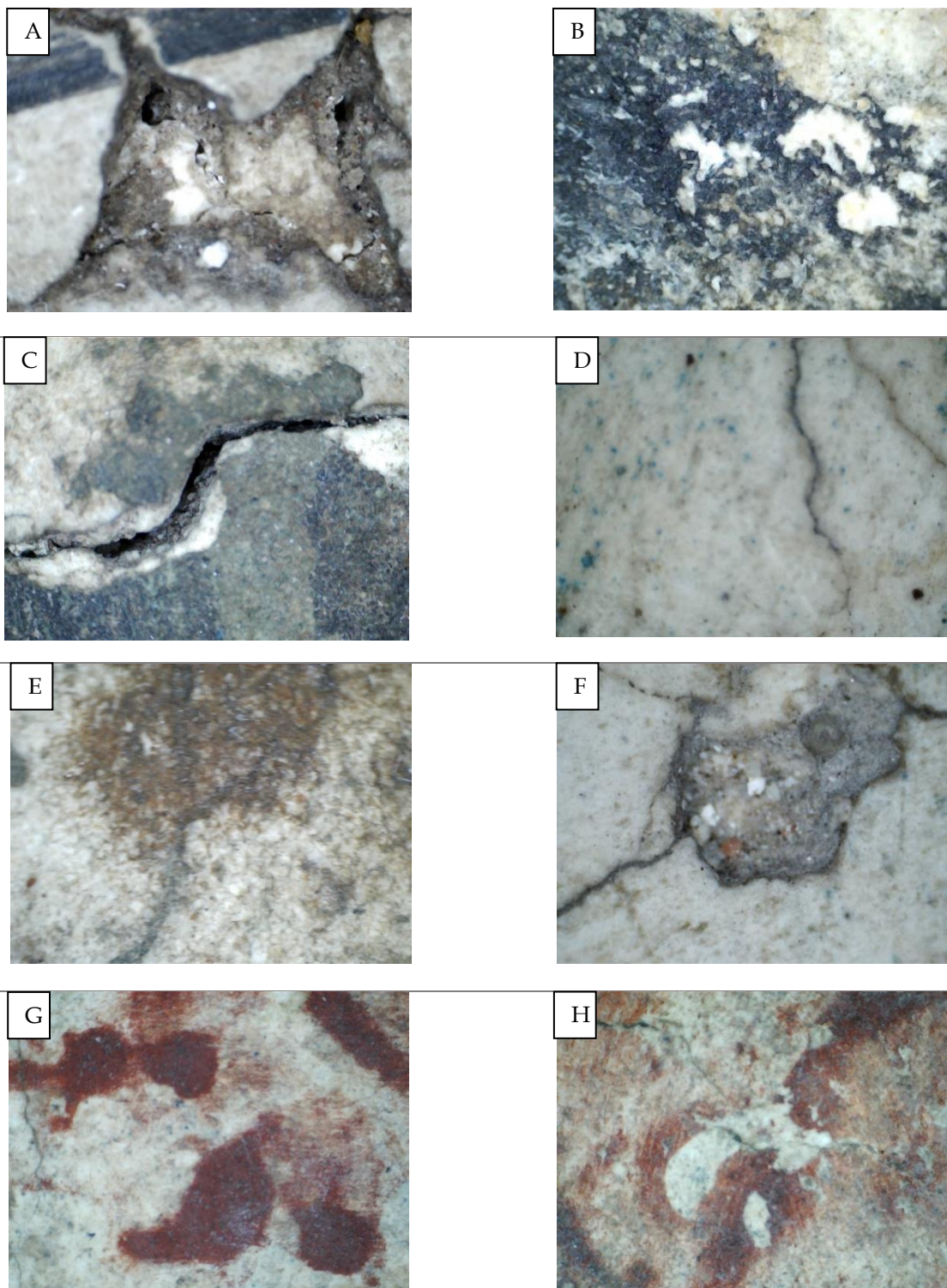


Figure 14. Aspects of damage of the mural: (A) Crack with loss, (B) Previous conservation, (C) Previous conservation plus crack, (D) Losses in the color layer, (E) Fading in color, (F) Small hole, (G), (H) Red color residue (Hematite).

3.2. X-ray diffraction

Samples (1) were brought from the walls of the Monastery of St. Apollo at Bawit, and an x-ray analysis was done on them to identify the components of the mural that is being studied. Mineralogical

compositions of brick were determined by X-ray diffraction (XRD) which indicated in (Fig. 15). (Table 1) shows that they were mainly consists of quartz (SiO_2), showed other minerals of plagioclase (Albite, $\text{NaAlSi}_3\text{O}_8$) showed other minerals of plagioclase

(Albite, $\text{NaAlSi}_3\text{O}_8$) Orthoclase (KAlSi_3O_8), Silicone oxide (SiO_2), Calcite (CaCO_3) in addition to halite (Sodium Chloride), iron oxide (Hematite Fe_2O_3) and clay minerals (Abd El-Tawab 2014; Abo El-Yamin 2013).

The description of the sample showed that Mud brick and the presence of clay minerals in the mural may lead to accelerated weathering and that these minerals play an important role in the processes of crystallization of clay that lead to the disintegration

of the surface and minor cracks, as clay minerals allow the absorption of water and this leads to pressure on the outer coating layer that allows cracks, and the presence of many metals leads to physical and mechanical properties are not homogeneous, along with climatic changes and this long-term difference between dry and wet conditions. Leads to more mechanical pressures that cause layer loss and peeling (Sallam, 2016).

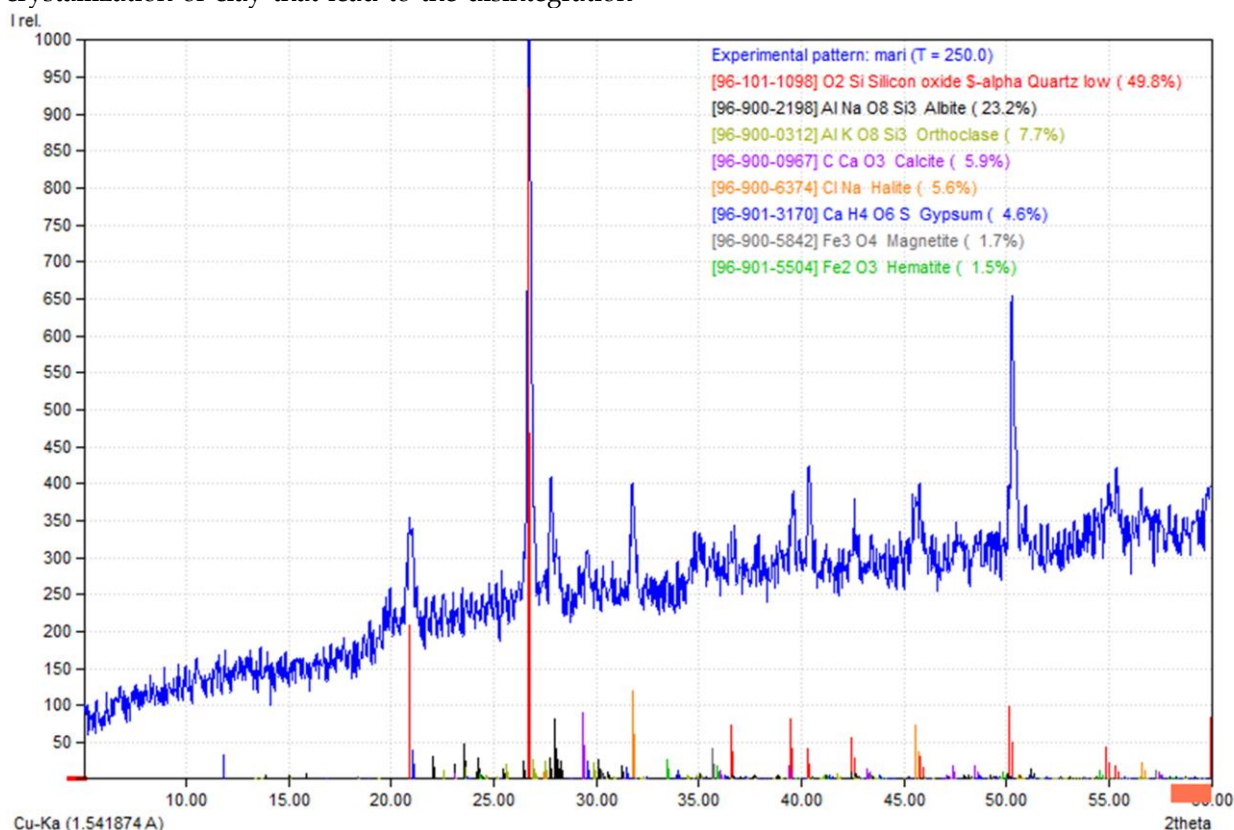


Figure 15. X-ray diffraction analysis spectrum.

Table 1 The X-ray diffraction analysis.

N.	Name	Chemical Structure	%
1	Quartz	SiO_2	49.8
2	Albite	$\text{Na Al Si}_3\text{O}_8$	23.2
3	Orthoclase	$\text{Al K Si}_3\text{O}_8$	7.7
4	Calcite	CaCO_3	5.9
5	Halite	NaCl	5.6
6	Gypsum	$\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	4.6
7	Magnetite	Fe_3O_4	1.7
8	Hematite	Fe_2O_3	1.5

3.3. Scanning Electron Microscope with EDX

Sample (1): The EDX microanalysis shows major amounts of silicon with minor amounts of calcium and aluminum. It explains that consists of Silica (Si), Aluminum (Al), which is the Aluminum Silicate, the main component of mud bricks, as well as Calcium

(Ca), Iron (Fe), which indicates the presence of remnants of red hematite on the site of the monastery, Magnesium (Mg), Potassium (K) and Titanium (Ti) which are considered as soil impurities. Also contains Halite, which is sodium chloride salt (NaCl). (Fig. 16), (Table 2).

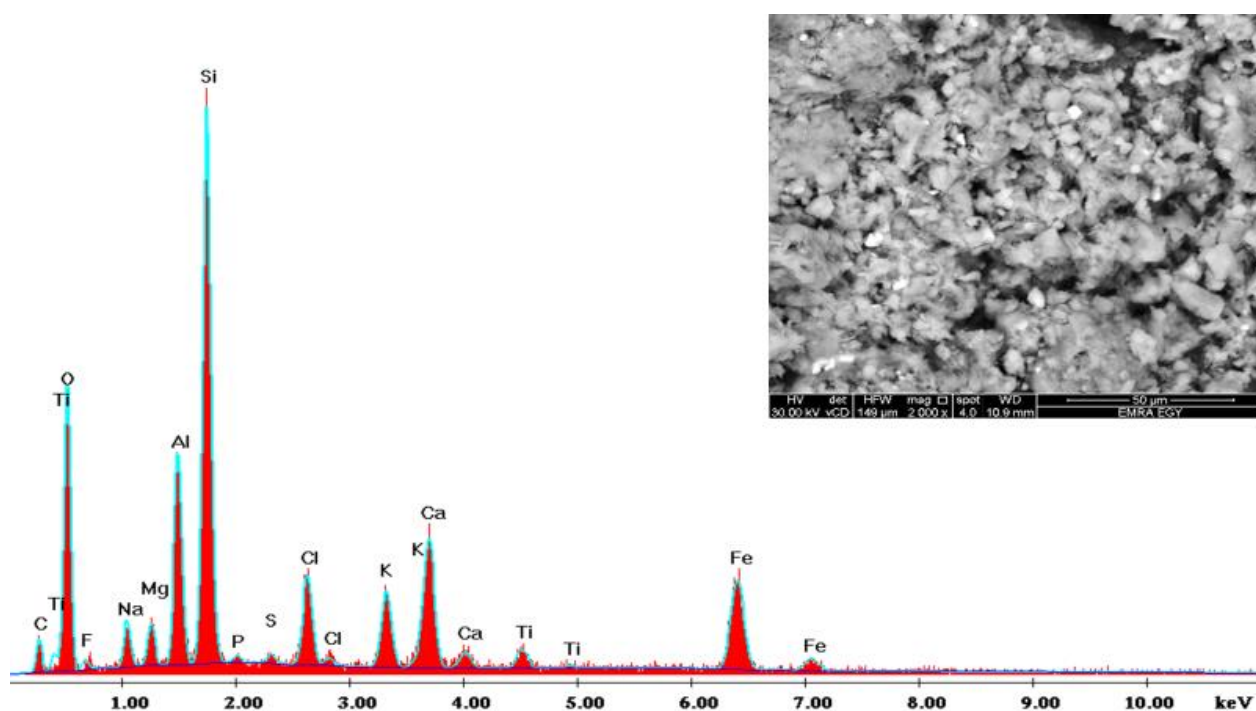


Figure 16. SEM-EDS chart shows the composition of the sample which considered the mural support.

Table 2 The proportions of the elements found in the EDX for the mural support from the monastery.

Element	Wt %	At %	K-Ratio
C K	10.46	17.97	0.0150
O K	35.70	46.05	0.0723
F K	1.56	1.70	0.0021
NaK	3.35	3.01	0.0084
MgK	2.07	1.75	0.0072
AlK	7.49	5.73	0.0339
SiK	19.49	14.32	0.1010
P K	0.34	0.23	0.0015
S K	0.36	0.23	0.0021
ClK	3.30	1.92	0.0215
K K	2.85	1.51	0.0223
CaK	4.93	2.54	0.0409
TiK	0.96	0.41	0.0078
FeK	7.12	2.63	0.0628
Total	100.00	100.00	

Sample (2): The sample turns out that the sample contains used to set layers where there appears to be Calcite (CaCO_3), Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), Quartz (SiO_2) and Halite (NaCl). (Fig. 17), (Table 3).

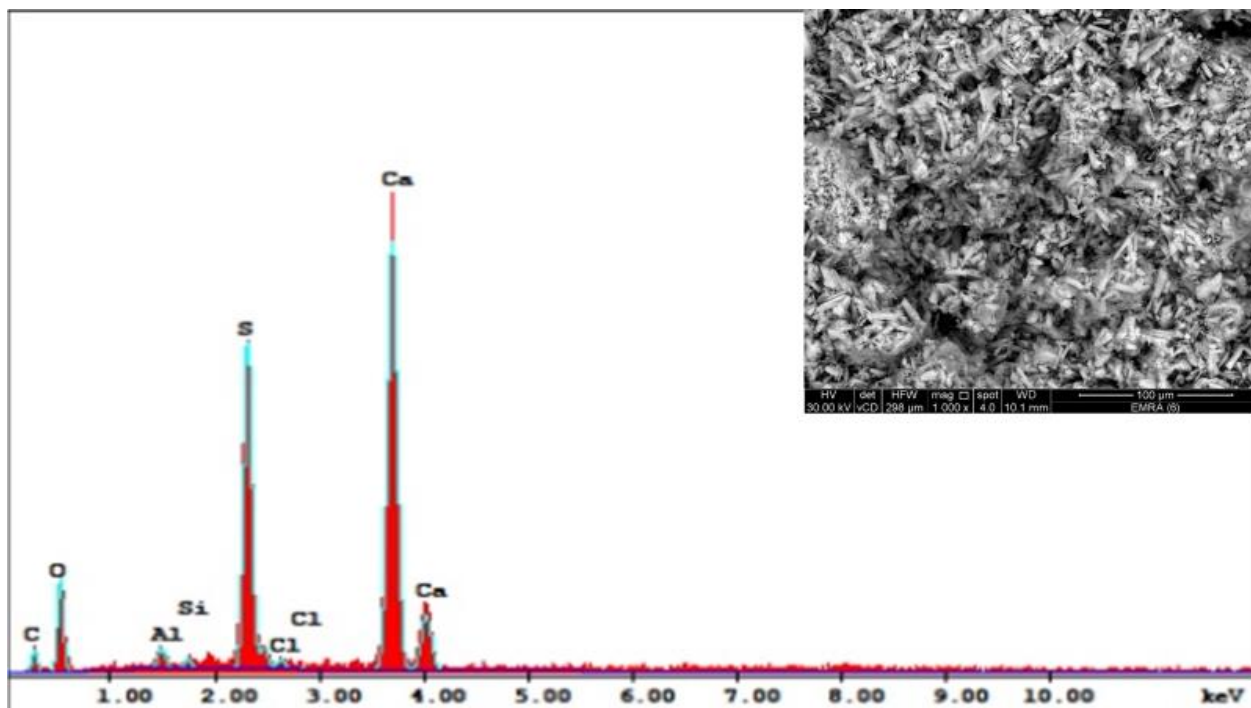


Figure 17. SEM-EDS chart shows the composition of the mural sample.

Table 3. The proportions of the elements found in the EDX for the sample taken from the mural

Element	Wt %	At %	K-Ratio
C K	11.60	20.26	0.0197
O K	39.15	51.31	0.0456
AlK	1.42	1.11	0.0067
SiK	0.60	0.45	0.0037
S K	16.19	10.59	0.1355
ClK	0.67	0.40	0.0046
CaK	30.35	15.88	0.2654
Total	100.00	100.00	

3.3. Attenuated Total Reflectance - Fourier Transform Infrared (ATR-FTIR)

The samples were placed inside a spectrometric analysis, the device is running to give the analysis as a chart graph paper to determine the functional

groups present in the samples and to know the presence of any organic materials added as color media. The result indicated that the absence of a color medium function group, and the present of gypsum function group (Fig. 18), (see, Table 4).

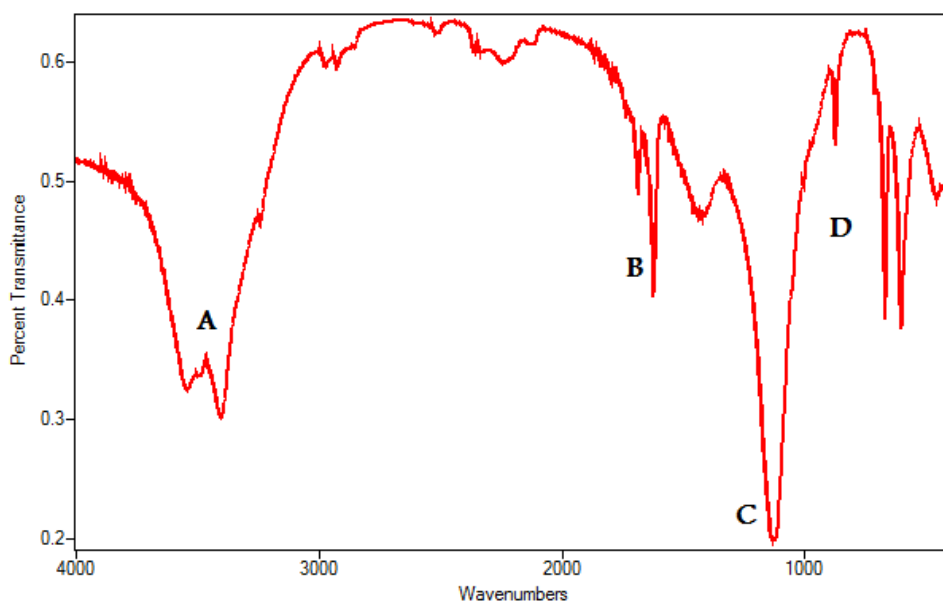


Figure 18. FTIR results Shows that no chromatic medium found in the sample as evidence of the use of the fresco technique in the mural.

Table 4 Shows the result of FTIR analysis.

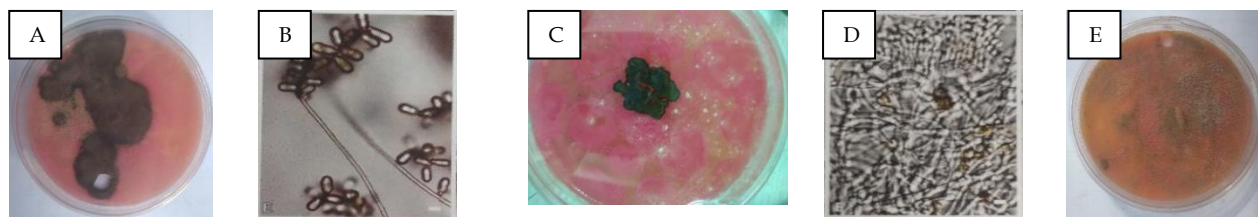
N	Function Group	Sample	Gypsum Standard
A	OH Stretching	3200-3350	3200-3600
B	S=O Stretching	1620-1680	1600-1700
C	SO ₂ Stretching	1125	1140-1080
D	S-O Stretching	918	850-980

4. STUDY OF FUNGAL DETERIORATION

The samples were taken from different places of the painting and from the wooden frame then were placed in PDA environment (Potato Dextrose Agar), this is used for the cultivation of fungi, which consists of 200 grams of potato extract, 20 grams of dextrose, 20 grams of agar and add a liter of distilled water, and the environment is cooked and stirred and then placed in flask, each flask is 100 cm³, and placed inside the autoclave for sterilization at 125°C under air pressure 1 for 20 minutes and then left To cool, then to be liquefied and poured into Petri dishes with a diameter of 9 cm in sterile conditions, then to cultivate the spaces under sterile conditions and incubated at 27 degrees for a period of 7 days until the fungal growth appeared on the surface of the environment (Mansour 2013) (Yosr, 2018).

Then the purification stage is where the PDA environment is poured again in addition to Rose Bengal material in new Petri dishes and the sterile needle pollination needle is passed to each fungus type in the new dishes. After the fungi are purified, they are preserved 7 days at 25 degrees. Then, microscopic slides are made to identify the type of each fungus according to practical references specialized in the field of microorganisms. The result of fungi was appeared as: *Aspergillus flavus*, *Aspergillus niger*, *Aspergillus parasiticus*, *Aspergillus restrictus*, *Botryodiplodia*, *Trichoderma sp* and *Trichothecium roseum* (Figure 19 A-N) (Mansour, 2020).

Fungals were identified morphologically according to previous reports (Ellis and Ellis, 1997; Raper and Fennel, 1965; Samson et al., 2004, 2010).



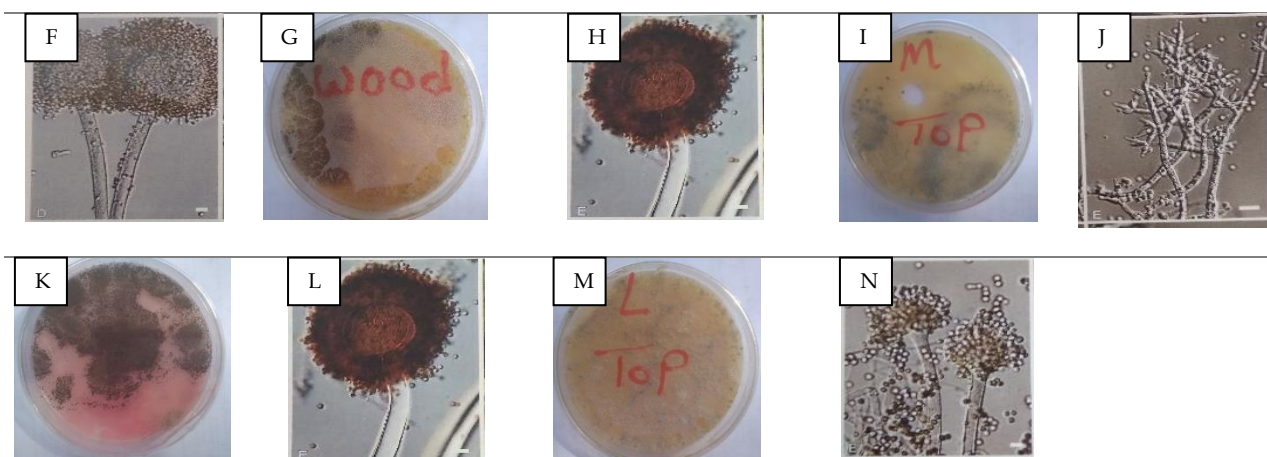


Figure 19. Fungi appeared at the samples: (A&B) *Trichothecium Roseum*, (C&D) *Aspergillus Restrictus*, (E&F) *Aspergillus flavus*, (G&H) *Aspergillus niger*, (I&J) *Trichoderma pers.*, (K&L) *Aspergillus niger*, (M&N) *Aspergillus Parasiticus Speare*.

4. DISCUSSION AND CONCLUSION

The study proved that the mural (study case) - preserved in the Coptic Museum in Cairo-, was located in the monastery of St. Apollo at Bawit in Asyut, and this monastery was established by the end of the fourth century and appeared until the ninth century and has been excavated in it since 1904 at the hands of Clédat and has resulted a lot of artistic sculptures that are valuable and an artistic wealth that must be preserved. Therefore, tests and analyzes were carried out on the mural to determine the stratigraphic analysis of the mural, its chemical composition and the coating technique used and proved that the results of the EDX that was taken from the monastery itself to identify the type of mural support (the subject of study) and knew that it has a ratio of the orthoclase, quartz, which is the basis of the mud bricks and some impurities of gypsum, magnesium, potassium and titanium, as well as a percentage of halite and the result of EDX that was taken from the mural itself, the layers of preparation that were above the mural support were known to be calcite CaCO_3 , gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, and sand SiO_2 (Ali, 1995). The infrared rays appears the absence of a color medium, which means that the painting was executed in a fresco technique (Salama, 2019), which is appropriate for the case of asceticism of the Coptic

artist, which is depicting a mortar of lime moistened with colors mixed with water and when it dries, it will be more stable and I have used the common colors in this period as mentioned by (Salama 2019), said the red (hematite Fe_2O_3), green (malachite $\text{Cu}_2\text{CO}_3 (\text{OH})_2$), black (carbon C_6) and White (calcium carbonate CaSO_4) (Vázquez, 2019). The result of the USB digital microscope showed the non-apparent manifestations of damage and the extent of the deterioration reached by the mural due to internal factors of the heterogeneous wall mount type of organic materials and inorganic materials and the stages of removing the plate from the monastery and transferring it to the Coptic Museum in Cairo and also the external factors like heat, humidity and the salts that appeared in the results of the analyzes, which results the cracks, separations, gaps, scaling, discoloration or loss, and also showed previous conservations and sterile cotton swabs from different places of the mural, and then we identified the types of microbiological damage from the fungi species with optical microscopy. After completing this study, it is considered the first step to develop a treatment and maintenance plan to maintain the mural and also develop a suitable museum presentation to preserve it from various damage factors.

ACKNOWLEDGEMENTS

Authors would like to thank Prof. Maisa M.A. Mansour, Department of Conservation, Faculty of Archeology, Cairo University, for her support during the fungal study.

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