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STUDIES ON THE DETERIORATION OF COPTIC MURAL PAINTINGS IN THE MONASTERY OF MARTYRS AND THE LUXOR TEMPLE

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Abstract

In this study the surfaces and cross sections of deteriorated Coptic mural paintings were investigated using Computer Tomography (CT) scan images and video, and points (voids) on the surface were analyzed. To our knowledge, it is the first report on the application of CT scan for the investigation of deteriorated Coptic mural painting surfaces in Upper Egypt. The samples tested were collected from two sites: the Monastery of Martyrs (Deir alShuhada-Esna) and the Luxor temple. The selection of these monasteries was due to their historical importance, which is directly related to Egyptian Coptic heritage. The deteriorated surfaces of the selected mural paintings were characterized using new avenues of computed X-ray tomography (CT scan) in order to gather sufficient information about their composition and structure. The obtained results show that CT scan images provided us with detailed information about the sample porosity and structure. In the case of the Martyrs monastery, it was found that the mural paintings consist of one layer which contains clay minerals (kaolinite, montmorillonite, and illite) in the form of coarse plaster. On the other hand, the Martyrs Monastery showed higher porosity than the Roman Fresco in the Luxor Temple.

Keywords: *CT-scan; Deterioration; Conservation; Coptic mural painting.*

Introduction

Since Greek and Roman times, the Coptic Mural paintings in the monasteries located in the areas of Esna and Luxor have been prepared using semi-fresco technique. This technique was applied either directly on plaster layers of fresh lime, or on several lime plaster layers containing over-painting (multi layers). Some of these monasteries show considerable Coptic and Arabic texts that appear on the mural painting, e.g., the paintings in the monastery of Martyrs, the Monastery Anba Hedra in Aswan and the Luxor Temple, representing some of the most famous Coptic texts in Christian history. These texts that are found on the Coptic mural paintings are of great value for the documentation of Coptic art [1-6]. Recently, most of the layers of mural paintings containing the text layers have been severely damaged due to poor preservation, as in the case of the murals of the Monastery Anba Hedra. Generally, due to the harsh weather conditions in the upper region of Egypt, the mural paintings are exposed to high temperatures (40-50°C) in summer and low temperatures (5°C) in winter, vandalism over the

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last forty years, and wind erosion. The large differences in temperature have caused repeated variations in the volume of the plaster, leading to cracks, contraction fissuring and peeling of the vertical walls as shown in Fig. 1 [7, 8].

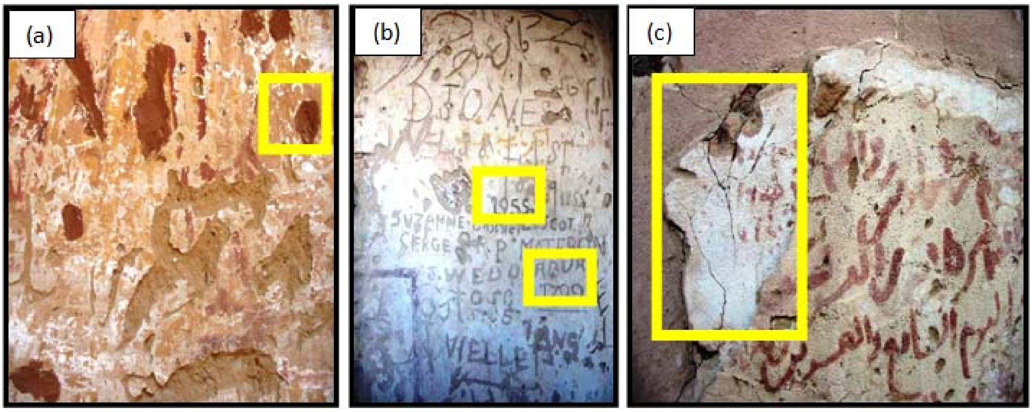

Fig.1. Deterioration of the mural painting: (a) Faulty restoration works on the surface of a mural painting; (b) Vandalism damage on the surface of a mural painting; and (c) Cracks and exfoliation

The damage/deterioration of the Coptic mural paintings located in the upper area of Egypt, as shown in figure 1, can be related to the following:

1. Loss of strength and granular disintegration due to chemical mineralogical physical changes, and convenient pigment detachment;
2. Loss of the thin painting applied to the subsurface layer, which has led to desegregation of the surface and diminished cohesion between the wall and the mortar of the fresco;
3. The alteration of the pigment, as a result of water penetration by diffusion through the fresco from the wet wall to the pictorial layer;

The CT scan technique has been used extensively in virtual reconstruction and morphological analysis of the craniums of ancient Egyptian mummies [9].The first application of CT scan has been in the medical imaging field, where it was used to create a three-dimensional image of the internals of an object from a large series of two-dimensional X-ray images taken around a single axis of rotation. This technique has proven be an effective non-destructive testing method for the creation of 3D images of artifacts in archaeology. Currently, it is reported that this technique is used at the Meander Medical Centre in the Netherlands for the scanning of samples collected from Buddha statues. Their studies revealed the presence of a mummy inside the structure of a Buddha statue [10]. In the near future, it is expected that the role of CT scans will expand in areas such as imaging and analysis of different archaeological artifacts including metals, mummies, stone, ceramics, wood and mural paintings.

The word "tomography" is derived from the Greek tomos (slice or section) and graphein (to write) [10, 11]. The advantage of this technique is that the sample can be cut into sections at any angle, allowing for the creation of a 3D structural image. This makes the CT scan an important tool for archaeological sample characterization [12, 13]. CT scan technique can provide more information than a single X-ray image and the evaluation quality is usually far better with CT than with Digital X-ray. Therefore, the CT technique is implemented in this study in order to distinguish the multi-layers of over-painting on Coptic murals for the selected sites and to identify the hidden structures.

The main objective of this study is to investigate the surfaces and cross section of Coptic mural paintings using CT scan images and video to analyze the points (voids) on the surface. To our knowledge, this work is the first application of CT scan in the investigation of the deterioration of Coptic mural painting surfaces in Upper Egypt. In this study, the tested samples were collected from two sites: the monastery of the Martyrs (Deir alShuhada) (Fig.2) and the Luxor temple (Fig. 3). These monasteries were selected due to their historical importance to Egyptian Coptic heritage. The deteriorated surfaces of the selected mural paintings were characterized using new avenues of computed X-ray tomography (CT scan) in order to gather sufficient information about their composition and structure.

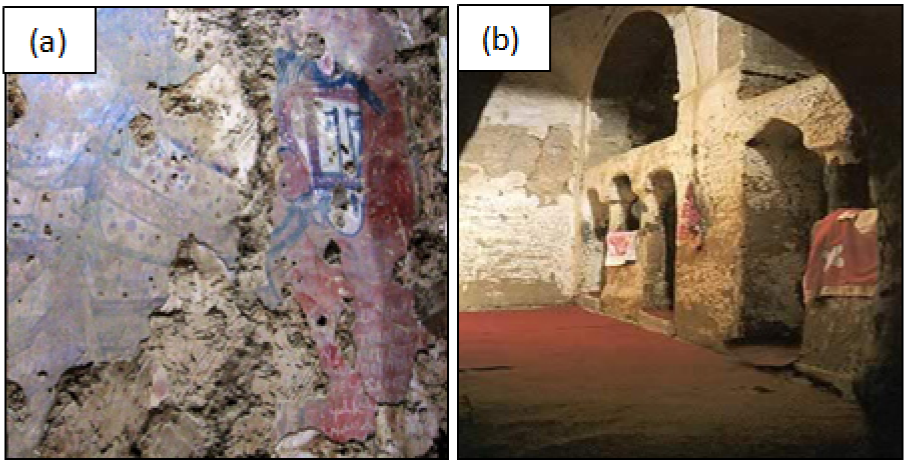

Fig. 2. (a) The church of the martyrs showing the fragment plaster;
(b) Interior view of the Church at the Monastery

Fig. 3. Interior view of the church at the Luxor Temple

Experimental

Sample collection

The fragment samples were collected from the surfaces of mural paintings by taking small flakes from the surface. The photographic images of the collected samples are show in

Fig. 4, and their details are listed in Table 1. The sample collected from Luxor temple was found in good condition in comparison to the one collected from the Martyrs monastery, which showed damage due to granular disintegration as a result of the chemical-mineralogical-physical changes. The dimensions of the samples ranged from 1.5 × 0.8 × 0.5cm to 2 × 1 × 0.9cm. The cross sections of the samples were prepared from the small fragments taken from the mural painting surfaces.

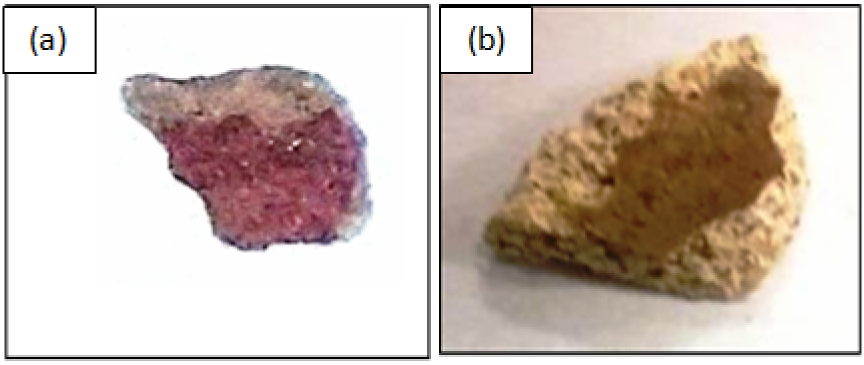

Fig. 4. Images of the samples collected from:
a - Monastery of Martyrs at Esna; b - Luxor temple - Luxor.

Table 1. Sample details including typology and location

Sample	Typology	Location
Monastery of Martyrs at Esna	Red mural painting	Luxor
Roman Fresco	Fading Red mural painting	Luxor temple - Luxor

CT scanning (imaging)

For morphological characterization, mural paintings were scanned using a micro CT (Quantum FX, PerkinElmer, Waltham, MA, USA). The scans were made under tube voltage 90kV, tube current 160 μA, field of view at 20mm, and scan time of 4.5min. Quantum FX is a cone-beam micro CT system, with the X-ray source and the detector rotated around a stationary sample by 360 degree during scanning. All X-ray imaging is based on the attenuation of X-ray as it passes through the different parts of a sample. The X-ray attenuation / co-efficient value based on the density difference between different parts of the sample is collected and constructed as CT images. By combining a series 2-D CT images generated from 360 degree rotation, a full 3-D image is reconstructed by built-in software Viewer (PerkinElmer). The special characteristics of the CT-images allow 3D and 2D reconstructions of the samples at a high defined resolution up to 4.5μm. This allowed the study to distinguish the layer structure as well as to study morphology of the surfaces. All imaging was done at Karolinska Institute, Stockholm, Sweden.

Results and discussion

Monastery of Martyrs at Esna

Investigation of the sample surface layer shows that this layer is directly applied over the coarse lower plaster made from mud (kaolinite, montmorillonite, and illite). Mud brick was often used in the monasteries located in the desert of Upper Egypt; being a good insulator of heat, it was found to be a suitable building material for this environment [14].The investigation of the samples collected from the monastery revealed that the surface of the mural paintings consisted of one plaster layer (Fig. 5). Other reported studies on the characterization of mud plaster caves show the successful application of several techniques such as polarizing microscope, laser scattering devise and SEM. These studies indicated that the major components of plaster samples are quartz, calcite, and sepiolite, and a clay mineral in a minor quantity [15].

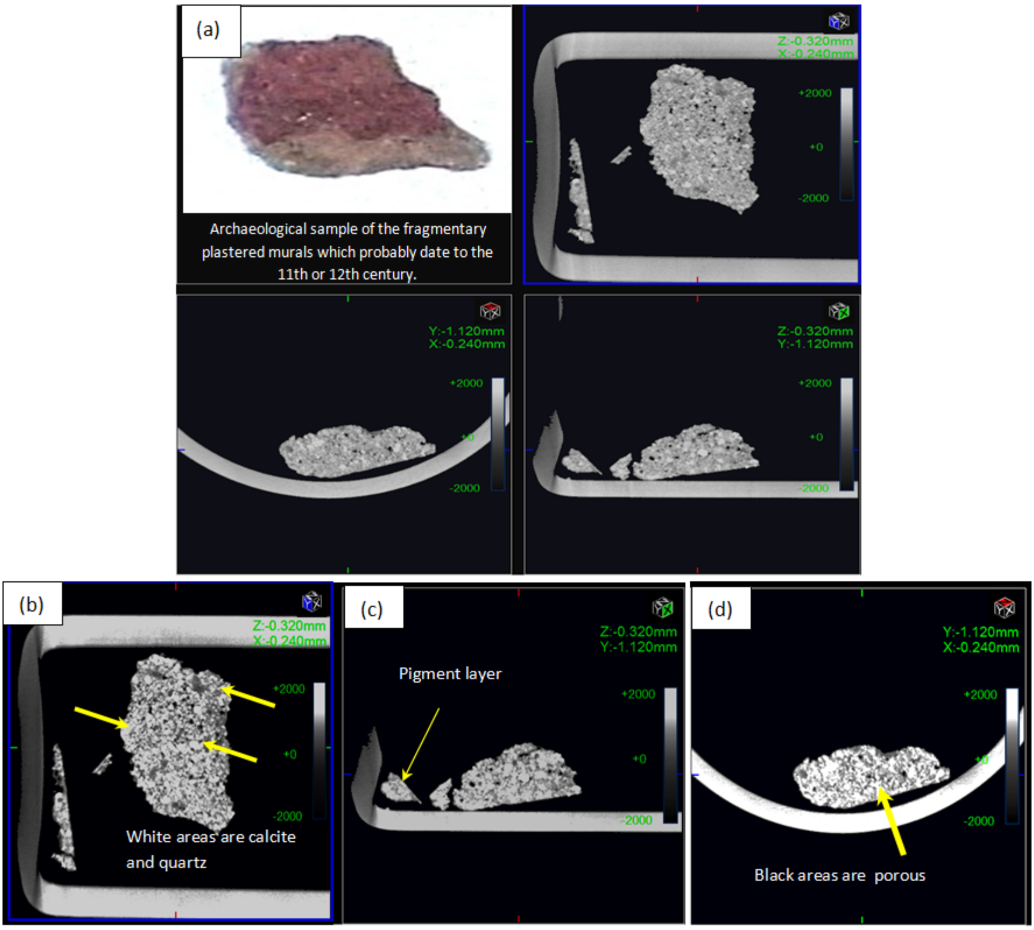

Fig. 5. CT scans: a - Three orthogonal views of the mural painting; b - CT horizontal section of the sample showing white areas; c - CT horizontal section showing paint layer flaking; d - CT image showing black areas are porous;

The sample characterization showed that the painting layer is directly applied over the lower coarse mud plaster. The presence of the clay minerals in the mural painting may accelerate the weathering. In principle, these minerals are hydrous phyllosilicates that are composed of Al, Mg, Fe (II) and Fe (III) and to a lesser extent, of other ions of Ni, K, Na and Ca. These ions play a significant role in the crystallization processes of clays that lead to surface disintegration and micro-fissures, causing porosity in the materials and following loss of the layers of painting [16]. The paint layer is one layer as shown in figure 5c. The clay minerals have high hygroscopic properties, enabling the absorption of water. The resulting swelling leads to pressure on the paint layer exterior, causing plaster removal, bulking and cracks. The presence of several minerals in the samples may lead to heterogeneous physical and mechanical properties. Together with climate changes, this long term variation between wet and dry conditions leads to different types of weathering due to dimensional fluctuation. The average temperature in the selected sites varies from 50°C in July to 10°C in January. The high temperature may lead to thermal shock in the minerals and loss of cement material (calcite and gypsum), specifically gypsum (calcium sulphate dihydrate), which is dehydrated and transformed into a lower hydrous phase (hemihydrated phase), then finally transformed into the brittle anhydrous phase (anhydrite) [8].

Roman Fresco in the Luxor Temple

The CT scan images show that the over painting layers in the Luxor temple consist of two layers as shown in Fig. 6. The first layer has high quality; the second layer is directly applied over the surface of the temple from fine lower plaster made from gypsum, calcite and quartz.

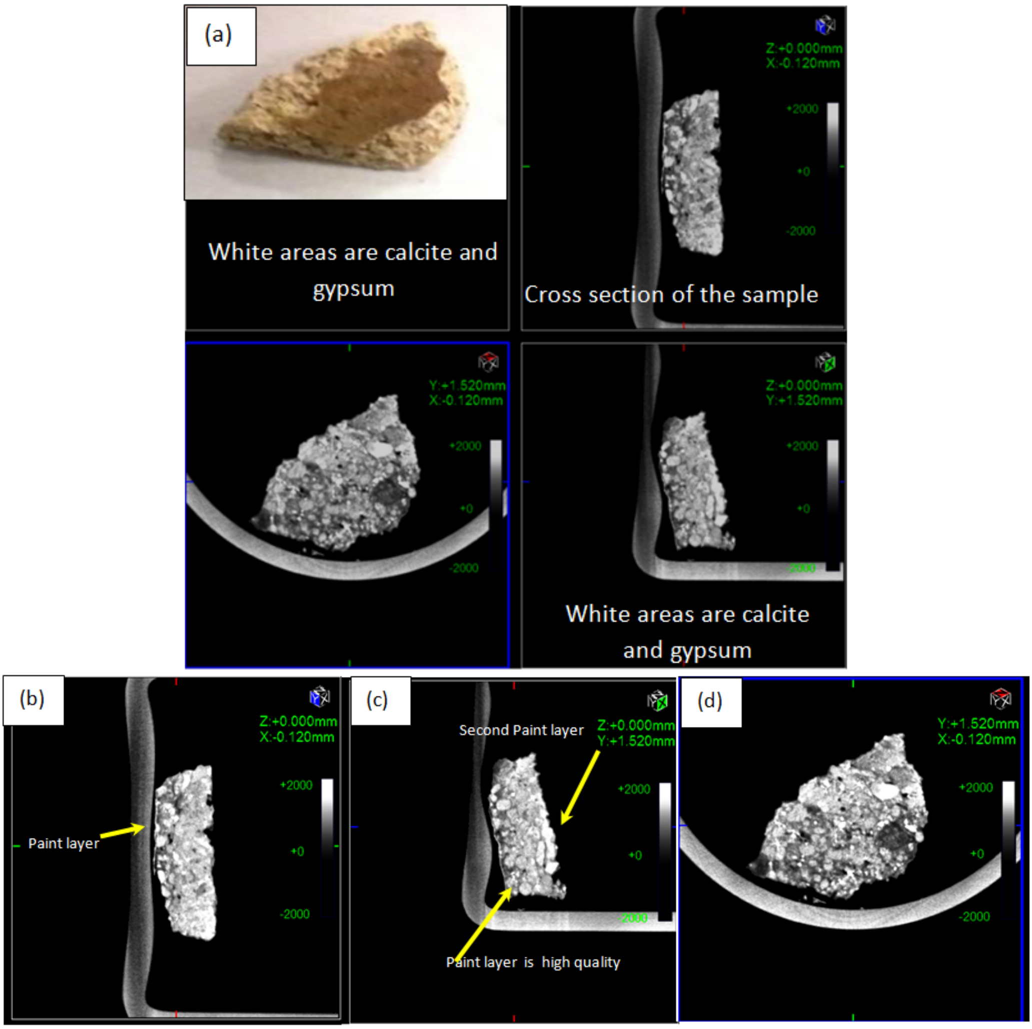

Fig. 6. CT scans: a - 3D image of the CT of the Roman Fresco; b - CT horizontal section showing paint layer thickness; c - CT horizontal section of the sample showing two paint layers; d - CT horizontal section showing mineral composite;

The CT image shows a single slice illustrating the stratigraphy of a modal Fresco mural painting: two layers were combined to form the first layer as a technique to produce high quality and smoothness; these layers are rich in quartz (as the major component), calcite and gypsum. On the other hand, the secondary layer is thinner than the first layer and its major component are quartz and gypsum. In addition, this layer covers the surface of the temple; some dark areas were noted on the surface due to the loss of quartz grains, calcite and gypsum. Furthermore, the CT image analysis showed that the pores of the paint layer are similar to those of the ground layer, which may be due to temperature and relative humidity variations, mechanical stresses and physio-chemical properties of the sample (mineral content). The combination of quartz, calcite and gypsum caused the change of gypsum to anhydrite which is weaker than gypsum, leading to the loss of quartz grain, loss of plaster layers due to cracks, and large porous areas. These may lead to the flaking of the outer surface layer and the loss of the original painting structure.

Conclusions

CT scanning is well–suited to artifact and cultural material documentation via high-resolution imagery, allowing the viewing of the samples and objects from different angles. 3D images are also useful for conservation purposes. The results we obtained by CT scanning strengthen the case for the use of this technology in the description of the characterized layers and documentation, and the conservation of Coptic mural paintings. The following points were highlighted: CT scan images of the Monastery of Martyrs mural painting show that it was done using Fresco technique and consists of a single layer. The samples collected from the Monastery of Martyrs were found to be in bad condition and therefore need urgent consolidation due to the detachment of the paint layer from the ground layer. On the other hand, the CT scan of the samples collected from the Roman Fresco in the Luxor Temple showed that they consist of overpaintings (multi layers). These layers are rich in quartz as the major component, calcite and gypsum (white areas). In comparison between the samples collected from the two sites, the paint layers in the Luxor Temple exhibit higher quality than those of the Monastery of Martyrs at Esna. In the future we intend to expend the use of the CT scan technique for the characterization of other samples collected from areas such as the monastery of Qubbat Al Hawa in Aswan, St. Simeon Monastery in Aswan, Saint Matthew the Potter (Deir al-Fakhuri) in Esna – Luxor.

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