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Preliminary Multi-Band Imaging Investigation on Items from the Aga Khan III Necropolis, Aswan (Egypt)

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Abstract
This study is aimed at the investigation of several items, including fragments of cartonnages, coming from the Aga Khan III necropolis, in West Aswan (Egypt). This preliminary analysis campaign, whose final goal would be the characterisation of the materials used for making and decorating the findings, was performed by means of multi-band imaging technique.
The on-site measurements were performed by using portable instrumentation consisting of a modified camera equipped with different excitation sources and specific filters. The captured multi-band images have allowed the formulation of some preliminary but insightful considerations on the chemical nature of the pigments employed. Especially, the characteristic fluorescence of Egyptian blue, detected by means of VIL (Visible Induced Luminescence) technique, permitted both highlighting its presence/absence on the decorated surfaces and obtaining some fascinating and unique images of the objects on which that pigment was used.

I. INTRODUCTION

The characterization of the materials used for making and painting objects of artistic and historical interest can give vital information such as the availability of natural pigments and the painting technique as well as the ability f making pigments from raw materials and, consequently, information that deals with the technological expertise in a particular historical period. Furthermore, it can even help with authenticity and/or dating issues of the artwork [1-4]. The present work aimed to investigate the nature and composition of the pictorial layers of four different Egyptian artefacts found in West Aswan, Egypt.
In particular, spectroscopic analyses were performed directly on site, on artefacts excavated in the area surrounding the Mausoleum of the Aga Khan, within the campaign of Miaswan Project and headed by Prof. Piacentini. The necropolis covers around 1000 years (6th cent. BCE-4th cent. CE). The analyzed artefacts were three different cartonnages and one piece of pottery.
The cartonnages that were investigated in the present study come from the Aga Khan III necropolis, in West Aswan (Egypt) and were found within the campaign of the MIASWAN project; up until now, two campaigns of the EIMAWA mission (Egyptian-Italian Mission At West Aswan) in the framework of the MIASWAN (Mummies Investigations Anthropological & Scientific West Aswan) project were conducted by the scientific research group. The necropolis covers a time frame of about 1000 years (6th century BCE-4th century CE). The area of the excavation is 100,000 square metres, of which approximately 25,000 were mapped in January-February 2019, uncovering the entrances to 226 tombs.
Of this vast necropolis, one tomb, nr 26, was excavated, which revealed the presence of 35 mummified bodies and numerous objects. Further tombs were excavated in

subsequent years, returning objects and fragments of cartonnages of different sizes and including foot covers, head covers, collars and small fragments that still show very vibrant and bright colours.

Do to the restrictive Egyptian laws, no object can be transported outside Egypt nowadays. Therefore, only in-situ and non-destructive measurements through portable instrumentation would be allowed.

For this reason, in this first measurement campaign we wanted to evaluate the possibility of performing on-site analyses and we started with the lighter and easier-to-use portable devices at our disposal, with the idea of conducting further investigations during subsequent study campaigns with true spectroscopic techniques (portable Raman and FTIR) that could provide information on the chemical nature of the pigments and any binders used on these painted objects.

To this end, in order to carry out a preliminary assessment of the colours and materials, we made use of multi-band equipment consisting of a camera provided with different excitation sources and specific filters.

II. EXPERIMENTAL

Among the different findings, in this research a fragment of a painted cartonnage (about 6 x 5 cm), a statuette with human features (about 5 cm high) and a small metallic object (about 4 x 3 cm) excavated in the Aga Khan necropolis were analysed.

Multi-band imaging measurements were carried out using a camera with a 28 megapixels APS-C BSI sensor 28mm 1:2.8 lens and a set of sources and high-pass or low-pass filters as follows:

- 365nm LED UV source for UV Fluorescence and UV Reflection;
- 440nm Blue LED source for Blue induced Fluorescence;
- Visible/IR source with Tungsten filament for IR Reflection 950 and 1070 nm;
- Red source for Visible Induced Luminescence;
- No UV no IR "hot mirror" filter for Visible and UV-induced Fluorescence;
- High-pass filter 950 nm for IR reflectography;
- -High-pass filter 850 nm for Visible Induced Luminescence;
- Narrow Band IR filter 1060-1080 nm for IR reflectography;
- Yellow filter.

Furthermore, a USB microscope with a 5 Mpixels sensor and includable/excludable polarising filter was utilsed. Finally, Visible/IR source with Tungsten filament was used for grazing light imaging.

III. RESULTS AND DISCUSSION

The investigations were carried out both at the excavation site (the map in which the site is indicated by a red circle and the Aga Khan Mausoleum are shown in Fig. 1) and inside the storage where some of the excavated items were moved and analysed (Fig. 2).

By means of the multi-band imaging equipment, several images were acquired highlighting the colours' different responses for each considered spectral range. For each painted object (or detail of a certain object), different illumination source/filter combinations were considered in order to obtain the following:

a) image in the visible region;
b) luminescence induced by UV radiation;
c) visible induced luminescence (VIL);
d) Infrared reflectography.

Each of these images allows for getting different and specific information on the nature of the pigments present on the artefacts. Especially interesting is the VIL image, which unequivocally shows the presence of Egyptian blue because of its peculiar response if subjected to visible light.

Fig. 1. Map of Egypt (font: Google) indicating the EIMAWA excavation site in west Aswan (see the red circle above) near the Mausoleum of Aga Khan III (bottom).

Fig. 2. Multi-band analysis set-up inside the storage where some of the excavated items were moved.

It is worth mentioning that the intense solar radiation could have interfered with the measurements. For this reason, in order to make on-site measurements on the pieces on the EIMAWA excavation, it was necessary to create a sort of "dark room" inside which the pieces to be studied were placed. The dark room was made of a cardboard box covered with black cardboard so as to completely absorb visible and infrared radiation. A hole was made at the top end of the box into which the camera was inserted. Figure 3 (right) shows how the image of the photographed object appears inside the darkroom.
On the basis of the response observed in the UV-induced fluorescence image (fig. 4, top right), it is interesting to observe how the two shades of red give a different response, which may suggest the presence of different pigments. More in-depth studies on reference samples will have to be carried out in the laboratory to hypothesise an attribution).

Fig 3. Some fragments of a cartonnage excavated during 2023 campaign (on the left) and the equipment while being used on samples (on the right)

In addition, the luminescence of Egyptian blue can be observed very clearly from the VIL image (fig 4, bottom right). The fluorescence of Egyptian blue proved to be so peculiar and intense that it could be used as a specific tool for the detection of that pigment on the majority of the analysed objects [5, 6].
In fact, the small statue that was aforementioned in the experimental section was examined at 360°, but no evidence of brilliance was obtained in none of the photos taken through the VIL setup. To check the results out, the VIL experiment was also performed simultaneously on the small statue and on an Egyptian blue containing sample (used a reference in this case). This proved unequivocally the efficiency of the VIL technique in the detection of this particular blue pigment and, at the same time, the absence of it on the small statue, which was rather curious and deserves further investigation to highlight the nature of that blue pigment.
The same experiment was repeatedly done on the majority of the excavated objects, especially because the founding of Egyptian blue is *per se* a kind of both dating and authentication mean, since its use is quite specific for objects made in Egypt in between the 3rd millennium B.C. and the Roman period, after which the pigment was almost abandoned [5, 6, 7]. In fact, it is reported in the literature that the secret recipe to make Egyptian blue was lost at some time in the late Roman period and the research of Orna et al on this topic, did not find any written evidence that Egyptian blue was produced after the Roman period [8].
Nevertheless, it must be said that the issue of Egyptian blue pigment, especially its possible later production and use in the artwork after that period has been rather discussed in the very last years, since several occurrences were reported in paintings dating to the Middle Ages and the Renaissance [9-11].

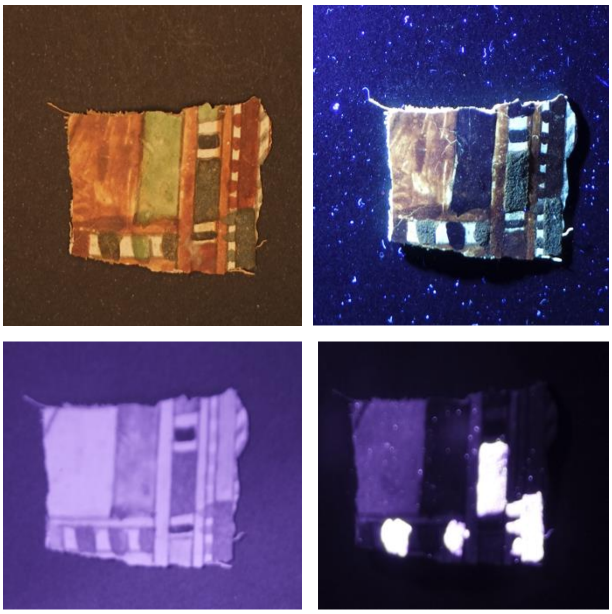

Fig. 4. A fragment from a cartonnage examined on-site in different conditions: i) RGB colour image; ii) UV fluorescence image; iii) IR reflectography; iv) VIL image

Also, the USB microscope was used for the on-site analysis, since it enables to obtain useful images for the study of materials and, in some cases, for colours identification. In Fig. 5 the USB tool is shown while working on a small metallic object.

Fig. 5. On-site analysis by means of a USB microscope.

IV. CONCLUSIONS

This research has allowed us to perform on-site multi-band imaging measurements on one of the most important archaeological Egyptian sites currently being excavated.

The preliminary assessment confirmed the presence of a wide series of interesting painted objects extracted form the tombs and some new information about the chemical composition of the artifacts could be done just on the basis of these analyses.

The results of the analyses were thought to be crucial by the archaeologists who took part in the excavation, to the point that a new campaign of measurements has been planned.

Given the good performance of our on-site setup, even in such extreme condition in terms of climate and experimental discomfort, further developments of this work will include investigations by means of portable spectroscopic techniques such as FTIR and Raman spectroscopies in order to better explore the colour palette used for the paintings.

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