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New insight about the mural painting branches of Roman baths in Reggio Calabria

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***Abstract* – The Roman *thermae* in Reggio Calabria (Italy) provides many information regarding both engineering and technology for this type of buildings. A small treasure of three survived mural paintings encloses information about the artistic style and the ancient luxury of the baths. In order to get light on the executive technique and conservation state we performed the investigation of these paintings by following a non-invasive approach composed of multispectral imaging and spectroscopic analysis. By so doing, we determined the pigment palette and the distribution of some pigments allowing us to make some hypothesis about the executive technique and to provide a basis for a future virtual restoration of the paintings.**

I. INTRODUCTION

This work presents the results of a study performed with non-invasive analyses on three mural painting branches belonging to the Roman *thermae* of Reggio Calabria. The complex was discovered in 1887 by De Lorenzo and Eng. De Rao, during the demolition of a 16th cent. Spanish wall bastion (San Matteo) needed for the enlargement of the adjacent Via Marina [1]. The building, part of a private building dating back between the 2nd and the 3rd century AD, is characterized by many construction phases. Planimetrically, it is developed around a small circular-shaped room (*frigidarium*) decorated with a mosaic pavement and plaster painted in imitation of marble: on the eastern side, some large steps give the access to a rectangular basin with cold water; on the western one, there is the heated sector, made up by the succession of three rooms equipped with *hypocaustum* (*tepidarium*, *laconicum* and *caldarium*), with a large oval-shaped basin.

According to the studies [2] carried out during the excavations, the paintings representing a marine topic were pertinent to the cold plunge-bath (*frigidarium*) (indicated with the n. 7 in the plan drawn by Eng. De Rao). In the detailed technical report of the excavation, they are described as *"fairly large bricks still having a very fine plaster attached with figures of fish and plants"* [3].

The painting branches are currently exhibited at level D of the National Archaeological Museum of Reggio Calabria, Italy (Figure 1).

The figures of fish represented in the drawings seem to have some differences, however, from those ones in fragments under investigation. The presence of an intervention curb does not allow to accurately detect the sequence of the constituent layers; however, it can be clearly observed that the plaster is applied to an original support consisting of large bricks, confirming the description provided by De Rao in his report [2]. Nowadays, it has been decided to restore the paintings and, before each treatment, a diagnostic campaign was performed in order to reveals the nature of the pigments, and to drive the restoration, considering the importance of a tailored approach able to recovery and protect the painting by using proper materials [4,5]. A non-invasive and multi-technique approach [6-10] was used to investigate the artefacts by using multispectral and photogrammetric photography, X-ray Fluorescence Spectroscopy (XRF) and Fiber Optic Reflectance Spectroscopy (FORS) techiniques.

Fig. 1. The three branches of the wall paintings exhibited at the National Archaeological Museum of Reggio Calabria (before the restoration).

II.INVESTIGATION

First of all, a detailed photographic acquisition was performed by using a multispectral camera and different sources; moreover, some acquisitions included the use of position references in order to reconstruct the 3D model of the painting surface. Once obtained the images, these drove the choice of the spots to be analysed with the spectroscopic techniques.

Multispectral imaging was performed with a NX3300 20.3 MPX camera equipped with Manual UV-IR objective and a long pass filter at 950 nm for IR imaging and lighting the paintings with a halogen light for infrared reflectography and a red led light (640 nm) for Visible Induced Luminescence (VIL) [11].

An RGB photogrammetric survey was carried out using a Canon EOS M3 camera in order to obtain a digital copy of the groups of painted fragments. Photogrammetry is a well-suited technique for the illustration and reconstruction of Roman wall painting. Compared to the traditional photography, photogrammetry can offer three-dimensional documentation that captures the seams, cracks and warps in the surfaces of the wall. Some of the shots were taken keeping the optical axis of the camera in a vertical position with respect to the top surfaces, while others with camera placed in oblique position: the latter allowed us to acquire the support thicknesses in their correct dimensions. The metric correction of the model was guaranteed by the use of control points (targets), which were placed at known distances. The first project consists of 54 photograms; the second is made up by 66 images, while the third has 69 images. Finally, each of these datasets was processed using the software Agisoft Photometric through the usual workflow: correction of optical distortion of cameras (by “Lens” plug-in); alignment of the frames by tie points between adjacent frames; dense cloud generation; generation of 3D polygonal mesh; generation of texture; exporting of results. The operation was repeated with the multispectral camera: specifically, shots were taken at a distance of about 30 cm, to obtain high-resolution images of every single portion of the frescoed surface. These frames were merged together by photo-mosaicking in order to obtain an overall high-resolution image. The texture obtained was also used to coat the 3D model created by digital photogrammetry.

XRF spectra were acquired in situ through a portable Tracer III SD Bruker AXS spectrometer equipped with Rhodium Target X-Ray tube operating at 11 µA and 40 kV. The detector is a silicon drift X-Flash SDD with Peltier cooling system and 3-4 mm diameter spot. The instrument allows to detect elements with an atomic number > 11. The S1PXRF® and ARTAX® softwares rule the data acquisition and spectra analysis, respectively.

FORS spectra were acquired in situ thought a UV–VIS–NIR Ocean Optics portable fibre-optic spectrometer. The instrument is equipped with a DH mini light source, a detector operating in the spectral range 350 –1100 nm (USB 2000 + XR1) and a reflection bifurcated probe, in which seven illumination fibres are installed around a central reading fibre, providing illumination and detection of diffused light from the same direction.

III. RESULTS

The photos acquired with multispectral camera (Figure 2) provided a general view of pigmented area, fissures and lacks. However, the most interesting results came from VIL images (Figure 2 c, f, i) which reveals the presence of a pigment luminescent in infrared range homogeneously distributed on most of the painting. The luminescence follows the distribution of blue area even if it is possible to observe it on the uncoloured area thanks to the high quantum yield of this pigment, which can be associated to the Egyptian blue, quite diffused in Roman paintings [12,13].

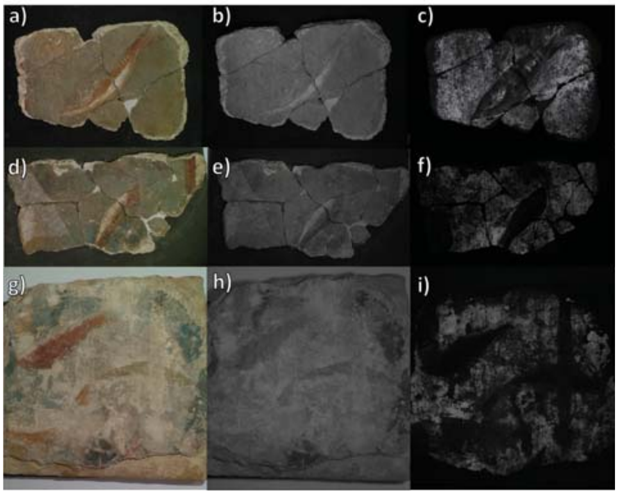

Fig. 2. Multispectral images of the paintings. a, d and g) visible photos; b, e and h) IR reflectography; c, f and i)VIL images.

It is also interesting to note that the luminescence highlights the cracks and the damaged area where the abraded surface lost the painting layer (compare Figure 2 g and i). Furthermore, the luminescence indicates that for some white decoration of the fish of the first painting (Figure 2 a and c) the blue and white pigments were mixed together.

The photogrammetric survey (Figure 3) allowed us to get, for each painted branch, an accurate and metrically as-built documentation, which can be investigated in different format: coloured point cloud, 3D mesh, and tiled model. The high resolution of the point cloud model allowed to reconstruct in detail the morphology of the painted surfaces and to map the small cracks and damage from decay. It was also possible to use the 3D model as a framework to visually re-contextualize the paintings within the complex. Moreover, the 3D model can be also used as a digital support for the restoration activities and virtual reconstruction of the pieces, as well for their valorisation and promotion.

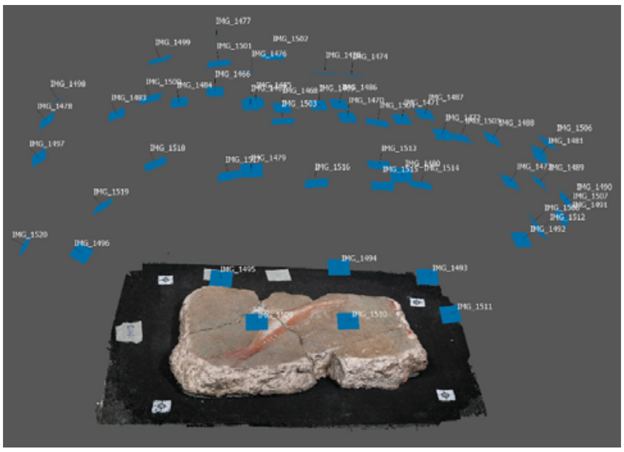

Fig. 3. 3d point cloud with camera position.

XRF spectra (Figure 4) show the presence of Calcium (Ca) for all the analyzed spots according to the preparation layer constituted by a mortar. The spectrum of blue is characterized by the presence of Copper (Cu) peak, indicative of the Egyptian Blue, according to the VIL observation. The spectra of red and green spots show a higher Iron (Fe) content so it is possible to connect these colors to earths pigments. For all spectra, a small signal of Sulphur (S) is recognized.

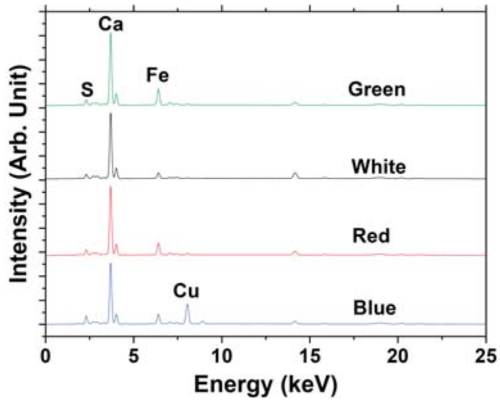

Fig. 4 XRF spectra of the colored area.

FORS spectra, acquired in several representative colored areas of each painting (Figure 5), show the same profile for each color.

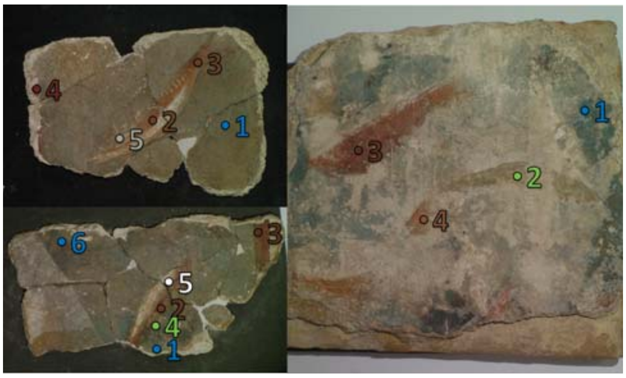

Fig. 5. FORS analyzed spots.

Fig. 5 Colored areas of each painting analysed by FORS technique.

FORS spectra of the green, red and blue area were compared with the ones of the identified pigments reported in literature (Figure 6), according with the compositional XRF results. The measurement on white area didn't provide evaluable curves, so they were not analyzed.

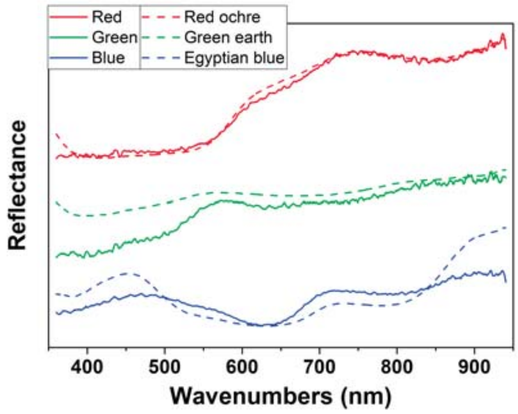

Fig. 6. Reflectance spectra of the colored area (continuous lines). The dashed lines are the reference spectra of the identified pigment.

The spectrum of the red area shows the typical S shape of ocher with two characteristic inflection points respectively at 550 and 700 nm. Furthermore, there is a perfect overlapping with the reflectance curve of the red ochre according with the iron presence.

The curve of the green area shows a broad reflectance band at 570 nm that is characteristics of the green earth pigment, according with the presence of iron. The lower values of reflectance respect to the reference curve can be attributed to the low thickness of the green paint and thus to the contribution of the background. Green earth is the most common green pigment used in the past together with copper green. , The combination of two pigment yellow + blue (e.g. yellow earth and Egyptian blue) and yellow + black is also documented [14].

The blue curve is characterized by the absorption at 560, 628 and 790 nm, characteristic of the electronic transitions of the Egyptian blue [15]. The presence of a shoulder band around 570 nm could be due to the presence of a small amount of the green earth pigment probably mixed with the Egyptian blue to tailor the color of water.

IV. CONCLUSIONS

The performed investigation reveals the presence of earths and Egyptian Blue as pigments. Thanks to the high sensitivity of multispectral imaging based on VIL technique, it is possible to observe the original distribution of the blue, helping not only to imagine the ancient fashion of the painting but also to reconstruct the pictorial technique and provide an overview of the conservation state of the painting layer. The non-invasive investigation permits the identification of all pigments: red ochre, green earth and Egyptian blue, recognizing also the area where two pigments were mixed together.

The obtained 3D models and 2D orthophoto-mosaics were used as a support for the compositional study of the painted surface and its degradation. In fact, the 3D models, which include both the painted layers and their supports, can be considered as faithful digital replica with a quality comparable to real objects. On this basis, it was possible to create, for each fragment, a map of degradation, marking fractures, cracks and any other detail useful for the restoration of the artefacts.

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