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THE MEDIAEVAL CRYPT OF SAINT SEPULCHRE IN ACQUAPENDENTE (ITALY) STUDY AND PHOTOGRAMMETRIC DOCUMENTATION OF THE PAINTED SURFACES

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Abstract

The aim of this paper is the study of the paintings on architectural elements in the mediaeval crypt of the 'Santo Sepolcro' (Holy Sepulchre) in the Cathedral of Acquapendente (Northen Lazio, Italy). The scientific approach has been developed through the mapping of the traces of original painting still visible on the architectural elements of the crypt. The mapping was done by analysing the paint pigments and binders still preserved in small fragments on the architecture of the crypt. Then painting samples were taken for laboratory analysis aimed at identifying the composition of pigments and binders. These samples were examined through micro-stratigraphic analysis, Fourier transform infrared spectroscopy and X-ray fluorescence spectroscopy. To reach the established goal, in situ documentation was performed by visible and ultraviolet fluorescence photogrammetry. In order to obtain a reconstructive three-dimensional model of the architectural elements with colours as much similar as possible to the originals, the obtained model was rendered using the colour palette gathered by the scientific analyses.

Keywords: medieval, analysis, digital, 3D, documentation

1. Introduction

The investigation of cultural heritage composition is nowadays a well-consolidated approach aiming at charactering original and restoration materials to better address the conservative procedures [1-6]. The study of these materials could supply information about construction techniques, conservative history of the artefact, possible transformation of the original appearance of the artwork, etc. Today, thanks to the potentialities of non-invasive multispectral techniques, it is possible to obtain a lot of information about artworks without sampling and to address the eventual taking of samples [7-9].

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Figure 1. Positioning of the medieval churches with painted crypts in Central Italy. From Google Earth (accessed: September 6, 2019).

Figure 2. A view of the crypt of Saint Sepulchre. The right side of the sacellum is visible in the left part of the image.

Figure 3. Photographs of columns and capitals with traces of red, yellow and white colours.

Having in mind these general assessments, the topic of this paper is the study of the paintings on the architectural elements in the mediaeval crypts with a particular focus on the crypt of Holy Sepulchre of Acquapendente, a little town between Lazio, Umbria and Toscana regions, in Central Italy, where other churches exhibit similar painted architecture (Figure 1). The crypt of Acquapendente has been dated back to the 9^{th}-10^{th} century and is divided into nine naves by twenty four columns some of which still exhibit the original capitals (Figure 2) [10-12].

The great relevance of the crypt is linked to the presence of the Holy Sepulchre, also named *sacello* (sacellum), which is considered by several historians to be the oldest copy of the Holy Sepulchre of Jerusalem still surviving in Europe [13].

Several mediaeval crypts today exhibit architectural elements without paintings often because they were removed during restoration or other interventions [14]. Fortunately, in other cases, the original colours are still visible and it could become possible to reconstruct the original appearance of the architectural decorations of the mediaeval crypts.

This is the case of the crypt of Acquapendente, located below the Cathedral of Saint Sepulchre [15]. In fact, by carefully observing the architectural elements of the crypt, it has been possible to see a lot of colour traces that may be referred to the original painting apparatus (Figure 3) [11].

In order to investigate the colour traces in the architectural elements of the crypt, according to a well-consolidated diagnostic approach, a careful documentation in situ was performed through visible and ultraviolet fluorescence photography (UVF), this last being particularly useful to highlight the possible presence of organic materials [16-18].

Photographic documentation was made according to a photogrammetric approach in order to obtain 3D digital models of the capitals. This approach allows for a diagnostic documentation to be gathered and for the possibility to elaborate tri-dimensional re-constructive models [6]. These models can be processed by 3D graphic software for obtaining a photorealistic re-construction of the original painting colour detected with the traditional techniques, i.e. XRF spectroscopy, cross-section, FTIR etc.

Video microscope acquisitions were also gathered in situ for better highlighting the surface colours. X-ray fluorescence spectroscopy (XRF) was also performed for pigment analysis, being a non-invasive technique widely used in cultural heritage for pigments characterization [19-24]. After these non-invasive analyses, some micro-samples were taken for laboratory analysis through optical microscopy and Fourier transform infrared spectroscopy in order to investigate the painting stratigraphy and characterize the composition of pigments and binders [25].

The combined use of the above mentioned techniques allowed for obtaining complete information about colour traces and for proposing a possible painting reconstruction.

2. Experimental

Visible and UVF photography was performed by a Nikon D5300 digital camera equipped with 60 mm focal zoom lens. Visible lighting was obtained through 250 W incandescent lamps. For obtaining UV fluorescence, the painting was irradiated with two 365 nm filtered sources, operating at 3000 mW positioned at 45° in respect to the surface. In front of the camera lens, Kodak Wratten filter 2B and 85B were added to remove undesired component of spectrum.

Video microscope acquisitions were gathered by a Mirazoon MZ 920 portable digital instrument equipped with zoom lens ranging from 50 to 200 magnifications.

X-ray fluorescence spectroscopy was performed by the portable equipment Surface Monitor II (Assing™). The measuring conditions were the following: Ag tube operating at 40 kV, current 76 μA, acquisition time 60 s.

Micro-sample cross sections were examined under the Zeiss Axioskop polarizing microscope equipped with Zeiss AxioCam digital camera. Cross-sections were examined also under ultraviolet radiation by a mercury vapour lamp connected to the microscope in order to observe the induced fluorescence of materials.

Organic materials were investigated through infrared spectroscopy by using a Nicolet Avatar 360 spectrometer. The instrument operated in the MIR spectral range (400-4000 cm^{-1}) with a resolution of 4 cm^{-1}. Micro-samples were mixed with spectrophotometric grade potassium bromide (KBr) and inserted in the DRIFT (Diffused Reflectance Infrared Fourier Transform) accessory. KBr was used also as background.

Three-dimensional model was obtained using Agisoft PhotoScan® software, as widely explained in a previous published paper [6]. Agisoft Photoscan® is a user-friendly software package providing a comprehensive Structure from Motion approach which integrates digital photogrammetry and the computer vision facilities with the ability to process unsorted photographs into photorealistic, geometrically-accurate, and georeferenced 3D models.

The photogrammetric workflow produced a mesh that was then rendered with the same software in order to create the photorealistic 3D model. For obtaining the 3D model with the distribution of the colour traces detected during the investigation of paintings, the mesh was exported into 3DS MAX software to texturize the capitals with the pigment colours derived from the analysis above described, i.e. videomicroscope, macro-photographs, cross-sections. The texture obtained by a graphic software (28x21 cm, resolution 72 pixel/inch) were re-modelled on the capital mesh through 3DS MAX and V-Ray software.

3. Results and discussion

The colours detected on the architectural elements of the Saint Sepulchre crypt are red, yellow and white (Figure 4). The videomicroscope acquisitions suggest the use of a simple palette probably made of natural ochre and calcite based pigment for white.

Figure 4. Videomicroscope acquisitions of red, white and yellow colours at magnification 50x.

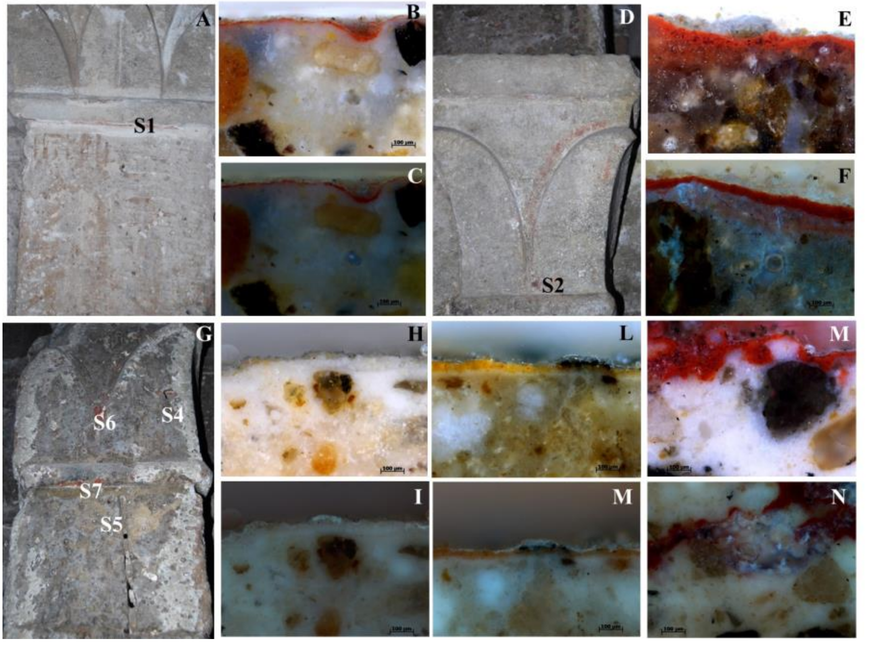

Figure 5. Photographs of the sampling points and microphotographs of cross-sections under visible and ultraviolet fluorescence: A) sampling S1, B) and C) cross section of sample S1 under visible and UV, D) sampling S2, E) and F) cross section of sample S2 under visible and UV, G) samplings S4-S7, H) and I) cross section of sample S4 under visible and UV, L) and M) cross section of sample S5 under visible and UV, M) and N) cross section of sample S7 under visible and UV.

The results of the analysis performed on the micro-samples are collected in the Table 1.

Table 1. Results of the analysis performed on the micro-samples collected from the architectural elements of the crypt.

Sample	Colour	Analysis	Results
S1	Red + white	XRF, FTIR, cross-section	Ca-based white and red ochre on a plaster made of lime and sand. Traces of gypsum.
S2	Red	XRF, FTIR, cross-section	Red ochre applied on a thin layer of plaster with addition of protein binder.
S3	Yellow-orange	XRF, FTIR	Fe-oxide based pigment, calcium carbonate and traces of gypsum.
S4	Yellow + white	XRF, cross-section	Fe-oxide based pigment, calcium carbonate, plaster made of lime and sand.
S5	Yellow	FTIR, cross-section	Yellow ochre on plaster made of lime and sand (presence of $CaCO_3$).
S6	Red-brown	XRF	Fe, Mn and Ca detected suggesting a brown earth.
S7	Red	XRF, FTIR, cross-section	Presence of gypsum suggests a restored area. White plaster made of lime and sand, red ochre. Cr was also detected.

They confirmed the presence of calcium carbonate in the plaster and the use of iron oxide pigments. The presence of gypsum (traces or main compound, as in sample 7), suggests the use of cement, containing sulphates, in previous intervention. The presence of traces of chromium in sample 7, suggests that this element could be part of the constituent materials.

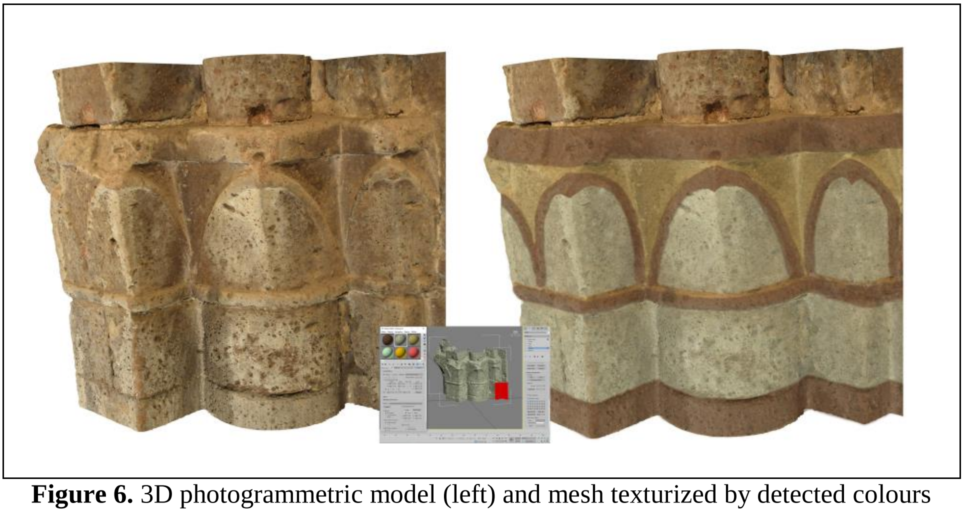

Figure 6. 3D photogrammetric model (left) and mesh texturized by detected colours (right). The GUI (Graphic User Interface) of 3DS Max is also shown in the figure.

In fact, the traces of potassium, titanium and manganese, associated to iron, can be attributed to earth and ochre and to the stone constituting the architecture of the crypt. In only one sample (S7) chromium was measured by XRF spectroscopy. This element can be associated both to original material and to restoration pigment (chromium based pigments such as chromium oxide and lead chromate); the absence of lead suggests the first hypothesis, i.e. chromium is part of the original materials.

As shown in Table 1, five micro-samples were used for obtaining cross-sections, particularly useful to study the painting technique and to characterize the plasters [26, 27]. Photomicrographs of these five samples are displayed in Figure 5 together with the sampling points. Apart from sample S2, in the other examined cross-sections the plaster appeared white with coarse aggregates rich of limonitic minerals

The last step of the work is the reconstruction of the possible original appearance of the capital colours. In Figure 6 the result of the photogrammetric approach and of the colours reconstruction is shown on one capital where the traces of pigments were more representative of the possible original palette (yellow, red and white colours).

4. Conclusions

The results presented in this paper highlighted an interesting topic that is often irrelevant in history of art and architecture studies: the presence of pictorial apparatus in medieval crypts. The capitals, frames, walls were painted by simple decorative elements created generally with few colours such as red, yellow, white and black.

Pigments were applied on thin lime based mortars or directly on the stone, without ground layer, by protein binder.

Photographic documentation through visible and ultraviolet fluorescence photography helped in mapping the traces of the original paintings. Spectroscopic techniques gave information about pigments and binder composition. Cross-section analysis supplied knowledge of the stratigraphy of the paintings.

Scientific analyses and digital photogrammetry have provided data to attempt the reconstruction of the painted surface in a capital of the crypt.

The results encourage us to consider the scientific approach as valid and potentially usable for the mapping and reconstruction of the entire pictorial apparatus of the architectural elements in the medieval crypt of the Holy Sepulchre of Acquapendente.

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References

[1] A. Lo Monaco, C. Giagnacovo, C. Falcucci and C. Pelosi, Eur. J. Sci. Theol., **11(2)** (2015) 73-84.

[2] C. Pelosi, L. Calienno, D. Fodaro, E. Borrelli, A. R. Rubino, L. Sforzini and A. Lo Monaco, J. Cult. Herit., **17** (2016) 114.

[3] F. Balletti, A. Lo Monaco, G. Agresti, L. Calienno and C. Pelosi, Eur. J. Sci. Theol., **13(2)** (2017) 13-24.

[4] F. Balletti, C. Pelosi, A. Schirone, T. Nedelcheva, S. Regis and A. Lo Monaco, Eur. J. Sci. Theol., **14(2)** (2018) 121-129.

[5] C. Pelosi and L. Lanteri, Eur. J. Sci. Theol., **13(2)** (2017) 1-2.

[6] L. Lanteri, G. Agresti and C. Pelosi, Heritage, **2** (2019) 207-215.

[7] G. Luciani, C. Pelosi, G. Agresti and A. Lo Monaco, Eur. J Sci. Theol., **15(3)** (2019) 209-220.

[8] S. Laureti, C. Colantonio, P. Burrascano, M. Melis, G. Calabrò, H. Malekmohammadi, S. Sfarra, M. Ricci, C. Pelosi, J. Cult. Herit., **40** (2019) 1-16.

[9] L. Lanteri and G. Agresti, Eur. J. Sci. Theol., **13(2)** (2017) 35-40.

[10] S. Nardini, *Acquapendente. Guida alla scoperta*, Annulli Editori, Grotte di Castro (Italy), 2008, 29-34.

[11] R. Chiovelli and S. Pifferi, *I colori ritrovati, in Il Sacello della Cattedrale di Acquapendente tra Canterbury a Roma. La copia più antica del Santo Sepolcro*, C.I.S.Sa.S. Centro Internazionale di Studi sul Santo Sepolcro, Acquapendente, 2014, 31-56.

[12] R. Chiovelli, *Cronologia delle vicende storiche ed architettoniche della Basilica del Santo Sepolcro*, in *Il Sacello della Cattedrale di Acquapendente tra Canterbury a Roma. La copia più antica del Santo Sepolcro*, C.I.S.Sa.S. Centro Internazionale di Studi sul Santo Sepolcro, Acquapendente, 2014, 111-148.

[13] M. Lewy, *Il Sacello di Acquapendente è la più antica imitazione del Santo Sepolcro di Gerusalemme rimasta in Europa?*, in *Il Sacello della Cattedrale di Acquapendente tra Canterbury a Roma. La copia più antica del Santo Sepolcro*, C.I.S.Sa.S. Centro Internazionale di Studi sul Santo Sepolcro, Acquapendente, 2014, 15-22.

[14] G. Carbonara, *La reintegrazione dell'immagine. Problemi di restauro dei monumenti*, Bulzoni, Roma, 1976, 181-183.

[15] L. Lanteri and C. Abramo, Eur. J. Sci. Theol., **14(1)** (2018) 173-180.

[16] C. Pelosi, L. Lanteri, G. Agresti and U. Santamaria, Eur. J. Sci. Theol., **12(1)** (2016) 271-281.

[17] S.R. Amato, D. Bersani, P.P. Lottici, P. Pogliani and C. Pelosi, Archaeometry, **59(6)** (2017) 1050.

[18] C. Pelosi, G. Agresti, M. Andaloro, P. Baraldi, P. Pogliani, U. Santamaria, M.F. La Russa, S.A. Ruffolo and N. Rovella, Archaeometry, **58(4)** (2016) 659.

[19] G. Capobianco, C. Pelosi, G. Agresti, G. Bonifazi, U. Santamaria and S. Serranti, J. Cult. Herit., **29 (**2018) 19.

[20] M. Mantler and M. Schreiner, X-Ray Spectrom., **29(1)** (2000) 3.

[21] P. Moioli and C. Seccaroni, X-Ray Spectrom., **29(1)** (2000) 48.

[22] R. Cesareo, S. Ridolfi, M. Marabelli, A. Castellano, G. Buccolieri, M. Donativi, G.E. Gigante, A. Brunetti and M.A. Rosales Medina, *Portable systems for energy-dispersive X-ray fluorescence analysis of works of art*, in *Portable X-ray fluorescence spectrometry: capabilities for in situ analysis*, P.J. Philip & M. West (eds.), RSC Publishing, Cambridge, 2008, 206–246.

[23] K. Janssens, G. Van der Snickt, F. Vanmeert, S. Legrand, G. Nuyts, M. Alfeld, L.Monico, W. Anaf, W. De Nolf, M. Vermeulen, J. Verbeeck and K. De Wael, *Non-invasive and non-destructive examination of artistic pigments paints, and paintings by means of X-ray methods*, in *Analytical Chemistry for Cultural Heritage*, R. Mazzeo (ed.), Springer, Cham, 2016, 77-128.

[24] A.N. Shugar and J.L. Mass (eds.), *Handheld XRF for Art and Archaeology*, University Press, Leuven, 2012.

[25] M.R. Derrick, D. Stulik and J.M. Landry *Infrared Spectroscopy in Conservation Science*, The Getty Conservation Institute, Los Angeles, 1999, 252.

[26] S.R. Amato, D. Bersani, P.P. Lottici, P. Pogliani and C. Pelosi, Archaeometry, **59(6)** (2017) 1050.

[27] C. Pelosi, G. Agresti, M. Andaloro, P. Baraldi, P. Pogliani, U. Santamaria, M.F. La Russa, S.A. Ruffolo and N. Rovella, Archaeometry, **58(4)** (2016) 659.