# Book of Abstracts

5th BM-Mellon Symposium

# A Closer Look at Murals

## Recent Advances in the Conservation and Scientific Investigation of Wall Paintings

A Symposium in Conservation Science held with support from the Andrew W. Mellon Foundation

Stevenson Lecture Theatre, Clore Centre, The British Museum

30 May 2019

# ORAL PRESENTATIONS

# SESSION 1

# INNOVATIVE CONSERVATION TREATMENTS (1)

## Keynote lecture

# Nanoparticles and chemical gels for the consolidation and cleaning of wall paintings

Piero Baglioni

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Works of art that constitute our cultural heritage are subject to deterioration. Their surfaces interacting with the environment are the most prone to aging and decay; accordingly, soiling is a prime factor in the degradation of surfaces, chemical and mechanical degradation are often associated to soiling and lead to the disfigurement of a piece of art. The effects of these processes are usually strongly amplified in the presence of protective coatings (mainly acrylic and vinyl polymers), applied in previous restoration treatments.

We pioneered the synthesis and the application of several advanced systems for the consolidation and the cleaning of works of art, as hydroxides nanoparticles, microemulsions and chemical/physical gels.

In this talk, examples from conservation workshop of Beato Angelico, Piero della Francesca, Picasso, Pollock, de Chirico, etc., will be highlighted on inorganic nanoparticles for the consolidation of wall paintings and stones and example of new chemical gels for the cleaning of painting and in particular modern and contemporary art.

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[1] Chelazzi D., Giorgi R., Baglioni P. (2018). Microemulsions, Micelles and Functional Gels. How Colloid and Soft Matter Preserve Works of Art. ANGEWANDTE CHEMIE. INTERNATIONAL EDITION, p. 1-7.

[2] Baglioni M., Montis C., Chelazzi D., Giorgi R., Berti D., Baglioni P. (2018). Polymer Film Dewetting by Water/Surfactant/Good-Solvent Mixtures: A Mechanistic Insight and Its Implications for the Conservation of Cultural Heritage. ANGEWANDTE CHEMIE. INTERNATIONAL EDITION, vol. 57, p. 1-6.

[3] .Baglioni, M., Montis, C., Brandi, F., Guaragnone, T., Meazzini, I., Baglioni, P., Berti, D. (2017). Dewetting acrylic polymer films with water/propylene carbonate/surfactant mixtures - Implications for cultural heritage conservation. PHYSICAL CHEMISTRY CHEMICAL PHYSICS, vol. 19, p. 23723-23732.

[4] Raudino M., Giamblanco N., Montis C., Berti D., Marletta G., Baglioni P. (2017). Probing the Cleaning of Polymeric Coatings by Nanostructured Fluids: A QCM-D Study. LANGMUIR, vol. 33, p. 5675-5684.

[5] Mastrangelo R., Montis C., Bonelli N., Tempesti P., Baglioni P. (2017). Surface cleaning of artworks: Structure and dynamics of nanostructured fluids confined in polymeric hydrogel networks. PHYSICAL CHEMISTRY CHEMICAL PHYSICS, vol. 19, p. 23762-23772.

[6] Baglioni P., Carretti E., Chelazzi D. (2015). Nanomaterials in art conservation. NATURE NANOTECHNOLOGY, vol. 10, p. 287-290.

# A new grouting system for the preservation of indigenous paintings on rock supports

Andrew Thorn

*ARTCARE, Australia*

Indigenous paintings applied to natural rock supports, constitute the most prolific painting type on the planet, found on every continent and applied to almost every rock type. Such paintings have been dated to over 25,000 years, in a tradition that has continued until at least the 1980's.

The rock supporting such paintings is chosen for its suitability for paint application rather than its long-term durability. Suitable surfaces will not always be the most stable as paintings will be applied to eroded niches and cracks in the rock to suit compositional requirements.

Almost every rock type has been painted on with sandstone, granite and limestone being the more common, but marble, tuff and many other variable rock types being chosen.

When considering the stabilization needs of a repair material for rocks that support paintings surviving for thousands of years in uncontrolled environments, one early thought is that the treatment itself must be durable. Many of the criteria for a satisfactory grout material have been well articulated for indoor mural paintings of the European tradition[1]. These are perfectly suited to lime based mural paintings not exposed to extreme outdoor environments. Sandstones have chemical and physical components that require specific grout and mortar design. Lime based grouts present negative attributes when applied to exposed siliceous rocks, namely the propensity of calcium carbonate to convert to gypsum, and the nutrient contribution of calcium that can result in a flourishing bio-colony after only a few years, rendering all attempts at colour matching futile.

Another limitation of lime-based grouts, shared with other mineral based grouts, is their inability to form a cohesive grout in very narrow voids that necessitate the use of very fine granulometry.

The research outline in this paper describes a grout and mortar system relying on the adhesive and cohesive properties of lithium silicate, particularly at fine granulometry constraints. The research describes the controlled strength of mortars and their ability to support biota in parallel growth habit with surrounding rock. Mortars have been developed for both siliceous and calcitic rocks.

Lithium silicate grouts remain structurally stable when injected into voids as small as 200 microns and can disperse effectively into much finer voids. Flow properties and the ability to penetrate debris filled voids have been explored.

Lithium silicate is also an effective consolidant, imparting similar granular consolidation as that achieved with ethyl silicate, but due to its rapid cure and in an entirely hydrophilic state, several benefits will be discussed, including the continuity of treatments form consolidant through grout to mortar without interruption. All phases can be applied to wet surfaces.

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[1] Ferragni D, Forti M, Malliet J, Mora P, Teutonico JM, and Torraca G. Injection grouting of mural paintings and mosaics. In NS Brommelle, EM Pye, P Smith and G Thomson (eds), IIC Preprints, Paris, 2-8 September 1984, 110-116.

# Wall painting by Gaudenzio Ferrari, 1507: polysaccharide gel for the selective cleaning treatment

Anna Borzomati[1], Massimiliano Caldera[2], Emanuela Ozino Caligaris[3], Anna Piccirillo[4]

[1] *Freelance Conservator, Rome, Italy*
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[3] *SABAP-NO, Italy*
[4] *Centro Conservazione e Restauro "La Venaria Reale", Italy*

The wall paintings treated in this restoration project are part of the western side of the Chapel and were removed from the wall in 1960 due to their highly degraded conditions.

The upper part of the paintings was covered by a dark gray substance. Chemical analyses identified this layer as an organic fixative, most probably wax based, and a protein based fixative probably glue.

Upon completion of the restoration work, a notebook was found bearing the title "Restoration of frescoes" carrying the notes of a student of the restorer who had carried out the treatment in 1960. All information regarding previous conditions of the paintings, deduced through direct observation, was confirmed by the treatment report in the note book.

To clean the beautifully delicate and compact surfaces of the fresco, differentiated gels were required: in particular a polysaccharide based gel (Agar-Art) was used, but in a new modified version, prepared to a smooth creamy texture for better contact with the surface.

The gel was dissolved in 4% water, heated twice to a temperature above 85 °C and mechanically deconstructed during the cooling phase, using a whipping tool by hand in order to trap more air in the gel, thus producing a very soft foam.

The wax was removed from the surface by adding a 20% solvent mixture[1] to this "gel cream" and applied over a sheet of "English tissue" (20 minutes of contact).

Cleaning was carried out in very small portions in order to control the action of the gels: approximately 120 applications for a surface of approx 4.73 $m^2$.

For the removal of the facing[2] and for removal of glue fixative residues, the Agar-Art gel was used in the traditional way and was therefore dissolved in 4% hot water and was applied to the surface whilst still lukewarm with a brush in its liquid phase. The film was allowed to dry to a gel texture and was then removed. The surface was further cleaned with hot water and soft sponges.

For the removal of the dark layer covering the flesh tones of faces, a clay based gel was used LaponiteRD®[3]

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[1] Selected ternary mixture: Isopropyl alcohol15%, Acetone 15%, Isottano 70%, characterized by values: Fd 81, Fp 8, Fh 11.

[2] That was made in two applications: the first with "English tissue" and cellulose ether: methylhydroxyethylcellulose Tylose®MH300 (Sigma-Aldrich now Merck) at 5% in H2O, the second, with the same Tylose in the same % and cotton canvas.

[3] Purified colloidal synthetic clay.

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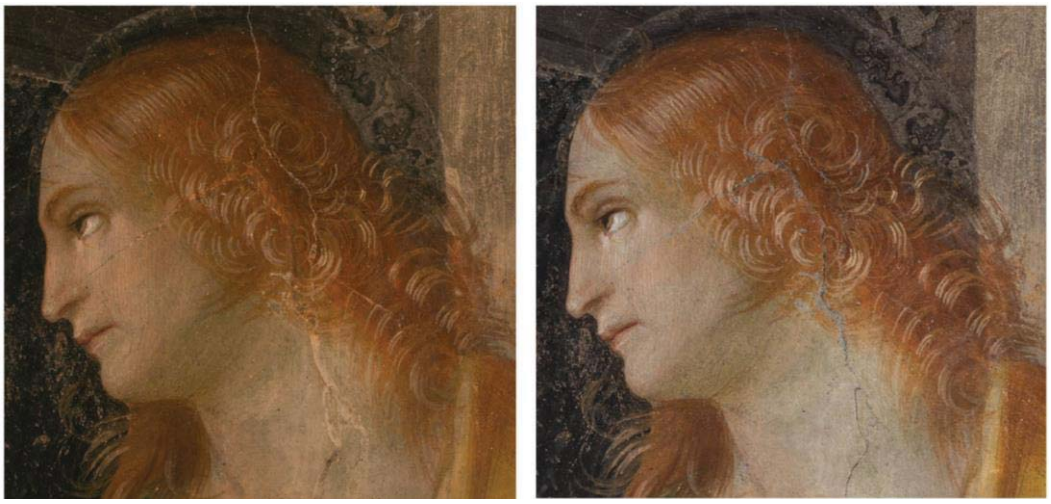


Detail of before and after cleaning.

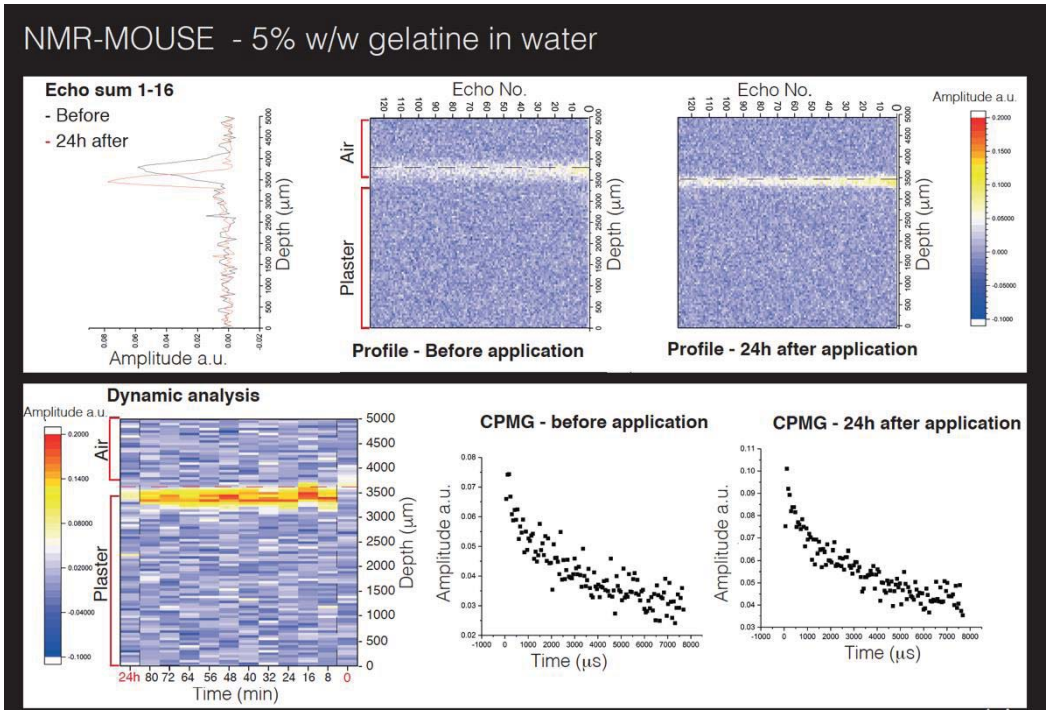
# Tracking the penetration and deposition of organic adhesives: an assessment with unilateral NMR and fluorescent labelling

Amarilli Rava[1], Aviva Burnstock[1], Karolina Soppa[2], Emma Richardson[3]

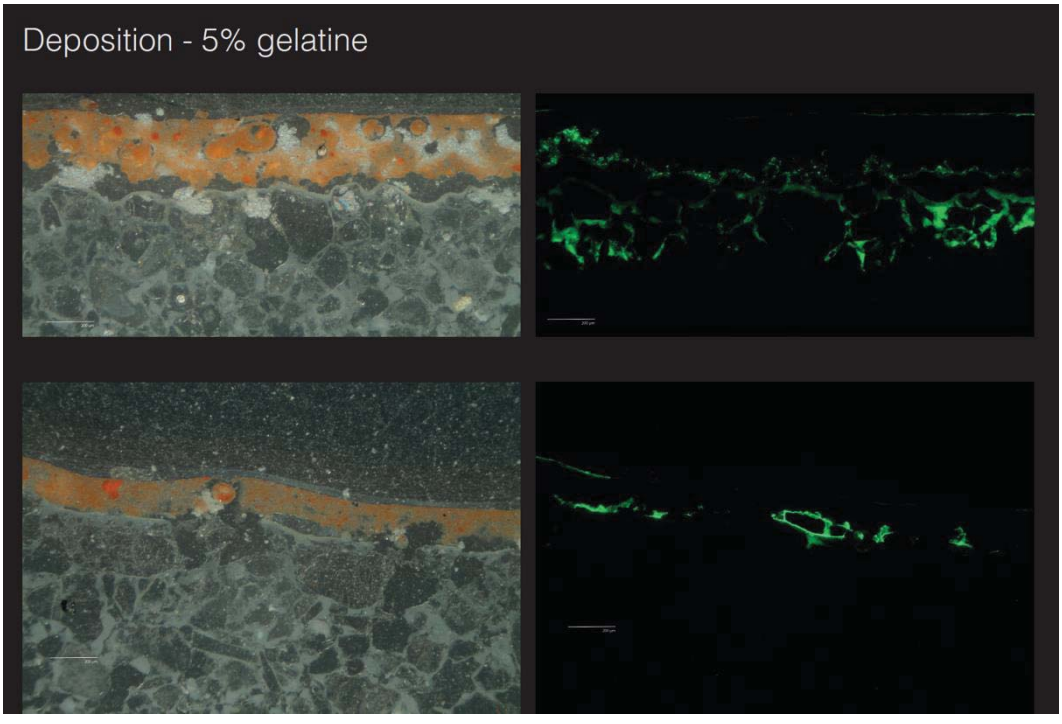
[1] *The Courtauld Institute of Art, United Kingdom*
[2] *Bern University of Applied Sciences, Switzerland*
[3] *Department of History of Art, University College London, United Kingdom*

Flaking of paint layers is a widespread deterioration phenomenon that conservators face on a regular basis. Traditionally, lack of adhesion in wall paintings is addressed by treatment with adhesive materials, applied behind or above the lifted paint layers. In order for the intervention to be successful, the adhesives must be deposited at the interface between the lifted paint and underlying support; penetration and deposition are therefore of paramount importance. The current study investigated invasive and non-invasive methods to determine penetration and deposition of adhesives for readhesion interventions. The research was undertaken using a combination of non-invasive unilateral NMR techniques and fluorescent labelling of polysaccharide and proteinaceous materials. Gelatine, a common material used in conservation and Jun Funori, a purified polysaccharide extracted from the red algae genus *Gloiopeltis Furcata*, were injected between organically bound paint layers and lime-based plaster supports. Results show that unilateral NMR can be used to gather real-time information on the penetration and evaporation of the carrier and ultimately the deposition of the adhesive in the stratigraphy as well as tracking solvent penetration and evaporation.

For this research, depth profiles of experimental replicas of wall paintings with flaking paint were assessed before, during and after the application of the two adhesives at a range of concentrations. Analysis undertaken 24 hours after treatment clearly showed that the adhesive had dried, seen as a shorter relaxation time, demonstrating that the water component was lost from the matrix. Deposition of the flourochrome tagged adhesives was assessed through imaging of cross and thin sections after treatment. Gelatine was tagged with 5- (6-) Carboxyfluorescein Succinimidyl Ester (5(6)-FAM SE), while 5- (4,6-) Dichlorotriazinyl Aminofluorescein (5-DTAF) was used for Jun Funori. Results show that concentration of the adhesives is affecting rheological and surface tension properties of the adhesives and can play a crucial role in system penetration and adhesive deposition.




NMR-MOUSE analysis showing the sample depth profile before and after adhesion of the paint layer (above), dynamic analysis after adhesive injection and relaxation properties of the maximum amplitude slice in the sample before and after treatment.




Thin section of a sample treated with 5% gelatine tagged with 5(6)-FAM SE. The adhesive can clearly be seen bridging the paint layer and plaster. The penetration does not exceed the first few hundred of micrometres in the plaster layer.

# SESSION 2

# INNOVATIVE CONSERVATION TREATMENTS (2)

# Vertical Gels: Innovative methods and materials for the conservation of wall paintings in the tablinum of the House of the Bicentenary at Herculaneum

Leslie Rainer and Giulia Russo

*The Getty Conservation Institute, USA*

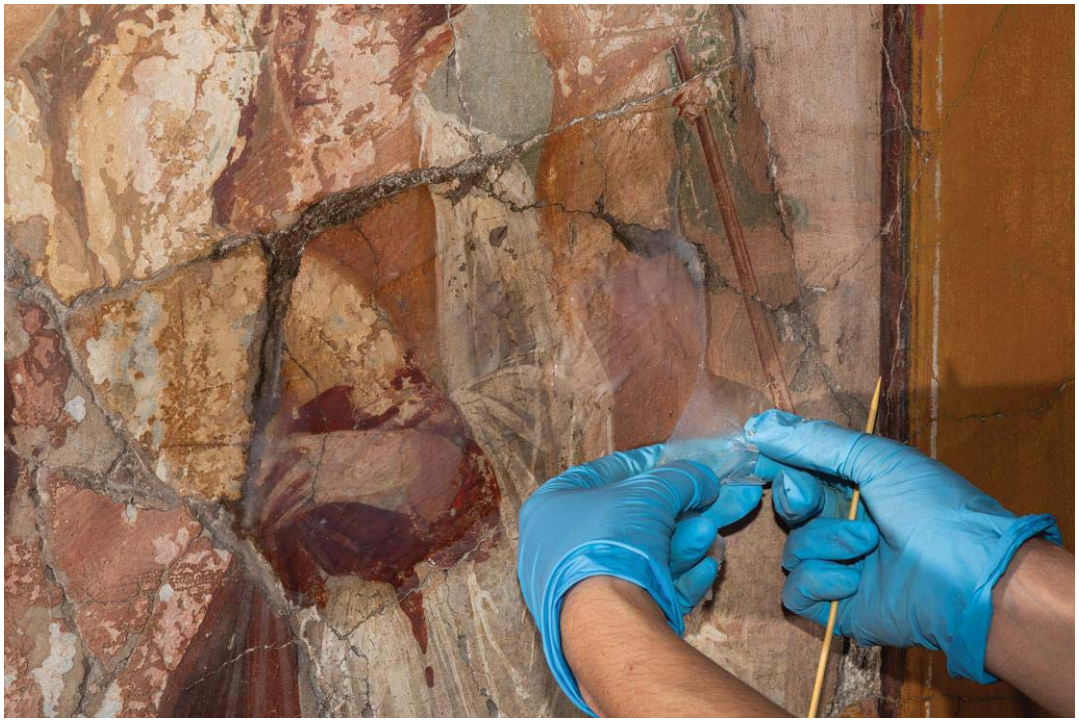
The wall paintings of the tablinum in the House of the Bicentenary at the archaeological site of Herculaneum are of high artistic quality, but suffering from severe deterioration. Due to the aesthetic and archaeological importance of the wall paintings and the conservation issues they demonstrate, the Getty Conservation Institute, in partnership with the Archaeological Park of Herculaneum and the Herculaneum Conservation Project is carrying out a pilot project to study and conserve these architectural surfaces.

The wall paintings in the tablinum show variable and complex conditions, including degraded wax and accumulation of other coatings applied in previous interventions, powdering and flaking paint, and salt efflorescence. These appear to be caused by a series of interconnected factors related to original painting technique, reconstruction methods, later intervention materials, and exposure to fluctuations of temperature and humidity in this semi-exposed space.

The conservation team adopted a methodological approach to the project based on background research, condition assessment, scientific study, and testing to develop appropriate and effective methods and materials for the treatment of the wall paintings. One of the main conservation challenges was the reduction of degraded wax and surface accumulation. A series of cleaning methods and materials was tested, including dry cleaning, free solvents, different gels, laser cleaning, and mechanical removal.

All methods trialed were evaluated using visual examination, digital microscopy and macro photography. Due to the variable condition of the wall paintings, the challenge was to find an efficient and effective treatment for the entire room. A further challenge was to find a substitute for toluene, one of the few materials found to be effective in early trials to remove the degraded beeswax and other coatings. The necessity to find a greener alternative to this solvent led the team to develop a method that combined an alternative solvent mixture applied in a rigid gel.

This presentation will discuss the selection of these two materials based on the following criteria: low toxicity, extended dwell time on the surface, stability of the gel and good adhesion to a vertical substrate, confinement of the cleaning action, ideal retention / release of the solvent, and no surface residue. This dual cleaning system provides a promising alternative to traditional cleaning systems for the conservation of wall paintings.



# Testing an Er:YAG laser for the removal of insoluble coatings on a fresco from Byzantine Egypt

Lucia Pereira-Pardo[1], Stephanie Vasiliou[2], Tracey Sweek[2], Lucia N. Melita[3], Diego Tamburini[3], Elisabeth O'Connell[4]

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A Byzantine wall painting (c. 6-7th century AD) depicting the Three Hebrews in the fiery furnace and Sts Cosmas and Damian was detached from its original location in Egypt and brought to the British Museum in the early 20th century. Recently, concerns about its stability led to the removal of the wall painting from display and the implementation of a full conservation programme.

The exceptional historic records preserved in the Museum allowed us to date previous restoration efforts. In 1916 the fragments of the wall paintings were embedded in plaster and the lacunae were restored. Technical imaging (UVL) and microscopy of the surface revealed the presence of extensive overpainting and a thick coating, identified by FTIR as an alkyd resin and shellac, likely from a second restauration in 1955. These conservation materials now appear yellowed, darkened and glossy, altering the appearance of the fresco.

Various cleaning methods were tested to remove the disfiguring old restoration materials. Dry cleaning with sponges and swabbing with solvents managed to reduce the surface dirt, but were ineffective at removing the coatings. However, tests with a recently acquired erbium laser (Er:YAG) proved extremely promising at reducing these layers in a gradual and controlled way. Hydroxyl groups (OH-) are the main absorbers at 2940 nm, therefore Er:YAG is an appropriate tool for the removal of old organic residues and it has been used successfully on paintings[1]. Wall painting mock-up samples were prepared, aged and irradiated to investigate the material's damage thresholds; the mechanism of the laser interaction with shellac was investigated and the pigments in the fresco were analysed to determine their sensitivity to the laser.

Safe working parameters could then be established and involved a combined approach: first the surface was irradiated and in a second step the softened residues of the coating were gently removed by swabbing or lifting with a scalpel. By adjusting the laser fluence and number of passes, the treatment was flexible enough to decide whether to remove the coating completely or just reduce it, depending on area of the fresco and the desired aesthetic outcome. The result was assessed by microscopy, technical imaging and colour measurements and it proved extremely efficient and safe for the original materials.

Further conservation stages involved the replacement of the heavy wooden backing with a lightweight aluminium panel, the removal of fills, consolidation of voids and

[1] Striova J, Castellucci E, Sansonetti A, Camaiti M, Matteini M, De Cruz A, Andreotti A, Colombini MP. Free-running Er:YAG laser cleaning of mural paintings specimens treated with linseed oil, beverone and Paraloid B72, in R Radvan, JF Asmus, M Castillejo, P Pouli, A Nevin (Eds), *Lasers in the Conservation of Artworks: Proceedings of the International Conference LACONA VIII*, Sibiu, Romania, 21-25 Sept 2009, London: Taylor and Francis, 2011. 85-91.

finally the retouching. The full treatment has been filmed and a time lapse video is available online[2].

a)

b)

Microphotographs of the painting surface during laser trials before (left) and after (right) the laser removal of a) coating and b) overpainting.

Images of fresco (EA73139) during removal of overpainting.

[2] https://www.youtube.com/watch?v=HCzqoTHoCPY&t=6s

# Preliminary studies for the assessment of the treatment of wall paintings: cleaning tests for the removal of acrylic coatings and the study of the content of soluble salts with agarose gels and statistical colour maps

Aleix Barberà Giné[1], Silvia Marín Ortega[2], Silvia Llobet Font[3], Pere Rovira Pons[4] and Maria José Gracia Tarragona[4]

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[4] *Centre de Restauració de Béns Mobles de Catalunya, Spain*

The archaeological site of Els Munts has structures from more than seven centuries of occupation. The high-imperial residential area consisted of a large peristyle and a two-storey building from which only remains part of the semi-subterranean plant formed by a corridor and some annexed rooms. In these structures there is the most important group of roman wall paintings preserved in Catalonia. The paintings were discovered in the 90s decade of the previous century and where consolidated with the application of a thick acrylic coating.

This general resin coating obstructs the natural porosity of the wall paintings and has become a serious conservation problem aggravated by the presence of soluble salts. The free solvent cleaning it is not recommended because of dissolving the resin it re-penetrates into the porous system thus becoming even more irreversible. On the other hand, traditional solvent surfactant gels aren't recommended on ionic surfaces.

Furthermore, under the resin film there is a layer of concretions that covers the paintings, therefore, in order to achieve a complete cleaning of the wall paintings, it is needed a double approach that includes both the elimination of the resin and the removal of the concretions.

The use of emulsified gelled systems (xanthan gum emulsion without any surfactant needed) may be the most efficient way to achieve in a one-step process both the removal of the acrylic resin and the concretions layer. This methodology was taken into account under the following premises: achieving the removal of the resin without its penetration into the porous system; avoiding the presence of residues of cleaning products used and reducing the amount of solvents in order to work in a more secure and sustainable way.

The methodology proposed to obtain the values of soluble salts is based on the conductivity tests of Dr. Richard Wolbers (Delaware University). Systematic analyses are carried out applying a disc of agarose gel that interacts for 20 minutes on the surface, previously moistened with a drop of deionized water. The extraction of soluble salts is analysed with the Horiba® LAQUAtwin EC11 conductivity meter.

These numerical results, although they are relativized by different factors (environmental conditions, the intrinsic characteristics of the walls, such as porosity, composition or added materials in previous interventions, or the methodology of the analysis) allow us to evaluate the relation between the state of conservation of the paintings and the greater or lesser concentration of salts. To facilitate the interpretation of the results, colour statistical maps are carried out to complement the traditional alteration maps on orthophotographs obtained through digital photogrammetry.

Cleaning test with the buffered solution in xanthan gum with a solvent emulsion.

# SESSION 3

## NEW METHODS FOR THE NON-INVASIVE MATERIAL ANALYSIS IN SITU

## Keynote lecture

# Invasive or non-invasive? Destructive or non-destructive? Methodological approaches applied to the study of wall paintings

Giovanni Verri

*The Courtauld Institute of Art, United Kingdom*

The Courtauld Institute of Art has been involved in the conservation of wall paintings for over two decades. Since its inception, the fundamental role of the relationship between science and conservation has been recognised as essential for an appropriate design of a conservation intervention. Therefore, the development of scientific approaches for the long-term survival of wall paintings has been the driving factor of both staff and students. With the needs of conservators in mind, the Institute has in particular focused on: the design of imaging techniques, the refinement of methodological protocols and the development of affordable, compact and transportable equipment for in-situ conservation projects. This paper will present past and present examples of the Courtauld's involvement in the field, by discussing historic and recent technical imaging and field microscopy for the conservation of wall paintings developed for and by its students.

# Scanning the invisible. IR reflectography and macro-XRF as part of an integrated approach to a wall painting from around 1500

Estelle De Groote[1], Klara Peeters[1], Geert Van der Snickt[2]

[1] *KIK-IRPA, Belgium*
[2] *University of Antwerp, Belgium*

In 2018 the Royal Institute for Cultural Heritage (KIK-IRPA, Brussels) has studied a wall painting depicting the Last Judgement, situated in the Church of Saint Martin in Aalst, East Flanders. The mural dates from around 1500 and stylistically, it relates to Early Netherlandish painting. Initially, the project focused on art-historical and technical research and on formulating a proposal for conservation treatment. Soon, this study made explicit the high artistic quality and authenticity of the wall painting, which called for further investigation. Two non-invasive scientific imagery techniques were therefore applied.

Firstly, KIK-IRPA used infrared reflectography to study underlying layers. IRR visualized some changes made during the painting process, which implies the work of a creative artist, rather than a copy. Furthermore, it was found that the artist used a painted underdrawing and sometimes hatchings in the shaded areas. This process could point in the direction of methods used by the Flemish Primitives.

Secondly, the University of Antwerp applied the 'chemical imaging' technique of scanning Macro X-Ray Fluorescence. MA-XRF is a variant of XRF imaging that allows the visualization of the distribution of elements in a flat, macroscopic sample in a non-destructive manner. The application of this method on the Last Judgement in Aalst constitutes one of the first-of-its-kind field studies on wall paintings. Notwithstanding practical challenges (size and weight of the scanning device; limited accessibility of the mural), the results of the scan proved valuable. They allowed for an identification and an insight into the distribution of the pigments present and offered a deeper understanding of the painting process (e.g. pentimenti). They gave rise to new research questions (e.g. zinc as an indicator of the possible use of lacquer with a siccative?), while enabling subsequent sample taking in a very precise and limited manner.

The use of a well-known and an innovative scientific imagery technique offered a valuable addition to detailed observation by the restorer and the art historian, as well as a point of departure for well-considered laboratory analysis. The combination of these approaches lead to a holistic understanding of this unique work of art.

# Holistic non-invasive multimodal investigation of Mogao murals

Sotiria Kogou[1], Golnaz Shahtahmassebi[1], C. S. Cheung[1], Alex Hogg[1], Haida Liang[1], Biwen Shui[2], Wenyuan Zhang[2], Bomin Su[2]

[1] *School of Science & Technology, Nottingham Trent University, United Kingdom*
[2] *Conservation Department, Dunhuang Academy, China*

The Mogao cave complex along the Silk Road is a UNESCO world heritage site that consists of 492 Buddhist cave temples covered with wall paintings with a total surface area of 45,000 $m^2$, spanning the period between $4^{th}$ and $14^{th}$ century. It is an art gallery that offers an immense resource for the study of art history, religion, politics, culture and technology along the Silk Road over 1000 years.

A holistic, non-invasive, multimodal imaging and spectral analysis of the painting materials and techniques along with the inscriptions in various languages, was used to help answer art history and conservation questions. Spectral imaging (multispectral and hyperspectral imaging) has increasingly been adopted in the imaging of paintings. The automated remote spectral imaging of wall paintings using PRISMS developed by the ISAAC lab at NTU has enabled high resolution imaging (submilimetre) from distances of tens of meters making it possible to collect spectral data over large areas with the potential of imaging entire caves. A machine learning algorithm has been developed to automatically classify areas of the same paint mixture on murals at Mogao caves. Complementary non-invasive spectroscopic techniques such as XRF and Raman spectroscopy were then applied on regions accessible at the ground level to confirm the identification of the pigments of each unique paint mixtures. Optical Coherence Tomography (OCT) imaging of the surface and subsurface layers was conducted to separate the final sketches from the preparatory drawings. In addition, OCT combined with spectral analysis helped the understanding of the conservation issues.

This paper illustrates a holistic method for the study of wall paintings using a combination of automated large area spectral imaging scans from a long distances and other complementary non-invasive 3D imaging and spectroscopic methods.

# Long range remote Raman spectroscopy for wall paintings

Yu Li, C. S. Cheung, Sotiria Kogou, Alex Hogg, Florence Liggins, Luke Butler, Haida Liang

*School of Science & Technology, Nottingham Trent University, United Kingdom*

Material analysis plays an important role in the study of wall paintings, providing crucial information to researchers in history and conservation. Some challenges specific to in situ and non-destructive investigation of wall paintings arise from the inaccessible heights and remoteness of the sites. Traditionally, scaffolds are used, which are costly, inconvenient and unstable for sensitive measurements that usually require long acquisition time. Therefore, spectroscopic techniques that can be conducted from the ground at a large distance (> 3 m) are required.

In the Imaging and Sensing for Archaeology, Art history and Conservation (ISAAC) Mobile Lab, a high resolution remote spectral imaging system (PRISMS) has been developed and successfully deployed at remote sites recording the spectral reflectance in the visible and near infrared of wall and ceiling paintings. However, reflectance spectroscopy alone is sometimes not enough to give definitive identification of pigments. Therefore, complementary techniques are needed. Raman spectroscopy identifies molecular structural fingerprints by observing spectral shifts, corresponding to molecular vibration modes, from the excitation wavelength of the incident laser. To address the above issue, we have developed a remote Raman system that can operate under ambient lighting conditions and at a distance of 4m is as sensitive as a conventional bench top micro-Raman system. Orders of magnitude lower than those of typical micro-Raman systems, the laser intensity of this remote Raman instrument significantly reduces the chance of laser-induced degradation.

In this work, we present a mobile remote Raman spectroscopy system with a working distance of 3m to 15m. This talk will focus on applications of point-based long-range Raman spectroscopy and macro-Raman mapping in combination with remote spectral imaging at St. Barnabas Cathedral in Nottingham and the Brighton Pavilion to address history and conservation research questions.

# SESSION 4

## TECHNICAL INVESTIGATIONS OF DATE, CONDITION, TECHNIQUES AND MATERIALS

# Radiocarbon dating of wall paintings containing lead white

Cyrielle Messager[1], Lucile Beck[1], Ingrid Caffy[1], Emmanuelle Delqué-Kolic[1], Jean-Pascal Dumoulin[1], Solène Mussard[1], Marion Perron[1], Christophe Moreau[1], Christian Degrigny[2], Vincent Serneels[3]

*[1] LMC14, LSCE/IPSL, CEA-CNRS-UVSQ, Université Paris-Saclay, France*
*[2] Haute Ecole Arc Conservation-restauration, Switzerland*
*[3] Département de Géosciences, Université de Fribourg, Switzerland*

Lead white is the major white pigment used in European paintings from the Antiquity to the beginning of the 20$^{th}$ century[1]. This pigment is mainly composed of two lead carbonates, cerussite ($PbCO_3$) and hydrocerussite ($2PbCO_3.Pb(OH)_2$). Both are essentially synthesized since the Greek period with metallic lead, vinegar and horse manure that release heat and $CO_2$. Many authors have reported recipes for the production of lead white over time. Theophrastus wrote the first known recipe in the 4th century BC. Isode of Seville (6$^{th}$-7$^{th}$ century), Heraclius (9$^{th}$ -10$^{th}$ century) and Peter of S. Audemar (13$^{th}$-14$^{th}$ century) are known for their compiling work and their painting manuals reporting lead white production during the medieval period.

Recently, our laboratory proposed an innovative protocol based on carbon extraction from lead carbonates in order to date ancient lead-based cosmetics by radiocarbon[2]. We propose here to apply the method to wall paintings containing lead white. Samples are prepared by thermal decomposition at 400°C[3] and carbon isotopes are measured with the LMC14-AMS ARTEMIS facility[4].

We have tested the robustness of our protocol on painting samples coming from two different medieval wall paintings. The first study case is the courtly decoration of Margaret of Bavaria's dressing room (end of the 14$^{th}$ century) at the Château de Germolles in Burgundy, France, property of her mother-in-law, Margaret of Flanders, Duchess of Burgundy. The second study case is the rood screen of the church of the Cordeliers of Fribourg (end of the 15$^{th}$/beginning of the 16$^{th}$ century), Switzerland. We successfully dated all the samples and we have obtained for each study case a good agreement with the expected date. We will present in detail our protocol and discuss the results.

By using radiocarbon in lead white, we provide a new tool for dating wall paintings. Radiocarbon dating can give access to the absolute chronology of successive or multiple layers of decoration and can evidence later restorations.

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[1] Stols-Witlox, M., Historical recipes for preparatory layers for oil paintings in manuals, manuscripts and handbook in North West Europe, 1500-1900 : analysis and reconstructions 1400-1900, Université d'Amsterdam, 2014.

[2] Beck, L. et al., Absolute dating of lead carbonates in ancient cosmetics by radiocarbon, Communications chemistry, 1, 34, 2018.

[3] L. Beck et al., accepted in Radiocarbon.

[4] Moreau C., et al., Radiocarbon 55(2-3), 331, 2013.

# Technical investigations into the wall paintings of the Badal Mahal at Bundi (Rajasthan)

Samuel Whittaker[1], Amarilli Rava[2], Giovanni Verri[2]

[1] *Opus Conservation, United Kingdom*
[2] *The Courtauld Institute of Art, United Kingdom*

Among the numerous wall painting schemes of Garh Palace complex at Bundi, executed at various dates from the late 16th or early 17th onward, are the finest and most significant surviving wall paintings in Rajasthan. Between 2015 and 2017 the Courtauld Institute of Art undertook a collaborative project with the Maharaja Jitendra Singh of Alwar and Kuldevi Ashapura Mataji Trust to document, investigate and assesses the original technology and conservation needs of the wall paintings at the Garh Palace. This paper focuses on the exquisite paintings of ragamala and other subjects in the Badal Mahal that forms the earliest and most important scheme at Bundi.

High resolution imaging coupled with structure-from-motion photogrammetric processing was used to accurately record the paintings. Non-invasive technical examination of the paintings with photo-induced fluorescence imaging, portable XRF, FTIR and Raman and invasive polarised light microscopy revealed an extraordinarily rich and complex technology, though one that would be all too susceptible to damage by misguided conservation treatments. The highly sophisticated painting technology includes some remarkable features, such as an extensive use of organic colorants and of transparent sheets of mica, attached to the surface with animal glue, and employed to create reflecting surfaces in areas depicting water, metal and glass.

These remarkable paintings are currently under threat from active agents of deterioration. Historic and ongoing water infiltration has seriously affected some of the painting, with core sampling determining the presence of liquid moisture in the building fabric. Comparison of their present condition with photographs published in 2005 shows significant loss in several areas.

Deterioration of the paintings includes powdering of the plaster and loss of the paint layer due to salt activity. Preserving these exquisite paintings for the future involves not only understanding their complex but fragile technology, but also rectifying the failure of the building envelope and stabilising their environment.


Left, detail of wall paintings on the south vault, the lamp is one of the few surviving ones with its original mica application. Right, also on the south vault, a surviving piece of mica can be seen, here meant to enhance representation of water.

From left to right, visible reflected, IR-false colour, UV-induced visible fluorescence, visible-induced IR fluorescence. Technical imaging indicated the extensive use of organic colorants and mineral pigments such as lapis lazuli.

# Daniel Maclise's wall paintings in the House of Lords. Ongoing collaborative research informs current conservation approach

Rebecca Tehrani[1], Richard Lithgow[2], Katey Corda[3], Samuel Whittaker[4], Elizabeth Woolley[4], Caroline Babington[5]

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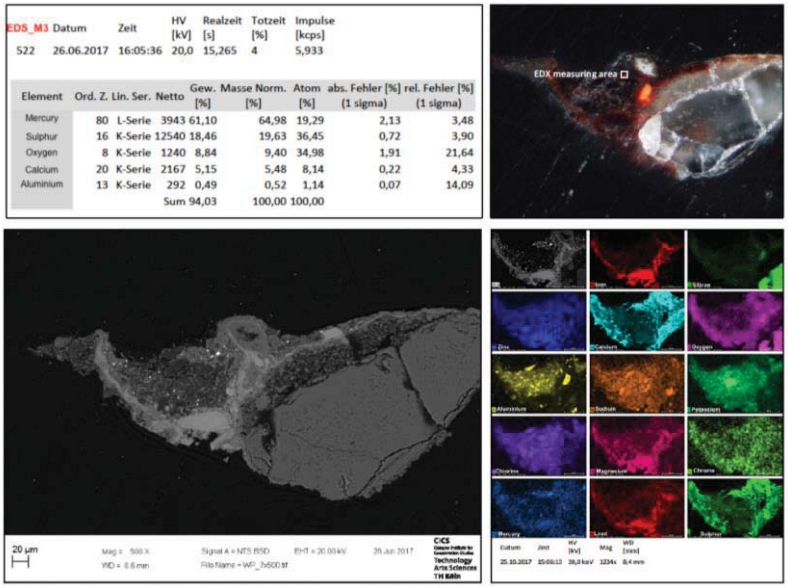
Ever since Daniel Maclise (R.A.) completed his two monumental water glass wall paintings in the Royal Gallery at the Palace of Westminster in 1865, their improved presentation has been the object of close attention. Over the past two centuries (1874 – 1964) deterioration, unsuitable coatings and changes in contemporary taste have resulted in numerous restoration and conservation treatments.

These past interventions, exacerbated by contemporary environmental conditions, have detrimentally affected their presentation and interpretation. As a result, a four-year conservation programme was commissioned by the Works of Art Committee of the Houses of Lords. This was informed by a preliminary collaborative research project between the Curator's Office and the Cologne Institute of Conservation Sciences (Cologne University of Applied Sciences), started in 2011. The characterisation of technique, materials and condition through archival research, non-invasive optical investigation and imaging, colourimetry as well as analytical techniques that included VIS/UV and polarised light microscopy, scanning electron microscopy (SEM) with energy-dispersve X-ray spectroscopy (EDX), Focal Plane Array-Fourier Transform-Infrared Spectroscopy (FPA-FTIR) and Fourier Transform-Infrared Spectroscopy (FTIR), as well as relighting trials laid the groundwork for a subsequent conservation project.

The research explored the painting's significance, function, use and initial presentation and reception within the Royal Gallery. Archival research allowed a detailed chronological account of previous interventions to be prepared with various aesthetic phenomena described. Added conservation materials were identified and located in their stratigraphic and topographic context, allowing them to be correlated with previous interventions.

Consequently, a novel use of a flash-based UV induced visible fluorescence imaging system was employed to map the entirety of the two 51m$^2$ paintings at high resolution. This was coupled with photogrammetric visible reflected imaging, processed with a structure-from-motion software package (Agisoft's Metashape). The resultant composite images were used to qualitatively assess the extent and type of added materials.

Building on these preliminary stages, choices over cleaning, reintegration and relighting approaches were explored through a pilot conservation phase. The preliminary research and conservation trials revealed the necessity to incorporate the differences in original water glass painting technique and physical history of the two wall paintings and develop individual conservation treatments for each. This has broken the well-established cycle of cleaning and recoating the paintings. The respective conservation approaches are now being successfully implemented and include; coating reduction to a resin varnish and heat treatment in combination with Evolon® microfilament fabric as a sorbent to reduce the detrimental impact of a wax coating.




Scanning electron microscopy and energy dispersive X-ray spectroscopy mapping (Zeiss EVO LS10; Carl Zeiss AG, Oberkochen, Germany) show the distribution of elements and indicate in this sample that a mercury pigment based paint layer was applied above a red earth pigment based paint layer.


Upper, composite images of the visible and UV-induced visible fluorescence (right) imaging used to map the surface both paintings. Lower, details showing the resolution achieved. The overall bluish haze to the UV images is a result of the presence of a resin varnish. Phases of repainting are also revealed, particularly evident in the face and body of the reclining figure.

# POSTERS

# Monitoring and controlling environmental factors

# Monitoring soluble salts new-formation on mural paintings surfaces. Testing on Leonardo Monochrome in Sforza Castle in Milan

Antonio Sansonetti[1], Cristiano Riminesi[1], Alessandra Botteon[1], Camilla Tartaglia[1], Alberto Felici[2], Mariarosa Lanfranchi[2], Cecilia Frosinini[2], Michela Palazzo[3], Francesca Tasso[4]

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Problems coming from soluble salts presence on mural paintings surfaces are well known. When the conservator is called at their removal through a desalination process, it is crucial to take into account the newly formed efflorescence. In fact in case of very fast kinetic of formation the general desalination aims should be re-considered.

The so called *Sala delle Asse* in Milan Sforza Castle is decorated by mural paintings on the walls and on the vault. Leonardo da Vinci designed tree trunks, branches, knots and coats of arms connected in an arbor. The current conservation works carried out by a multi-disciplinary staff since 2013 detected the presence of nitratine ($NaNO_3$), gypsum, epsomite and hexahydrite ($MgSO_4$ $7H_2O$ and $MgSO_4 \cdot 6H_2O$ respectively). These salt formations were removed from the surface during the preliminary works, several times from 2013 to 2018 (by dry and wet methods); the room's environmental parameters are not still stabilized for the exceptional duration of the conservation site, due to the complexity of the case, so they formed newly whitish and thin salt layers, visible only at a close observation, in particular in a restrict area in the proximity of a window in the so called *Monochrome* wall. Hence it is very important to monitor the soluble salts distribution and kinetic, in order to plan any further desalination.

Test areas were chosen and a special sampling procedure was designed in order to collect soluble salts avoiding any damage to the underneath plaster. BlitzFix® sponge cubes (3 cm sided) were loaded with a calibrated volume of MilliQ water and then gently rubbed on a given plaster surface. The same procedure was repeated on two rows (vertical line, then horizontal line) to survey the salts distribution, starting from the area where the whitish formations were detected at first. The sponge cubes were drained and the obtained solutions were analysed by means of Ionic Chromatography. Monitoring operations has been repeated every three months. The data were completed by means of SUSI device (System Unit Salinity Index), which is able to inform about the salt content, via non-destructive dielectric field measures. Reproducibility, precision and accuracy of the results are under evaluation. In a second step sponge cubes have been collected together with BlitzFix® clothes, made of the same polymeric material but 2 mm thick, in order to compare the results. Preliminary data are encouraging the staff, even if further cases on different murals should allow to implement the procedure.

# Nondestructive Diagnosis for the Conservation of Buddhist Temple Mural paintings in the Koryo Dynasty, Korea

Lee Hwa Soo, K. Seolhui, Y. Yeonggyeong

*Chungbuk National University, Korea*

Korea's National Treasure No. 46 Buseoksa Josadang Shrine Mural Painting was produced in the 3th year of King Woowang's rein in the Goryeo Dynasty and is a critical research material known for being the earliest Buddhist mural painting in Korea. It consists of 6 wall paintings that were decorated on earthen walls using dry painting technique. The mural painting was separated from the building in 1917, and then was repaired by a Japanese with plaster in 1927 and transferred to wooden frame. In 1985, cleaning with Impaco technique developed by the Florence Institute in Italy and fixation using Paraloid B-72 were conducted for it. This study presents the result of first non-destructive investigation into the preservation status of the mural painting to provide useful information for future preservation.

According to the investigation result, Buseoksa Josadang Shrine Mural Painting has prominent physical damage on painting layers such as cracks, peeling and exfoliation as well as excessive gloss and stains due to previous fixation. The walls mainly have traverse cracks on them, but they are also cracked, peeled off or damaged in the area where mortar was used for reinforcement. As even salt weathering is seen around the reinforced area, correction measures are necessary.

It is difficult to fully understand the wall structure due to wooden frame applied during the Japanese colonial period. However, the inside and outside of the walls were examined through GPR survey. The walls have at least two layers including finishing layer and wall layer composed of soil and mortar reinforcement.

Ultrasonic testing of wall surface showed that the walls themselves have good physical properties. However, ultrasonic velocities were very low around cracks on mortar-reinforced walls, which implies poor physical properties surrounding the reinforced area. In addition, thermal imaging identified exfoliation of painting layer from the surface of finishing layer.

Measurement of moisture on the surface found that the moisture content of each mural painting varies according to measurement period. On the other hand, the surface temperature of mural paintings tended to decrease in sequence from left to right, and the difference in surface temperature remained consistent regardless of measurement period.

Therefore, it is necessary to establish plans to adjust damage to the mural painting based on the result of diagnosis, evaluation and environmental assessment and to create an environment suitable for mural painting preservation through improvement and constant monitoring of the environment surrounding the mural painting.

# Innovative solutions for prehistoric paintings - Biodeactivation and Consolidation of rock art, Magura Cave, Bulgaria

Milyana Stefanova and Zdravko Kamenarov

*Tessart ltd, Bulgaria*

The Magura cave in Northwestern Bulgaria contains an impressive display of prehistoric paintings made of guano feces of cave-dwelling bats. More than 20000 visitors per year come to see the human figures and mysterious signs painted into the limestone as far back as 5500 years ago. In the last forty years the cave has suffered progressive microbial colonization, mainly attributed to the presence of visitors and the use of artificial light. The detrimental effects on the drawings and stone are biogeochemical/physical and aesthetic and lead to urgent need of multidisciplinary research and strategy for preservation.

The present study evaluates an innovative treatment that couples Atmospheric pressure plasma (APP) along with consolidating nanomaterials in an attempt to deactivate the existing microbiological film and to perform long-term consolidation.

As a first step, we propose Biodeactivation which deals with non-thermal plasma sterilization. It is carried out on lab samples inoculated with the targeted for Magura Cave microorganisms. The main advantage of the non-contact treatment with APP is the lack of any mechanical and chemical modification of the underlying stone/guano surfaces. The obtained biodeactvation is assured without heat, chemically aggressive, toxic and environmentally harmful liquid and gaseous agents. Therefore, it avoids the additional drawbacks connected to the use of traditional biocides and solvents.

The second step of the study compares an innovative phosphate treatment (newly engineered formulation DAP) with a commercial ethyl silicate (ES) product. DAP/ES are investigated in terms of consolidation efficiency and compatibility on lab samples representative for the stone and drawings in Magura Cave. The obtained results give information about penetration depth, mechanical properties, colour change, contact angle, water absorption and water vapour permeability.

In addition, a combination of plasma activation of the stone surface and consolidation is tested, which has synergistic effect and makes the combined treatments more efficient than each of the methods alone.

The study is first step of overall program aiming to propose decision-making tools for the conservation of the Magura paintings. Moreover the research is a fascinating challenge for all the scientists dealing with the problems of rock art.

Prehistoric paintings made of guano, Magura Cave, Bulgaria.

# Innovative conservation treatments

# Mural Painting Consolidation Using Nanolime in Riga Castle

Madara Rasina[1] and Indra Tuna[2]

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Riga castle is a National monument, built at end of 15th century and reconstructed between 17th and 19th century. A part of it is a residence for president of Latvia and other part will be Latvia National history museum. In year 2017 there were building archaeological research works carried out and during these works some exclusive mural paintings were discovered. In plaster openings their condition was rather bad. It was partly detached from wall and in some places, surface was deteriorated. Fragments of paintings that were discovered needed an urgent preventive conservation. It was a perfect case to carry out consolidation with nanomaterials.

In pre-restoration research there were lime plaster properties and paint materials investigated. The archaeological openings discovered several time periods of paintings. The earliest was a late gothic painting; in other openings were 18th century painting and 19th century colouring. Research and consolidation were carried out for late gothic and 18th century paintings. In both painting systems was identified lime – glue binding mixed with colour pigments - azurite, red lead, red ochre and verdigris.

It was clear that conservation works will require grouting with lime-based grouts and some filling with lime mortars – this is a well-known practise in Latvia for many years already. But the consolidation with nanolime was a new experience, which was done in cooperation with Czech restorer prof. Jan Vojtechvosky.

Consolidation was carried out using nanolime CaLoSil E25 in places where there would be grouting afterwards as well as on surface that showed deterioration (mainly plaster without colouring). Nanolime was applied two to three times and afterwards the surface was lightly sprayed with water. As the paintings are indoors, they dried out quite fast. The after-spraying was a must-do in this case. Consolidation showed a successful result – deterioration was stopped, there was no white bloom on surface and where it was needed for further work with lime-based grouting, it could be continued immediately.

As result of works was successful, team of conservation works would highly recommend proceeding this technology in soon coming building restoration process. Obtained results showed that this technology and materials were very compatible with historical substance as well as it showed that deterioration process is efficiently slowed down.

Riga Castle.


Riga Castle.

# Fresco Conservation in the Roman Forum: A Student Perspective

Sienna Hutton

*Istituto Italiano Arte Artigianato e Restauro, Italy*

There are few sites of greater historical saliency than the Roman Forum, including the frescoes in the Basilica dei Santi Cosma e Damiano. This year the Istituto Italiano Arte Artigianato e Restauro is working to conserve three frescoes in this historic basilica: one large wall fresco, extensively restored at an unknown date, and two smaller frescoes in archways with pre-existing minor preventative consolidations.

This paper sets out the methodology and techniques which frame the cleaning, consolidation and restoration of these frescoes, highlighting the variety of approaches used. As this project is not yet completed, results cannot be given at this stage, but will be included in the final presentation. Thus far, the larger fresco has undergone a vigorous cleaning, beginning with tests of predominantly MEK and a mixture of Ammonium Bicarbonate, EDTA Bisodico, and water in various application methods, of which the use of the aforementioned mixture, gelled with CMC and applied directly to the fresco was selected. This process was successful in removing the previous restorations, as well as the build-up of dirt both above and below these interventions. On the segment of imitation marble bellow the large fresco, a gel of methylene chloride and methanol was required to remove a heavy glossy layer as well as previous restorations which had altered the original design. The smaller frescoes have undergone a consolidation of Acrylem 33 and liquid mortar made from Ledan Tb1, injected below the surface. On all of the frescoes, previous grouting of wax, Gesso, lime and marble powder, and cement has been removed through the use of water, a mixture of ethyl alcohol, acetone, and white spirit, and various mechanical tools. The following steps will be to continue the injection of Ledan Tb1 on all of the frescoes, and to fill lacunae and cracks with various grouting. All of the grouting will use Grassello as a binder, and the filler of sand, powdered marble, or calcium carbonate will be chosen based of the size of the opening.

The final stages of restoration will depend on the decision of the inspector from the Soprintendenza. To conclude, this paper will illustrate the diverse preventative and restorative methods used in the conservation of these three frescoes, situated in the hub of Roman art and architecture: The Foro Romano.

The large fresco during the cleaning.

Injection of Acrylem and Ledan Tb1 into process one of the arches.

# Detachment and application of a support of a Kushite wall painting from Dangeil, Sudan: when tradition and innovation come together

Francesca Guiducci[1] and Julie Anderson[2]

[1] *Freelance archaeological conservator, Rome, Italy*
[2] *Department of Egypt and Sudan, The British Museum, United Kingdom*

The wall painting was excavated in the Temple of Amun in Dangeil, Sudan, and dates to the 1st century AD. It measures approximately 90cm high by 1.2m long and it is amongst the largest and best-preserved late Kushite wall painting fragments found thus far *in situ* in a non-funerary context.

The painting structure is composed of two layers of lime plaster and the surface depicts a repeating frieze of lotus flowers in different phases of blossoming; register lines have also been recorded. Pigments used are yellow and red ochres and Egyptian blue, the white lime as background colour. Pigments were applied on the dry plaster surface, resulting in a powdery and volatile paint film.

Despite being in good condition, the painting's survival *in situ* was threatened by the detachment of plaster layers in several areas and by the volatility of the pigments. More crucial in the decision to detach was the state of the wall face itself. It was structurally unstable, completely detached from its core, and partially collapsed. Other factors considered were the extreme weather conditions on site and the lack of a shelter; as well as the impossibility of ensuring the safety of the painting against anthropogenic elements. As a consequence, it was decided to detach the painting, being aware of the risks and downsides that such an operation entails, and to mount it on a new support.

The support was designed to be light, robust and resistant to the extreme weather conditions in Sudan. Materials chosen, carbon fibre and aluminium honeycomb, are fireproof, inert, resistant to pests and require no maintenance over the long-term. The support has also been designed to be self-supportive, for ease of transportation and display.

Detachment and support-making are never simple and straightforward operations. This is even more true when operating on site, in extreme weather conditions, without the technological equipment of a modern conservation laboratory and without access to many conservation supplies.

This presentation aims to argue how, by mixing state-of-the-art techniques with local wisdom and a good dose of ingenuity, it is possible to achieve results that are appropriate, effective and sustainable in the long-term.

The wall painting *in situ*.

Application of carbon fibre and epoxy resin during realisation of the support.

# Detachment and application on support of a Kushite wall painting from Dangeil, Sudan:

## *when tradition and innovation come together*

**Francesca Guiducci**, free-lance archaeological conservator
**Julie Anderson**, Curator for Sudan and Nubia, Department of Egypt and Sudan, The British Museum

A.W. Mellon Symposium
The British Museum
30th May 2019

### Dangeil Amun temple, an introduction

Since 2000, the National Corporation for Antiquities and Museums (NCAM), Sudan in cooperation with the British Museum, has been conducting excavations at Dangeil, a Kushite site on the right bank of the Nile, c. 350km north of Khartoum. Work has focused on a large well-preserved Amun temple situated in the centre of the12ha site. The excellent preservation of the temple complex makes the site unique in Sudan and an important part of the country's cultural heritage. C14 and accelerator mass spectrometry (AMS) date the temple to the 1st century AD, which is further confirmed by ceramics, and inscriptions of the rulers Amanitore and Natakamani.

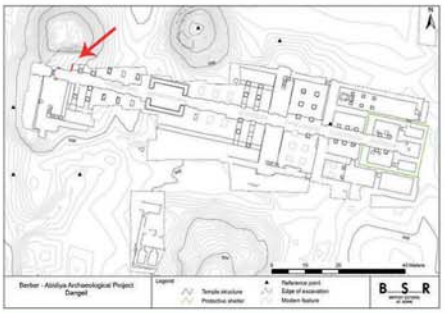
The temple (c. 120 x 35.5m) is oriented east-west towards the Nile and made of a mixture of materials including quartz arenite and ferricrete sandstones, fired and sundried bricks, and lime. Most walls stand between 1.5 and 3m high, have a mud brick core faced on the exterior with fired brick. Columns within the peristyle court and halls are comprised of drums of fired brick quarters or thirds. The carved sanctuary columns and wall panels are of sandstone as were the kiosk's cornice and column capitals. In antiquity, the structure was brightly decorated with painted lime plaster. The red, yellow and blue pigments used have been identified by Raman spectroscopy as haematite, and highly crystalline goethite ochres and a calcium copper silicate (CaCuSi4O10) commonly known as Egyptian blue.


### The wall painting

During excavation of the gate in 2015, part of a wall painting was discovered on the northern pylon inside the peristyle court. It was painted on lime plaster. The excavation was coming to a close, so it was not fully exposed and was covered for protection. Conservation of the painting, culminating in its removal from the pylon wall, commenced in autumn 2018.

The scene depicted is a repeating frieze of lotus flowers. The flowers and register lines were painted in yellow, red and blue pigments on white lime plaster. These are the same pigments as those used elsewhere in the temple. The image formed part of the lowest register on the wall.

Measuring approximately 90cm high by 1.2m long, this is the one of the largest Kushite wall painting fragments found thus far *in situ* in a non-funerary context, and it sheds light on the decorative programme the Kushites employed within their temples.



## Why detachment?

The painting's preservation *in situ* was threatened by the detachment of plaster layers in several areas and by the volatility of the pigments: without intervention, it would have not survived the winter season. Moreover, the supporting wall face was structurally unstable, completely detached from its core, and partially collapsed. Other factors considered were the extreme weather condition on site and the lack of a shelter; as well as the impossibility to ensure the safety of the painting against vandalism and theft.

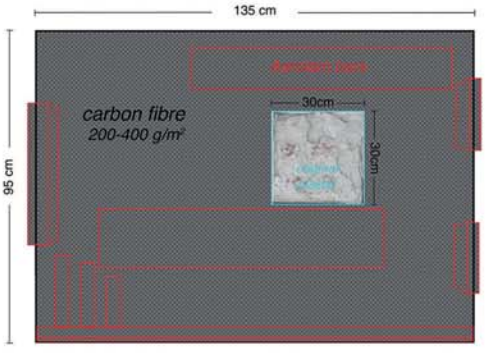
### The phases of the intervention

- **Documentation** by graphic and photographic means
- Surface **cleaning** by mechanical tools (wooden stick); *following tests any wet cleaning method was ruled out*
- **Consolidation** of the paint layer (Paraloid B44 5% to 10% w/v in acetone by spray); *strong consolidation was necessary for the painted film to survive the operations of facing and un-facing*
- **Facing** of the surface (2 layers of cotton gauze, with locally sourced PVA glue and water 1:1); *a water-soluble adhesive was chosen because its removal during un-facing should not have affected the Paraloid used for surface consolidation underneath*
- **Detachment** by mechanical means
- Building up of a **new support**
- **Removal of facing** with hot water
- Final **pointing** and **retouching** (to be completed)

### Detaching the wall painting

Detachment was undertaken by inserting short metal blades between the plaster layer and the wall, and hammering them to break the plaster. Once the short blades had reached their end, longer blades (about 1m length) were inserted. When the plaster was completely detached, the supporting wooden board was carefully tilted down in a horizontal position and transported back to the dig house.

The intervention was successful, and the painting was detached in its entirety. It was necessary to detach the corner as a separate piece, given its difficult position. For the most part, both layers of plaster came off the wall, while in some areas the first layer of plaster remained attached to the wall.




### The new support

Having encased the painting, still resting on the supportive board, in a wooden frame, this was then filled with several layers of hydraulic lime mortar (NHL 3.5), the last layer covering the reverse side of the painting as well. After having waited 20 days for the carbonisation of the mortar, three layers of carbon fibre textile of different weights (200 g/m2 and 400 g/m2) were applied with bi-component epoxy resin, and bars of Aerolam (aluminium honeycomb panel) were inserted both horizontally and vertically, acting as further support in critical areas, and in preventing flexion. It was decided to leave exposed a square of about 30x30cm on the reverse side of the painting, showing the original plaster.

The support was designed to be light, robust and resistant to the extreme weather condition in Sudan. Materials chosen, carbon fibre and aluminium honeycomb, are fireproof, inert, resistant to pests and require no maintenance on the long-term. The support has also been designed to be self-supportive, for ease of transportation and display.

# Cleaning and surface consolidation of a Roman wall painting coming from the Vesuvian area: traditional and innovative methodologies compared

Claudia Rubino[1], Michela Cardinali[2], Diego Elia[3], Paola Croveri[2], Paola Manchinu[2]

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The work aims at defining guidelines for the realization of the conservative intervention on a large wall painting fragment coming from the warehouse of the Frescoes Laboratory of the Pompeii Archaeological Site. The preliminary step to the planning of the conservative intervention consisted of a stylistic analysis of the painting, followed by a technical examination and a diagnostic campaign. The latter permitted to obtain more information about the artifact, like the characterization of the constituent materials and the non-original ones, attributable to alteration products or superimposed substances. The conservative issues mainly required cleaning and surface consolidation. The cleaning process aims at the removal of superimposed substances that can be traced back to previous interventions (protein material, acrylic material).

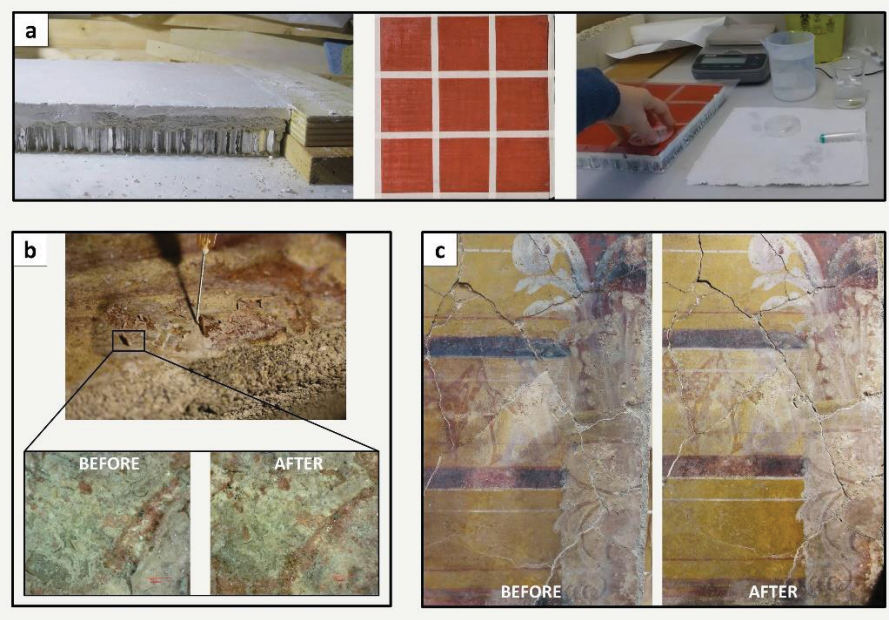
This process is intended to restore the original polychromy, whose brightness has been hidden by an acrylic protective coating that caused color saturation and gave a shiny appearance to the surface. A surface consolidation was required to restore the defects in adhesion of the painted layer, caused by the aging of animal glue applied during previous interventions.

These issues have been addressed in a thesis work, which foresaw a preliminary phase of evaluation of the materials and methods of intervention to be adopted for the cleaning and surface consolidation, by comparing traditional and innovative systems. This study aimed at guiding the choices for the subsequent phases of intervention on the artifact. It was carried out partly on specimens produced in the laboratory, partly using on-site tests.

Several portions of the pictorial surface revealed to be water-sensitive, so a first cleaning level for the removal of the acrylic coating was attended using a solvents mixture. Where possible, in order to achieve a uniform level of cleaning, satisfactory results were obtained using micellar solutions. The methodology applied to restore the defects in adhesion of the painted layer required a delicate selective cleaning process, made possible by means of a chemical gel.

Satisfactory results for the removal of the protein material were obtained employing "unstructured" agar and laser cleaning.

The intervention focused on portions of the pictorial surface considered to be representative of the preservative needs observed. However, the study examines the entire artifact, with the purpose of defining the guidelines to be followed to complete the restoration work.




Conservative intervention phases.

*A closer look at Murals. Recent advances in the conservation and scientific investigation of Wall Paintings.* A Symposium in Conservation Science, with support from the Andrew W. Mellon Foundation, 30th May 2019, The British Museum, London, UK

# Cleaning and surface consolidation of a Roman wall painting coming from the Vesuvian area: traditional and innovative methodologies compared

Claudia Rubino[1], Michela Cardinali[2], Diego Elia[3], Paola Croveri[4], Paola Manchinu[5]

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## Introduction

The work aims at defining guidelines for the realization of the conservative intervention on a detached wall painting coming from the warehouse of the Frescoes Laboratory of the Pompeii Archaeological Site. An interdisciplinar preliminary study has foreseen:

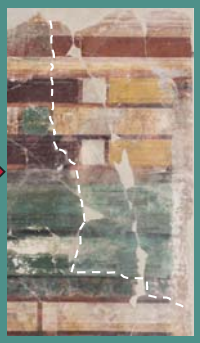
**Stylistic analysis:** representation of fake marble incrustation attributable to an initial phase of the **II Pompeian style** (between 80 and 40 B.C.).

**Technical examination:** detection of traces of the executive technique and previous interventions; identification of the main conservative issues.

**Diagnostic campaign:** characterization of the constituent materials and the non-original ones (degradation products, superimposed substances).

**Non-invasive investigations:**
- **IRFC:** Infrared False Color photography
- **VIL:** Visible-induced Luminescence
- **XRF:** X-ray fluorescence (spot and map*)
- **FORS:** Fiber Optics Reflectance Spectroscopy

**Micro-invasive investigations:**
Stratigraphic cross-sections observation:
- **OM:** Optical Microscopy
- **SEM-EDX:** Scanning Electron Microscopy/Energy Dispersive X-ray Spectroscopy

Sample area after intervention

## Conservative issues

The conservative issues mainly required cleaning and surface consolidation. The cleaning process aims at the **removal of superimposed substances** that can be traced back to previous interventions:

-**Proteinaceous material** attributable to an animal glue applied during interventions of surface protection;

-**Acrylic material** likely attributable to Paraloid B72 employed as a protective.

This process is intended to restore the original polychromy, whose brightness has been hidden by an acrylic protective coating, causing color saturation and a shiny appearance of the surface.

The cleaning process is also aimed at the removal of coherent deposits (biological patinas, carbonate incrustations, sulphates efflorescences, mineral concretions).

**Surface consolidation** was required to restore the defects in adhesion of the painted layer, caused by the aging of the animal glue applied in previous interventions.

## Materials and methods

Evaluation of the materials and methods of intervention to be adopted for the cleaning and surface consolidation was carried out primarily on **mock-ups** produced in the laboratory and partly on the painted surface. **Traditional and innovative systems were compared** by means of:

- **colorimetric measurements** (reflectance spectrophotometry)
- **water absorption test** (contact sponge method UNI 11432:2011 standard)
- observations with a **UV-VIS light Digital Microscope**

## Stages of intervention

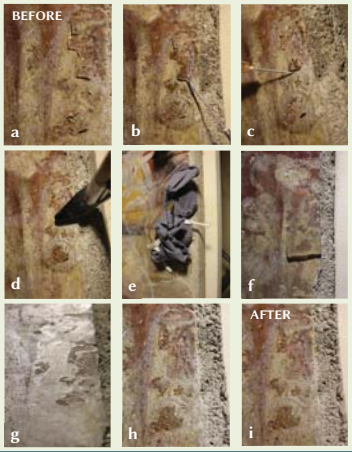
The intervention focused on a portion of the pictorial surface representative of the preservative needs observed, with the purpose of defining the guidelines to be followed to complete the restoration work.

**Whole surface** →
- I. Achievement of a first cleaning level
  - Removal of incoherent surfacial deposits
  - Thinning of superimposed acrylic material
- II. Consolidation of lifting paint layers

**Sample area** →
- III. Deepening of the cleaning level
  - Further removal of acrylic material
  - Reduction of concreted patinas
  - Removal of residuals of aged animal glue
- IV. Presentation proposal
  - Aesthetical mortar
  - Retouching

## Consolidation of lifting paint layers

| Critical issue | Adopted solution | Advantages |
|---|---|---|
| **Rigidity of the liftings** of the pictorial surface | Application of a **water / isopropyl alcohol mixture (1:8)** to soften the liftings **(b)** | **Avoid excessive swelling of** the superimposed **glue residuals** |
| Find an adhesive able to **counteract the superimposed glue residuals retraction** while drying | Application of **K52** (aqueous dispersion acrylic copolymer) at 5% (w/v) **in isopropyl alcohol (c)** | Application in in solvent **avoids excessive swelling ofthe superimposed glue residuals**<br>**Compatibility** with acrylic material by now incorporated in the substrate<br>**Well-known use on mural paintings** |
| **Lowering of the mayor liftings** | Warming by a **heated spatula, 40°C (d)** | **Recovery of adhesion** to the substrate |
| **Counteract regeneration of liftings while drying** | Application of **small weights**, interposing a siliconised polyester film at first and then a thick japanese tissue **(e)** | **Recovery of the continuity** of the pictorial surface |
| **Selective removal of the superimposed acrylic material** | Application of **Nanorestore Gel® Dry loaded with ethanol** for 5-10 min **(f-g)** | **Selective** superficial cleaning process<br>**Absence of residuals**<br>**No washing required** |
| **Removal of the superimposed glue residuals** | **Mechanical removal** by means of a scalpel. If necessary, prior **application of Agar gel** (3% w/v in water) to soften the glue **(h-i)** | **Avoid excessive swelling of** the superimposed **glue residuals** |




## Removal of acrylic material

### Tested systems and results

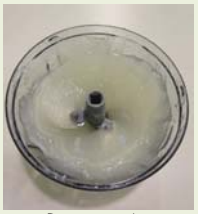
- **Solvent cleaning systems:**
  - **Free solvent mixture**
    - ✓ **surface control**
    - X risk of **excessive strain on the surface**
  - **Thickened or supported solvent mixture**
    - ✓ in **destructured Agar** (30% w/w): **gradual and efficient action**
    - X in **Gellan gum** (10% v/v): too **mild** action
    - X in **Vanzan NF-C** (50%v/v): **non effectiveness of retreatments**
- **Nanostructured systems (CSGI)****:
  - **Micellar solutions: Nanorestore Cleaning®** Polar Coating S, B and G
    - ✓ **recovery of absorption capacity**
    - ✓ **Polar Coating B:** satisfying results
    - X **Polar Coating S**: persistence of the **anionic surfactant**
    - X **Polar Coating G**: more interaction with the surface
    - X **unsuitable for water-sensitive surfaces**
    - X **washing required**
  - **Nanorestore Gel® Dry** water-based chemical gel based on **p(HEMA)/PVP**
    - ✓ **minimal mechanical strain**
    - ✓ **no washing required** if loaded **with solvents**
    - ✓ small amount of liquid released to the surface
    - X high cost
- **Biocleaning systems (ENEA)*****
  - **Suspensions of viable bacterial cells**
    - X **Ineffectiveness**: possible loss of viability
- **Laser cleaning**
  - **Nd: YAG** , λ = 1064 nm, LQS
    Nd: YAG, λ = 532 nm, QS
    **Er: YAG**, λ = 2940 nm, VS
    - ✓ **Nd:YAG**: best results with QS, λ 532 nm, FL= 3 J/cm2
    - X **difficulty to find optimal parameters**
    - X **Er: YAG: ineffectiveness**

| Selected systems | Suitable uses |
|---|---|
| **Free solvent mixture** ligroin/acetone (3:7) | First stage of cleaning requiring constant control of the surface and monitoring of its cohesion |
| **Solvent mixture** isopropyl alcohol / MEK / isooctane (46: 23 : 31) **in destructured Agar** (30% w/w) | Deepening of the cleaning level |
| **Nanorestore Gel® Dry loaded with ethanol** | Cleaning of delicate and water-sensitive areas of the surface |
| **Nanorestore Cleaning® Polar Coating B in pulp cellulose** | Eventual deepening of the cleaning level on non water-sensitive areas |

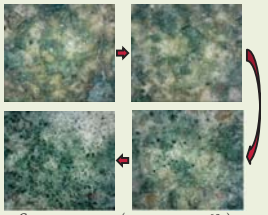

## Removal of animal glue residuals

### Tested systems and results

- **Aqueous systems:**
  - **Swelling in gel-supported water**
    - ✓ **mild swelling** observed
    - X **long times** required
    - X **poor adherence** to rough surfaces
  - **Swelling in hot water (40°C)**
    - natural sponge
    - wet japanese tissue warmed by a heated spatula
    - ✓ **swelling** observed
    - X **long times** required
    - X risk of **excessive strain on the surface**
  - **Swelling in hot gel-supported water (40°C)**
    - X **fluid Agar (3% w/v in water) at 40° C**: risk of surface damage during gel removal
    - ✓ **destructured Agar (3% w/v in water) warmed by a heated spatula**: effectiveness, good adherence to rough surfaces, respectful of the surface



Destructured Agar



Cleaning process (magnification 60x)

- **Biocleaning systems (ENEA)*****
  - **Suspensions of viable bacterial cells**
    - ✓ **Effectiveness**
    - X **poor control of the cleaning process**
- **Laser cleaning**
  - **Nd: YAG** , λ = 1064 nm, LQS/ SFR
    Nd: YAG, λ = 532 nm, QS
    **Er: YAG**, λ = 2940 nm, L / S / VS
    - X **difficulty to find optimal parameters**
    - ✓ **Er:YAG (λ 2940 nm) S/VS, FL< 6,4 J/cm2**

Er:YAG (λ 2940 nm), VS, E=100 mJ, 10 Hz, spot 2 mm, FL< 6,4 J/cm2

Photographic documentation after test


| Selected systems | Suitable uses |
|---|---|
| **Destructured Agar (3% w/v in water) warmed by a heated spatula** | Gradual removal of animal glue residuals on non-water-sensitive areas |
| **Er:YAG (λ 2940) S / VS**, FL< 6,4 J/cm2 | Treatment of water-sensitive areas |

*Macro-XRF (MA-XRF) portable scanner developed in LANDIS laboratory of IBAM-CNR and LNS-INFN, research coordinated by Paolo Romano, Catania (Italy); **Research Center for Colloids and Nanoscience founded by Ferroni E. and Baglioni P., University of Florence (Italy); ***Research coordinated by Anna Rosa Sprocati, Environmental Microbiology and Microbial Biotechnology Section, ENEA Casaccia *Research Center*, Roma (Italy)

# Laser cleaning

# The LASER uncovering intervention of the 16th century wall painting of *San Rocco in Ponte Capriasca (Switzerland)*

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The present work focuses on the uncovering intervention carried out on the wall painting of *San Rocco* (Saint Roch) located in the *Oratorio di San Rocco* in Ponte Capriasca (Switzerland). The high-quality artwork was realized around the end of the 16th century by an unknown artist possibly related to the school of Bernardino Luini, as was found out during the preliminary bibliographical and archival research.

The artwork representing Saint Roch was realized on a single *giornata* painted with different techniques: the layer with the preparatory drawing was made in a *fresco* technique using a mixture of ochre, earths and carbon black; the upper paint layers were carried out in a *secco* technique using lime and an organic binder (i.e. animal glue was identified for the blue background) and pigments such as earth pigments, smalt, cinnabar and lead-based pigments.

The condition of the wall painting was compromised due to the presence of a limewash layer covering the entire surface probably applied at the beginning of the 20th century. In the following years the original surface was severely scratched during the several attempts that were made to uncover the painting.

In 2012 SUPSI (Scuola Universitaria professionale della Svizzera italiana) began the study of the artwork and of methodologies for a safe uncovering during the conservation-restoration courses. Mechanical and chemical trials were carried out achieving different results without defining a final intervention methodology.

In 2017 it was possible to test different LASER systems (Nd:YAG 1064 nm, mode: QS, LQS, SFR) achieving very good results for the uncovering of almost the whole surface. The LASER treatment made it possible to uncover stable layers and powdering layers in a safe way; damage was observed only on the blue background due to the strong absorption of the brownish preparatory layer. The observation of the obtained results and of a cross section lead to the decision to use this methodology as the principle one for the final uncovering of the artwork. This intervention has demonstrated the suitability of different combined LASER systems for the safe uncovering of wall paintings.

The British Museum Mellon Symposia
London, 30th May 2019

# The LASER uncovering intervention of the 16-th century wall painting of San Rocco in Ponte Capriasca (Switzerland)

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**Keywords:** Wall painting, laser, limewash uncovering

## Introduction

The present work focuses on the uncovering intervention carried out on the wall painting of San Rocco (Saint Roch) located in the Oratorio di San Rocco in Ponte Capriasca (Switzerland). The high-quality artwork was realized around the end of the 16-th century by an unknown artist possibly related to the school of Bernardino Luini, as was found out during the preliminary bibliographical and archival research.

## Case study description

The artwork representing Saint Roch was realized on a single *giornata* painted with different techniques: the layer with the preparatory drawing was made in a fresco technique using a mixture of ochre, earths and carbon black; the upper paint layers were realized in a secco technique using lime and an organic binder (i.e. animal glue was identified for the blue background) and pigments such as earth pigments, smalt, cinnabar and lead-based pigments. The condition of the wall painting was compromised due to the presence of a limewash layer covering the entire surface probably applied at the beginning of the 20th century. In the following years the original surface was severely scratched during the several attempts that were made to uncover the painting.

## Materials and Methods

In 2012 SUPSI (Scuola Universitaria professionale della Svizzera italiana) began the study of the artwork and of methodologies for a safe uncovering during the conservation-restoration courses. Mechanical and chemical trials were carried out achieving different results without defining a final intervention methodology.
Investigations of the case study were made using non-invasive and invasive analysis such as multispectral imaging, p-XRF, colorimetry, microscopical analysis of samples, FT-IR, GC-MS, SEM-EDX.
In 2017, it was possible to test different LASER systems for the uncovering trials. Two main LASER systems were applied: an LQS (120 ns; E: 125, 250, 380 mJ) Nd:YAG 1064 nm (EOS1000 LQS by El.En. spa) and a QS/SFR (15 ns; E: 10÷140 mJ / 30-100 µs; E: 50÷1000 mJ) Nd:YAG 1064 nm (EOS QS by El.En. spa). Trials were carried out on the different colored areas by increasing fluences predominantly on pre-wet surfaces to identify ablation thresholds and the most suitable pulse duration. On uncovered areas the same fluences were tested to identify possible sides effects or damage in order to define the different damage thresholds. The surface was constantly observed using a portable microscope and, finally, a sample was taken from the covered/uncovered border for the evaluation of the result by cross-section (Figg. 5-6). Depending on the limewash thickness, different fluence values were used on the same areas. In some cases it was necessary to mechanically reduce the limewash before proceeding with the final removal with LASER.

## Conclusions

The LASER treatment allowed for the uncovering of stable layers and powdering layers in a relatively safe way; however, minimal losses were observed during the intervention. Considerable damage was observed only on the blue background due to the strong absorption of the brownish preparatory layer. This intervention has demonstrated the suitability of different LASER systems, combined with each other and in combination with traditional methods, for the safe uncovering of wall paintings.

## Acknowledgements

The authors would like to thank SUPSI for having provided the different LASER systems and for the logistical support, CTS Suisse SA for their restoration materials contribution, the *Fondazione San Rocco* and the parish council for their active participation.


*Fig. 1 Case study of San Rocco before uncovering, Oratorio di San Rocco in Ponte Capriasca (CH).*

*Fig. 2 Case study of San Rocco after the intervention.*


*Fig. 3. Comparison trial between scalpel uncovering (a) and LASER uncovering (b), white-blue dress in raking light.*


*Fig. 4 EOS1000 LQS trials on wet surface. 1) 0.44 J/cm²; 2) 0.63 J/cm²; 3) 0.99 J/cm²; 4) 2.54 J/cm²; 5) 3.98 J/cm²; 6) 0.49 J/cm²; 7) 0.88 J/cm²; 8) 1.27 J/cm².*


*Fig. 5 Cross-section of sample taken from the convered/uncovered border of the purple mantle (50x magnification).*

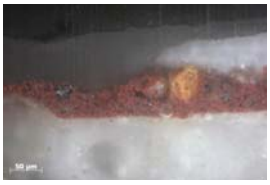



*Fig. 6 200x magnification of the covered/uncovered border confirmed the selectivity of the LASER uncovering method.*

| Area | EOS QS | | EOS1000 LQS | Observations |
|---|---|---|---|---|
| | QS (15 ns) | SFR (30-100 µs) | LQS (120 ns) | |
| **Purple mantle** | 0,81 J/cm² | 4.2 J/cm² | 0,49 - 2,54 J/cm² | QS: small losses.<br>SFR: pigment alteration; limewash residues. |
| **Light purple mantle** | 0,81 J/cm² | 4,24 - 7,9 J/cm² | Not tested | QS: pigment alteration. |
| **Red gaiters** | 1,02 - 1,22 J/cm² | Not tested | 1,76 J/cm² | LQS: small losses.<br>QS: higher fluences for the lighter area. |
| **White-blue dress** | 2,22 J/cm² | 4,24 – 9,55 J/cm² (No results) | 2.54 J/cm² | LQS: small losses. |
| **Brown frames and stick** | Not tested | 3,53 - 4,24 J/cm² | 0,63 - 1,76 J/cm² | LQS: small losses were observed.<br>SFR: limewash residues. |
| **Yellow frames and coat** | 1,22 - 1,91 J/cm² | 5,66 J/cm² | 0,63 J/cm² | LQS: small losses.<br>SFR: pigment alteration. |
| **Gray boots** | 1,83 J/cm² | 5,66 J/cm² | Not tested | SFR: was used on the darker area in order to preserve the upper paint layer. |
| **White-pink dog** | 1,22 J/cm² | 5,66 J/cm² | 1,76 J/cm² (Damage) | QS: was used to clean the pink area.<br>SFR: on the white; combination of laser and scalpel removal. |
| **Skin** | 0,81 J/cm² | Not tested | 0,63 - 1,76 J/cm² | Ion exchange resins pretreatment. |

*Tab. 1 Minimal interaction fluence and fluence ranges evaluated for the different colored areas.*

# Henib wall painting conservation project: laser and gels for superficial cleaning

Michela Cardinali[1], Christian Greco[2], Beppe Moiso[2], Anna Piccirillo[1], Francesca Zenucchini[1],Arianna V. Scarcella[1]

*[1] Centro Conservazione e Restauro "La Venaria Reale" , Italy*
*[2] Museo Egizio, Italy*

The conservation project of the six wall painting fragments from Henib chapel-tomb[1], in Qaw el-Kebir, has been carried out with a scientific and interdisciplinary approach, by a team of different professionals from the Centro Conservazione e Restauro "La Venaria Reale" and the Turin Museo Egizio, including conservators, curators, archaeologists and conservation scientists. In this perspective, conservative issues have been merged with archeological researches, in order to give back to the scientific community, but also to the general public, the six painting fragments, enhancing the knowledge of Egyptian tangible cultural heritage.

After preliminary bibliographic researches, a non-invasive analytical plan (including UV fluorescence, IR-reflectography, false color elaboration and visible light induced luminescence ) has been addressed to the study of the superficial distribution of different materials, in order to focus the topic area to analyze with further analytic technique, such as X-ray fluorescence spectroscopy (for pigments characterization) and Fourier transform infrared spectroscopy (for organic substances identification). Moreover, samples have been analyzed with optical and scanning electronic microscopy, with EDX, to obtain additional information about execution technique and materials used for different remedial treatments.

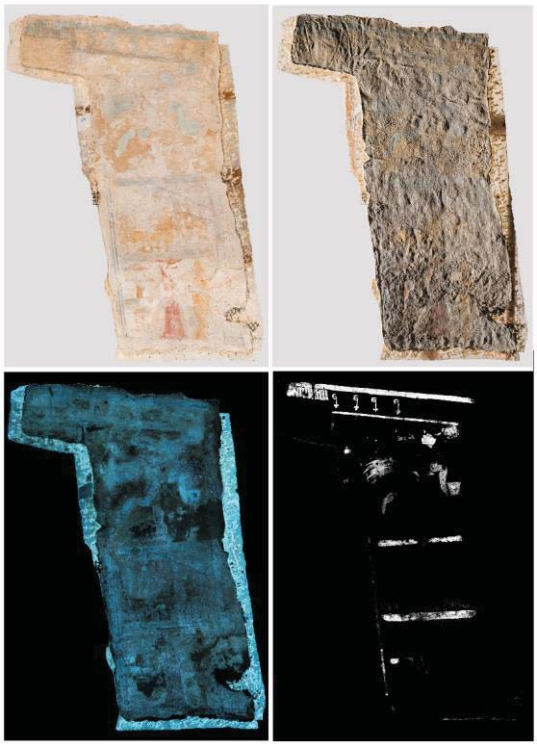
Following analytical campaign, superficial cleaning represented one of the main issues for fragments conservation because of the presence of a number of overlaid layers. An altered acrylic resin (Paraloid B72) has been documented all over the paintings surfaces, in addition to a dark substance, identified as the animal glue used in painting detachment and now responsible for superficial layers chipping and micro peeling. Considering the peculiar needs of every fragments a comparison on effectiveness of the cleaning was tested with different methods using: physic methods, solvents and water gels. Preliminary laser tests were done with three different Nd:YAG lasers EOS 1000 (Long Q-Switch) at 1064 nm, Smart Clean II (Short Free Running) at 1064 nm and Thunder Art (Q-Switch) at two different wavelength 1064 nm and 532 nm. The action carried out with the laser technology turned out to be fundamental for some fragments (n. 3, 4 and 6) which has been cleaned in two different steps; first the removal of the superficial deposit by laser and then a further step with chemical solvents.

The swelling of the animal glue has been obtained with the application of water gels with different water retention properties (Gellano®, AGAR and Nevek®).

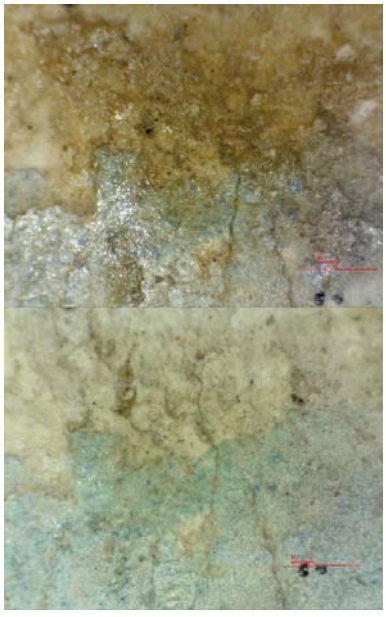
After the replacement of the previous support with a multilayer panel, composed of a PET layer, propped up with a glass fiber grid and backed by a honeycomb panel,

[1] E.M. Ciampini, *La sepoltura di Henib* (Camera funeraria CGT 7001; pareti di sarcofago CGT 10201-10202), CGT Serie Prima – Monumenti e testi, vol. XI, Torino 2003; A. Roccati, *Testi religiosi e funerari del II millennio a.C.*, in Museo Egizio di Torino, Civiltà degli Egizi. Le credenze religiose, Torino 1988, pp. 128-145; B.Moiso, M.Borla, *Pitture murali della tomba di Henib in Restituzioni 2018.* Tesori d'arte restaurati, a cura di C. Bertelli, G. Bonsanti, Venezia 2018, pp.32-37.

unsuitable plasters have been removed and all the lacunas have been filled with a sand and light stucco mortar[2].



Offering table, before conservation. Images in the visible light, UV, VIL: superficial morphology, presence of protective acrylic, pictorial additions and distribution of the Egyptian blue.



Images of videomicroscopy for monitoring the cleaning phases.

[2] M. Cardinali, *Relazione di restauro, in Restituzioni 2018. Tesori d'arte restaurati*, a cura di C. Bertelli, G. Bonsanti, Venezia 2018, pp.38-43.

# Er:YAG laser on painted surfaces- identifying the interaction of the laser radiation with pigments and binders

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A series of Buddhist wall painting fragments, acquired by the British Museum in 1936 and dated to the Ming Dynasty (1368-1644), requires treatment as part of an ongoing conservation programme. Some of the fragments present discoloured coatings, excessive plaster mounts and fills to the surface, that are obscuring the surface imagery. Previous conservation treatments using mechanical and solvent cleaning methods have proven to be difficult due to the fragility of the substrates. Therefore, the use of Er:YAG laser was considered.

Lasers have offered a good alternative as a non-contact and environmental friendly cleaning method in conservation due to their unique properties and precision. Er:YAG laser has demonstrated to be efficient for the cleaning of unwanted materials containing OH groups and have shown success in reducing aged coatings from painted surfaces. However, the Er:YAG laser is still not widely used in conservation and, to date, its effects on painted surfaces have not been systematically analysed.

In this study, we investigate the behavior of painted surfaces exposed to the Er:YAG laser radiation. Due to the potential vulnerability of the mural painting fragments that require cleaning, laser tests were first carried out on a set of mock-ups to determine the damage threshold values of pigments and binders. Tests were performed on pure pigments and paint layers prepared by mixing the pigments with animal glue and gum arabic. Paint layers were artificially aged in a climatic chamber for a period of 672h at a temperature of 40°C and relative humidity of 50%.

Laser tests were carried out using a Fidelis-XS (Fotona) Er:YAG laser, with a pulse duration of 100µs delivered through an articulated arm. Damage threshold values were investigated on fresh and artificially aged mock-ups both in dry conditions and using wetting agents (2-propanol and water) at different fluences and with a repetition rate of 2Hz. The assessment of the effects of laser radiation on the different substrates was carried out using digital microscopy, scanning electron microscopy (SEM-EDX), Raman, Fourier transform infrared spectroscopy (FTIR) and colorimetric analysis. In parallel, the identification of the coating and pigments on the wall painting fragments was performed. Optical coherence tomography (OCT)[1] was used to investigate the thickness of the coating layer.

The damage threshold values obtained and the identification of pigments on the wall painting fragments will provide a visual map and guidance to the conservator for a more selective and safer thinning and cleaning of the coating during conservation treatment.

[1] High resolution Fourier domain OCT in the 2 µm wavelength range, developed by the Imaging and Sensing for Archaeology, Art history and Conservation ISAAC Lab (School of Science & Technology, Nottingham Trent University, United Kingdom).

# New methods for diagnosis and recording

# Assessment of morphological and micromechanical changes in consolidated wall paintings using optical coherence tomography and micro indentation tests

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Wall painting consolidation reintegrates paint layers which lost their properties due to binder degradation. In Poland, it is a routine procedure that interferes with wall painting structure significantly. Since the mid-20$^{th}$ century, synthetic resins have enjoyed enormous popularity as consolidants. An attempt at a detailed analysis of this issue has been undertaken. The objective of the project was to understand the mechanism and changes associated with wall painting consolidation, and verify the knowledge of ageing of synthetic materials applied during this procedure, considering both the analysis of mechanisms of their application as well as the diversity of Polish wall painting techniques.

The project stages:

- Archival research to determine the Polish conservation practice;

- Analysis of the state of preservation of consolidated paintings in historic buildings;

- Analyses performed on specially prepared painting models subjected to the ageing process, consolidated using popular agents (Paraloid B-72, Primal AC 33, PVAC – Winacet Ret and DP 50, PVA – Mowiol 4-88). The aim was to establish the morphological changes in the consolidated painting surface during subsequent research stages (VIS, UV, SEM, OCT), optical changes (colour and lustre), mechanical resistance and physicochemical properties (micromechanical tests, wettability measurements).

The archival research gave information on the Polish consolidation practice, confirming the extensive application of synthetic resins and pointing out the most popular binders. *In situ* analyses confirmed polymer impact on basic properties of paint layers. Studies on models demonstrated that optical and morphological changes depend on the type of consolidant and its concentration. Using OCT, the presence of film on the sample surface was found, whereas micromechanical properties were more dependent on the original painting technique than the type of the consolidating binder applied. Indentation was a very sensitive tool for assessing alterations in the physical properties of paint layers in historic wall paintings.

The project was financially supported by the National Science Centre, Poland (no 2013/11/B/HS2/02991).

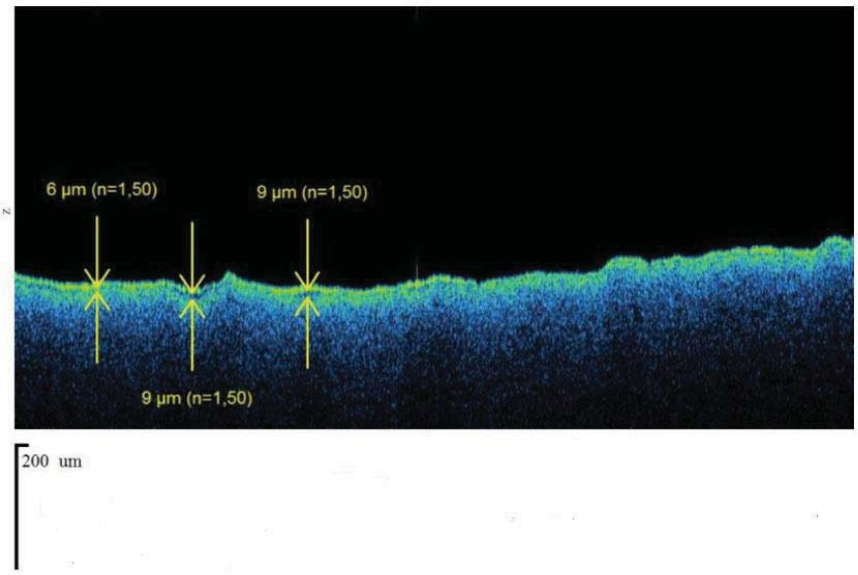
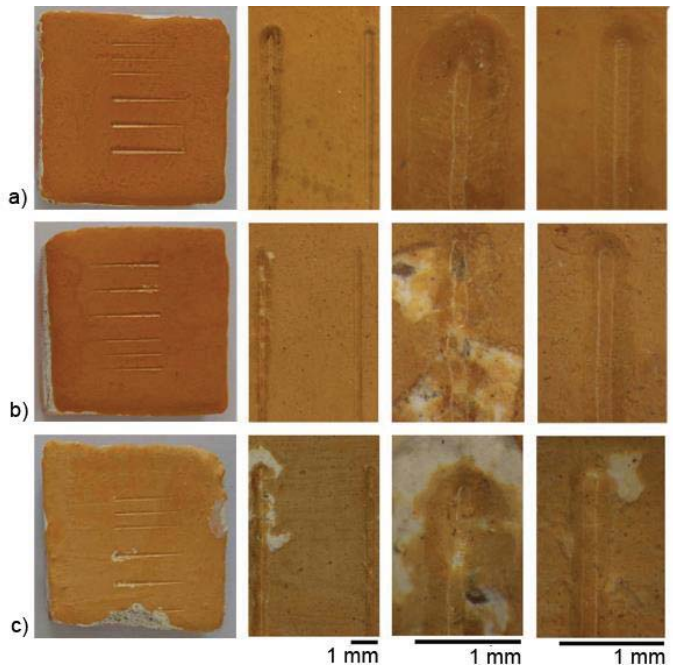



Image of a paint layer made using the glue technique, consolidated with 7.5% acrylic resin (Paraloid B-72), which created a film on the surface of the paint layer.




Images of paint layer surfaces consolidated with 5% acrylic resin (Paraloid B-72), after ageing process and the scratch test: a) animal glue, b) lime casein, c) lime.

# Reflected Ultraviolet (UVR) and Reflectance Transformation Imaging (RTI) for recording the Nabatean wall paintings in Petra, Jordan

Ayman Yaghi

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For the process of historical objects documentation and investigation, photography techniques provide great benefits in the field of scientific documentation and examination of wall paintings. Meanwhile photography has become an indispensable non-invasive tool in examining mural paintings. In the context of the current technological development, the use of imaging techniques has been multiplied in wall paintings examination and produced impressive results of collecting comprehensive information about wall paintings.

One imaging technique has emerged that records images by using the ultraviolet (UV) spectrum in the capturing process called Reflected Ultraviolet (UVR), which rely on the use of a converted full spectrum camera and certain UV transmitter filter, in addition to an ultraviolet radiation source, without needing for specific software to run it. This non-invasive technique is especially effective for the characterising pigments, as well as for the visualization of surface characteristics such as surface topography and irregularities. Furthermore, the technique helps detecting residual matter of various origins such a rest of previous conservation materials.

On the other hand, raking light photography has been proved to be a method that has contributed significantly to the examination of murals surfaces. In the midst of competition and acceleration among institutes involved in the examination of cultural property, HP Labs has developed the raking light technique in a professional computational method, based on specific approach and software named initially Polynomial Texture Mapping. Later, the technique has been developed by the Cultural Heritage Imaging Institute under the name of Reflectance Transformation Imaging (RTI).

The aim of using RTI and UVR for wall paintings examination is to obtain a detailed study about surface topography, materials, painting technique, and previous interventions, which have been verified by conducting RTI and UVR for the characterization and examination of the Nabatean wall paintings in Petra as a part of DFG project under the supervision of Prof. Adrian Heritage ACR FIIC from Wall Paintings Department at Cologne Institute of Conservation Science.

This paper also aims to present a mechanism method that enables the combination of RTI and UVR in the same image by processing the UVR images in RTI Builder software and displaying the final form in RTI Viewer.

Nabatean Wall Painting, Petra, VIS (© Ayman Yaghi 2018).

Nabatean Wall Painting, Petra, Reflected Ultraviolet indicates surface topography and previous conservation materials (© Ayman Yaghi 2018).

# Reflected Ultraviolet (UVR) and Reflectance Transformation Imaging (RTI) for recording the Nabatean wall paintings in Petra, Jordan

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PPCP Petra Painting Conservation Project

## Introduction

With the growing importance of the term "Conservation Ethics" and the development of ethical methods used in the examination and documentation of cultural properties, different non-invasive techniques have emerged in the field of examination and documentation of wall paintings. This research presents the performance of Reflected Ultraviolet (UVR) and Reflectance Transformation Imaging (RTI) as an examination techniques on the mural paintings in Petra.

## The Project

After the re-discovery of today's UNESCO World Heritage Site Petra in Jordan in 1812, large numbers of researches play very important role in meeting Petra's need for conservation and restoration. The DFG project "Characterisation and Conservation of Paintings on Walls and Sculptures from Nabatean Petra", is one of the projects which aims to approach several non-invasive methods to study the wall paintings in Petra. This multidisciplinary project funded by the German Research Foundation, and carried out by specialists based at the Technical University Berlin, The Humboldt University Berlin and Cologne Institute of Conservation Science in cooperation with The Department of Antiquities in Jordan.

## The Wall Paintings in Petra

Despite the abundance of archaeological artefacts in Petra, the archaeologists haven't discovered much number of wall paintings. Reflected Ultraviolet and Reflectance Transformation Imaging RTI were a part of the methods applied to examine and document the mural paintings in two different sites in Petra. The first one Villa ez Zantur, which contains a house has a large number of mural paintings were discovered in 1996 by the archaeologist Berard Kolb and dates back to the early 2nd century AD. The other site is Wadi as-Siyyagh, which is a residential complex has a number of mural paintings and dates approx. between 100 BC to about 100 AD.

Figure 1: View of the paintings, Villa ez Zantur © *Yaghi 2018*

Figure 2: View of the paintings, Wadi as Siyyagh © *Yaghi 2018*

## Reflected Ultraviolet UVR

Ultraviolet radiation has been widely applied in cultural heritage analysis and study. UV-based techniques have varied, this research presents Reflected Ultraviolet technique, which records only UV light in the region of 320nm to 390nm reflected from the subject to the converted full spectrum camera. All other radiation are prevented reaching the sensor by placing UV transmission filter on the lens. UVR wasn't widely used in the field of conservation, while it has a great history in forensics imaging. UV light bounce on the object and prove each phenomena on the surface such (fine details, cracks, exfoliation, surface irregularities, pigments identification). Applying UVR on the mural paintings in Petra has a great advantage of presenting the surface structure, previous conservation interventions as well as the rest of conservation materials. .

Figure 3a, b: Surface structure and rest of previous conservation materials, left VIS, right UVR © *Yaghi 2018*

Figure 4: Applying UVR © *Tehrani 2018*

Figure 5a, b: Rest of previous conservation materials, left VIS, right UVR © *Yaghi 2018*

## Reflectance Transformation Imaging RTI

RTI is light-based photographic techniques used to examine an object that requires more depth information. In other words, RTI is a computerized photography method depends on the use of a series of digital photographs of a fixed object, each one taken from the exact same position but illuminated from different angles to capture data of its shape and colour. As a part of DFG project, RTI proven to be a great technique for the examination and documentation of the mural paintings in Petra. The use of RTI technique provide a comprehensive survey the paintings includes surface structure, paint technique, change of paint's surface over the time, as well as some evidences of previous restoration interventions.

Figure 6: RTI approach UVR © *Yaghi 2018*

Figure 7: RTI principle © *Yaghi 2018*

Figure 8: RTI equipment © *Yaghi 2018*

Figure 9a, b: Surface structure and rest of previous conservation materials, left VIS, right RTI © *Yaghi 2018*

Figure 10a, b: Mark of polishing tools, left VIS, right RTI © *Yaghi 2018*

# Non-invasive analysis

# Insight into Paolo and Laura Mora wall painting sample collection at iccrom: painting technique and pigments from the Roman period

Milene Gil[1], Cecilia Laurita[1], Mafalda Dias[1], Ana Cardoso[1], Sara Valadas[1], Mirian Pressato[1], António Candeias[1,2]

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[2] *Chemistry Department, School of Science and Technology, Portugal*

ICCROM holds one of the most important and complete wall painting sample collections existing in a single institution. The 'Mora' sample archive comprises nowadays about 1200 material samples collected in 36 countries by Paolo and Laura Mora and their collaborators between the 1960s and the 1980s. The collection is a valuable knowledge resource for the study of wall painting technology but is at present under-researched, as very little of the collected material has to date been subjected to systematic scientific study. The aim of the current research was to explore the potential of the archive, with a particular focus on pigments and binders used in Classic Antiquity.

The collection holds about two hundred wall painting fragments from the Roman period, which present a unique opportunity for the study of ancient pigments and binders as the majority have not been subject to conservation treatments. Thirty-six samples were selected for non-invasive analysis using optical microscopy, spectrophotometry, FORS and EDXRF. Twenty-eight micro-samples of paint layers were further collected for μ-FT-IR, Py-GC-MS, μ-Raman, SEM-EDS and μ-XRD.

No organic material was detected as a binder, but rather only calcite and dolomite. Aragonite is found in most of the samples. With regards to the pigments, Egyptian blue, cinnabar, red ochre, yellow ochre, red lead, carbon black, green earth (celedonite) were identified, used pure, in mixtures or overlaid to reach certain hues. While in this instance the results are not controversial, nevertheless the study highlights the potential value of such historic archives, at present under recognized and vulnerable. This study is part of a larger initiative to ICCROM to safeguard the Mora archive and raise awareness regarding this issue.

The authors wish to acknowledge ICCROM (in particular Alison Heritage, Science Officer, and ICCROM Archives); ARCHMAT ERASMUS MUNDUS MASTER; Fundação para a Ciência e Tecnologia (FCT) for their support through PTDC/EPH-PAT/4684/2014 project: DB-HERITAGE – Heritage database on historical construction materials.

# Attribution investigation of frescos in Russo-Byzantine style from the Chapel of the Holy Trinity in Lublin (Poland)

Barbara Łydżba-Kopczyńska[1,2], Piotr Frączek[2], Monika Czarnecka[1,3], Janusz Czop[2]
Anna Klisińska-Kopacz[2], Michał Obarzanowski[2], Karolina Budkowska[2]

[1] *Cultural Heritage Research Laboratory, Faculty of Chemistry, University of Wroclaw, Poland*
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[3] *Eugeniusz Geppert Academy of Art and Design in Wroclaw, Poland*

The National Centre for Research on Heritage[1] was established in Poland in 2015 and offers multilateral research on objects and collections to Polish museum institutions. The center was designed as a project of the National Museum in Kraków and National Institute for Museums and Public Collections in Poland. The Center created exquisite opportunity for museums to perform the research projects on comprehensive material investigation of art and archeological objects. It is also focused on protection of collections through improvement of collection management and preventive conservation analyses. The presented study was 2-years project funded and accomplished by the Center.

The goal of the investigations was to establish the attributions of scenes created by three painters, probably Orthodox monks in the unique mural paintings in Russo-Byzantine style in the Chapel of the Holy Trinity in Lublin, Poland. The wall paintings funded by the King of Poland Władysław II Jagiełło were recognized as a one of the most valuable medieval historical treasure in Poland. The original paintings finished in 1418 were overpainted at the end of 18$^{th}$ century and finally rediscovered in 1899.

There were selected seven scenes attributed by the art historians to various painters. In the first phase the non-invasive analysis incorporating VIS and IR photography and UV fluorescence was carried out in order to evaluate the state of the preservation of analyzed paintings. Then the results of XRF analysis delivered information about applied painting palette and allowed to differentiate between the original fragments of the paintings and reconstructions made by the conservators in 20$^{th}$ century. In the second phase of the project were collected samples representative for all analyzed sciences and fragments of the wall painted decorations. The SEM-EDX analysis of the cross-sections revealed information about the material composition of the paintings layers and distribution of the pigments among them. The molecular identification of pigments, especially Cu based pigments was done by the micro-Raman spectroscopy.

It was assumed that mural paintings were created in two techniques: *fresco* and *fresco secco*. Preliminary identification of the biding media was carried out with the application of the FTIR spectroscopy. The more detailed analysis of the binding media used by the painters was undertaken with the application of the GC-MS.

The comprehensive multi-techniques methodology based on the non-invasive techniques and the more depth analysis of the samples elucidated the attribution of the frescos and verified hypothesis of art historians.

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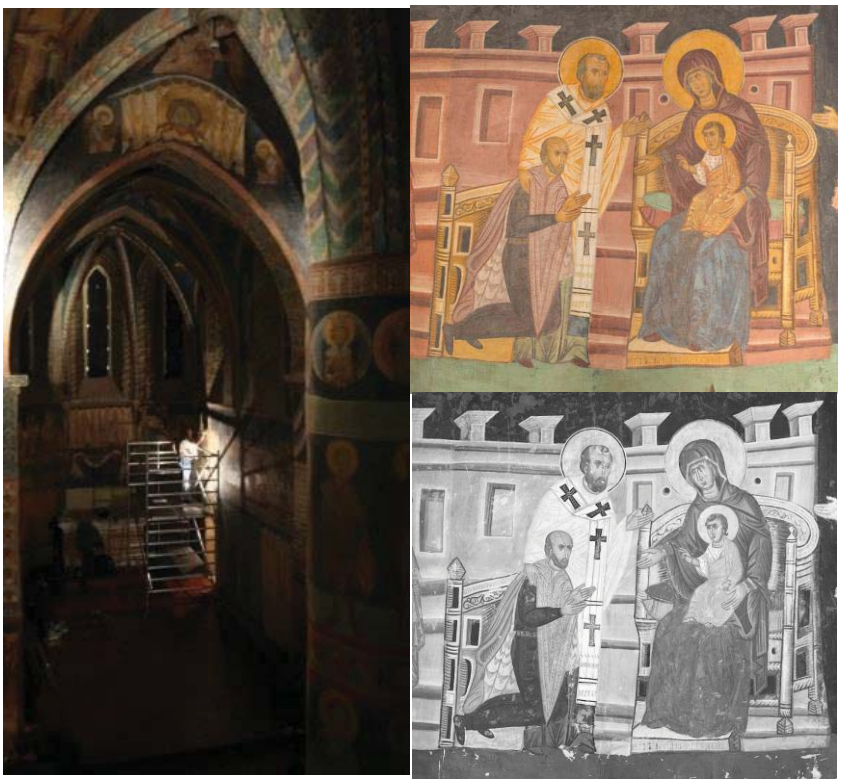
[1] Czop Janusz, Łydżba-Kopczyńska Barbara, Świątkowska Barbara, ''Krajowe Centrum Badań nad Dziedzictwem: nowa inicjatywa na mapie polskiego muzealnictwa = National Centre for Research on Heritage: a new initiative on the map of polish museology''. Muzealnictwo, 2017, 58, 123-133.



Chapel of the Holy Trinity in Lublin, Poland (on the left), VIS and IR photographs of *Donator's Prayer*.

# Unveiling the mural art of Almada Negreiros (1939-1949): a scientific study of the painting techniques and pigments as a guide for its future conservation

Milene Gil[1], Ana Cardoso[1], Yigit Helvaci[1], Sriradha Bhattacharya[1], Patrícia Moita[1], Catarina Miguel[1], António Candeias[1,2]

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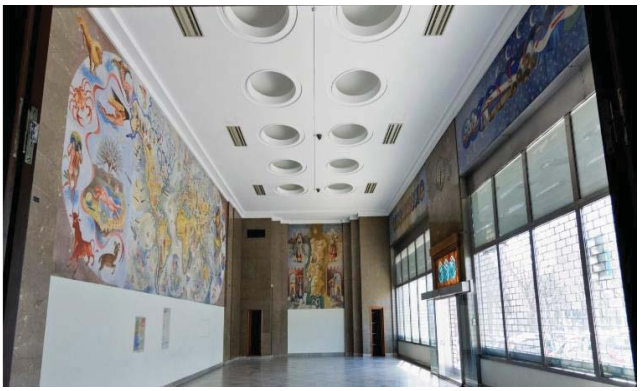
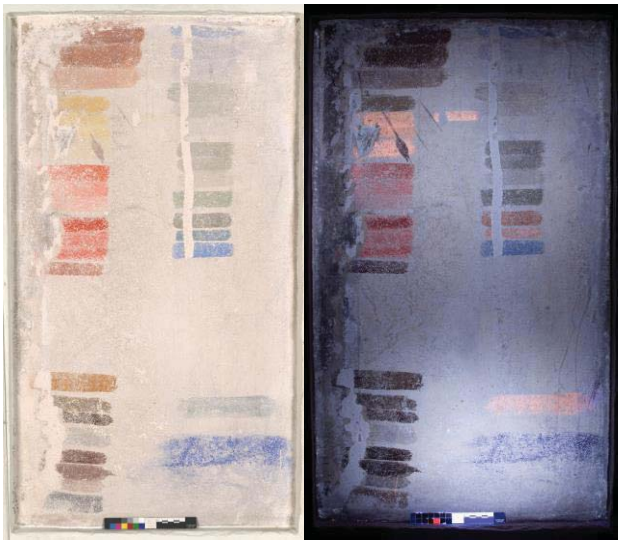
*[2] Chemistry Department, School of Science and Technology, Portugal*

Almada Negreiros (1893-1970) is a key artist of the first generation of Portuguese Modern Art. Over a sixty year multifaceted career, he created several works of art in emblematic architectural projects in Lisbon in the first half of the 20th c. Here is found the monumental mural paintings of Almada Negreiros, among which the five panels at the former headquarters of the renowned newspaper 'Diario de Noticias (DN)'. These paintings done in 1939-1940 were considered at that time his first achievement using the fresco technique. However doubts have been raised since then by conservators-restorers. This paper reports the analytical study carried out in the 'ex-libris' of DN, a painting entitled *mapa-mundi* with 54m$^2$ long and its color palette rediscovered behind wood cabinets, in 1991, during conservation works. The goal was to ascertain from the first time technical and material features and to understand to what extent Almada Negreiros has followed the old masters tradition.

The analytical setup has comprised non-invasive and micro-analytical techniques in situ and at HERCULES laboratory. First results reveals the use of a calcitic lime and coarse sand finishing mortar mixed with straw and pigments that goes beyond the traditionally used in fresco painting. Particular attention was given to the yellows and oranges with ultraviolet induced fluorescence in the visible.

The authors wish to acknowledge the owners of the mural painting for allowing the study; *Mural da História, Lda* for yielding samples of the color palette; Fundação para a Ciência e Tecnologia (FCT) for their support through PTDC/EPH-PAT/4684/2014 project: DB-HERITAGE – Heritage database on historical construction materials and finally, to IJF/DGPC for allowing microsampling and micro-analytical analysis.



On top: DN entry hall in 1940 and in 2017. The painting under study and the color palette beneath are on the left wall. On the bottom: overview of the color palette in Vis and UVF.

# Non-invasive characterization of condition, techniques and materials of the renaissance wall painting by Bernardino Luini in Santa Maria degli Angeli in Lugano

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[1] *Department of Environment and Construction, University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Switzerland*
[2] *CNR-Institute of Molecular Science and Technologies (ISTM), Italy*
[3] *SMAArt Centre and Department of Chemistry, Biology and Biotechnology, University of Perugia, Italy*

*The Passion and Crucifixion* wall painting is a monumental masterpiece by Bernardino Luini (1480-1532) covering the 120 $m^2$ of the *tramezzo* in the Romanesque Church of *Santa Maria degli Angeli* in Lugano. Luini is a famous pupil of Leonardo da Vinci and painted this mural, the most important Renaissance wall painting in Switzerland, at the apex of his career in 1529. Despite its relevance and cultural significance, this painting has never been study from the technical point of view until now. The objective of the study presented here was to investigate the painting technique and the conservation condition of the painting. The vast surface was cleaned and consolidated in the first half of the 20$^{th}$ century by Mauro Pelliccioli a renowned Italian artist and restorer.

Following a methodological approach, the project combined bibliographic and archival research with direct visual examination of the surface. The scientific investigations were almost exclusively non-invasive carried out on site by a multidisciplinary team. Several mapping and point analysis methods were used and included technical photography, p-XRF and reflection FT-IR spectroscopy. The latter, in particular, was provided by the mobile facility MOLAB. Following non-invasive investigations, a few unstable micro-fragments were studied with invasive non-destructive analysis (PLM/SEM-EDS/μFTIR) to inform and confirm the non-invasive data obtained.

The results of the study illustrate the richness of the painting materials and the technique used, but also confirm the effects of time and of harsh previous interventions. Luini and his workshop applied the plaster in the characteristic *giornate.* The complex scenes and the numerous figures were created with the help of only a few preparatory drawings, most having been painted directly without guidance. While most of the pigments used are typical of a traditional *a fresco* palette, Luini also employed materials from his easel painting practice, enriching precious details with gold leaf and using additional pigments such as Azurite, Malachite, Cinnabar and Yellow Lead, applied *a secco* with a tempera medium. In addition, the investigations revealed the presence of deterioration products on the surface such as gypsum and oxalates. The information obtained provides further knowledge about Luini's painting methods and is fundamental for future planning of a strategy for the preservation of this remarkable work of art.

The authors wish to acknowledge the MOLAB access within the IPERION CH (Integrated Platform for the European Research Infrastructure ON Cultural Heritage), funded by the European Commission (H2020 INFRAIA 2014-2015, GA n. 654028) and Dr. Stefan Zumbühl of Bern University of Applied Sciences

The wall painting is complete and cover the entire 120 sq.mt. of the *tramezzo.*

A detail of the painting in racking light

# A study on the appearance of indigo in false colour imaging

Moupi Mukhopadhyay[1], Giovanni Verri[1], Gianluca Accorsi[2] and Marco Pugliese[2]

*[1] The Courtauld Institute of Art , United Kingdom*
*[2] CNR Nanotec, Italy*

Indigo is an organic colourant generally extracted from the *Indigofera Tinctoria* and *Isatis Tinctoria* (woad) plants. It is widely used both as a dye and as a pigment all over the world. Although much research has been done on its identification using analytical investigations, such as Raman spectroscopy, it is with infrared false colour imaging that it is possible to spatially map its presence on a work of art. This paper will investigate the effect of pigment concentration and thickness on the reflective properties of indigo in the infrared range. The understanding of the role of the thickness/concentration of paint layers is important to interpret how infrared false colour imaging, which merges reflectance data in the visible (c. 500 nm – 700 nm) and infrared range (c. 700 nm – 1000 nm), is influenced by these parameters and the reflective properties of the substrate used as a preparation for its application.

By means of spectroscopic and imaging investigations, this work will qualitatively and quantitatively assess the transmission and reflection properties of indigo in the visible and infrared ranges on different substrates, to provide interpretation guidelines for false colour images.

The results of this study on test samples of known composition, as well as for a case study from Mangyu monastery in Ladakh, India, will be presented.

# Multi-technique characterisation of paint materials

# Tango Monastery, Bhutan: painting techniques for the 17th century wall paintings scenes

Lan Pu

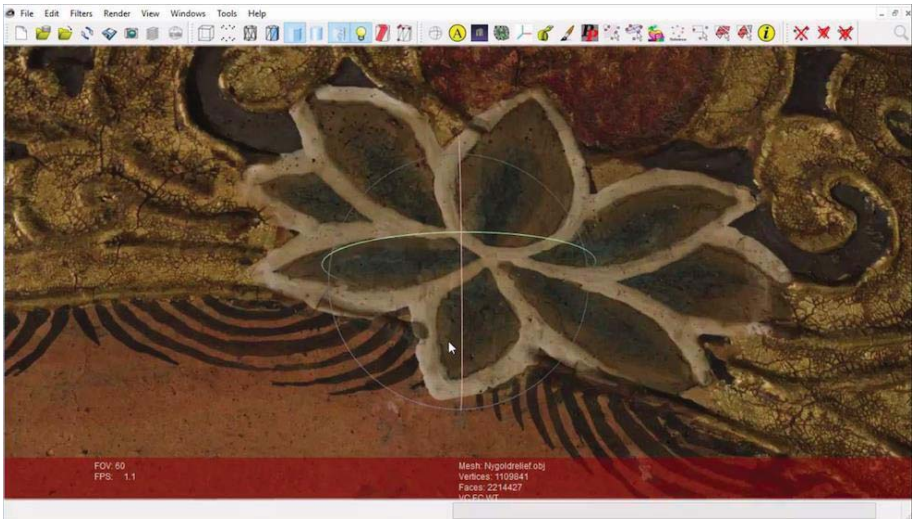
*The Courtauld Institute of Art, United Kingdom*

The Buddhist wall paintings of Bhutan are only now being studied in detail, and most have remained little known in this remote kingdom. Among the most spectacular survivals, whose extent and quality only became evident a few years ago, are the late 17th century paintings in the north shrine areas of the utse of Tango Monastery, near the capital Thimphu. These paintings show the Three Bodies of Buddha and the Sukhavati Buddha Land, and are the most important paintings of their date surviving in Bhutan.

Extraordinarily rich technically, especially in the complex gilding techniques employed, these wall paintings have now been studied in 2016 (for the Courtauld Institute and Department of Culture of Bhutan), in terms of all aspects of their materials, and painting methodology. Considering the remoteness of the site and the time limit, feasible investigation methodology was designed for onsite investigation. Technical examination—using micro-photogrammetry, multispectral imaging, micro- and macro-visible imaging—was complemented with invasive analysis and instrumental techniques.

The results were remarkable. This contribution will demonstrate how the 17th-century workshop—where several different hands can be discerned—employed complex preparatory techniques, including sealant and ground layers, underdrawings, and color notations to achieve the final rich appearance involving both rare pigments and use of organic colorants. For the gilding alone, three different techniques were used. As the most detailed technical study so far undertaken of any Bhutanese wall paintings, the findings will be related to the preparatory techniques so far known for other Buddhist wall paintings in Tibet and elsewhere.


Color natation of Pink.




Micro-photogrammetry of gilding.

Technical study of the paintings at Tango Monastery has been focused on two 17th-century schemes located in two shrines in the central tower (*utse*): the shrines of Sambhogakaya and Dharmakaya. The study is associated with a collaborative conservation project, undertaken in partnership between the Conservation of Wall Painting Department, Courtauld Institute of Art, and the Department of Culture of Bhutan. Recognizing the remarkable significance of these paintings, the Courtauld Institute began working with the Department of Culture in 2014, and with the gracious assistance of the Royal Family to find a solution to preserve both the structure and its valuable wall paintings in situ. The studied wall paintings were executed in 1688-9 under the rule of the 4th Desi Gyalse Tenzin Rabgye, and probably the only monument commissioned by him that still survives.

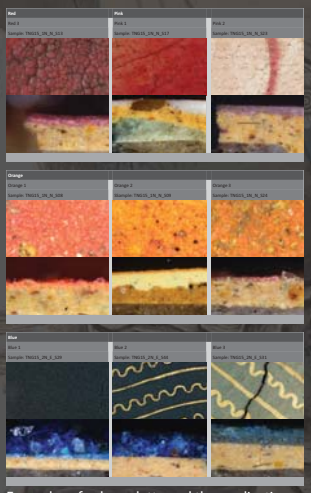
Among the few surviving sites from the 17th and 18th centuries in Bhutan, Tango Monastery is not only one of the country's most important monuments, but also has the most exquisite wall painting schemes from the period. Its magnificent wall painting schemes demonstrate exceptional craftsmanship with a mastery of draftsmanship, a rich palette, and sumptuous gilded reliefs decoration.

| Sequence by layer | Comments |
|---|---|
| Secondary plaster layer 1 | Earthen |
| Secondary plaster layer 2 | Earthen, polished |
| Sealant | Organic |
| Ground | Yellow mixture (jarosite and lead white), polished |
| Underdrawing | Black for composition and gilding |
| Raised gilding | Jewelry, ornaments and headpieces |
| Pigmented paint layers | Color achieved through mixing and layering |
| Glazes | Applied to raised gilding and for shading on figures |
| Flat gilding | Buddha flesh areas, gilded figures with incised decorative patterns (only investigated in 2N) |
| Compositional outlines | Red, blue organics, and black |
| Decorative gilding | Decorative patterns on robes and mandorlas |

Overview of application sequence

| Color | Pigment | Comments |
|---|---|---|
| Blue | Azurite ($2CuCo_3.Cu(OH)_2$) | Employed with different particle sizes |
| Green | Possibly brochantite ($Cu_4SO_4(OH)_6$) or chrysocolla ($CuSiO3.nH2O$). | Results of FTIR suggests that it is not malachite ($Cu_2CO_3(OH)_2$) |
| Yellow | Orpiment ($As_2S_3$) | |
| | Jarosite $KFe^{3+}{}_3(SO_4)_2(OH)_6$ | Employed in ground |
| Red | Cinnabar (HgS) | |
| | Red lead ($Pb_3O_4$) | Mixed with orpiment or cinnabar to create different orange hue |
| White | Possibly magnesite ($MgCO_3$) | Appears semi-translucent in cross-section |
| | White lead ($(PbCO_3)_2.Pb(OH)_2$) | Employed in ground |
| | Talc ($Mg_3Si_4O_{10}(OH)_2$) | |
| Black | Carbon black? | |

Identified mineral pigments



Examples of color palette and the applications

# Tango Monastery, Bhutan: Painting Techniques of the 17th-century Wall Painting Scenes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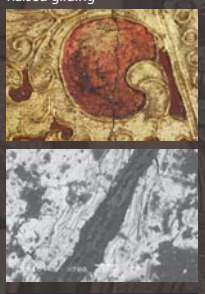
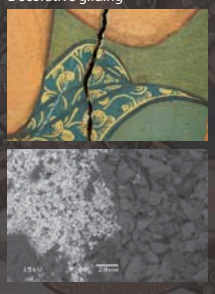
Raised gilding



Flat gilding

Decorative gilding

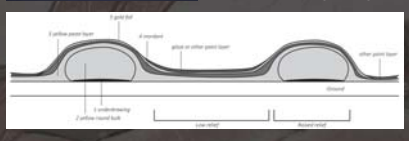




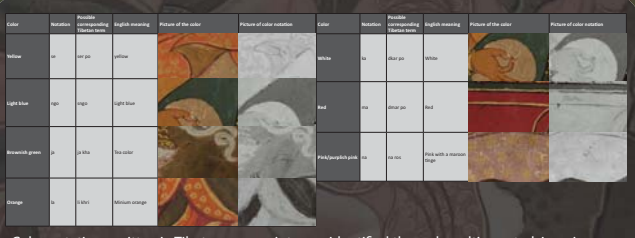




Extensive use of gilding is an outstanding feature of the wall paintings in both shrines, and a major focus of this study. Three different types of gilding were characterized: raised gilding, flat gilding, and decorative gilding.



Gold foil and powdered gold were both used in the making of gilding. SEM-EDX of an unmounted samples confirmed the employment of different gold materials.



Color notations written in Tibeten ume script were identified through multi-spectral imaging. Color notations were used extensively, particularly in areas with intricate designs such as fabrics.

Both non-invasive and invasive analysis methods were employed in the study. Due to the remote location of the site, all non-invasive techniques employed are portable, repeatable, relatively low-cost, and readily available. The study also explores the use of macro-photogrammetry for examining the surface topography of raised gilding.

Analytical methods used includes: macro imaging, portable USB microscopy, multi-spectral imaging, Macro-photogrammetry, Polarized Light Microscopy, micro-chemical tests, histo-chemical tests, Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy, Fourier Transform Infrared Spectroscopy with Attenuated Total Reflection.

# Enhance knowledge to improve conservation: the Iti and Neferu wall paintings

Michela Cardinali[1], Tiziana Cavalleri[1], Paola Croveri[1], Christian Greco[2], Beppe Moiso[2], Anna Piccirillo[1], Arianna V. Scarcella[1], Paolo Triolo[1]

*[1] Centro Conservazione e Restauro "La Venaria Reale", Italy*
*[2] Museo Egizio, Italy*

During the total refurnishing of Turin Museo Egizio, that forerun the 2015 reopening, an extraordinary legacy of ancient Egyptian mural art was investigated by a multidisciplinary team of conservators, archeologists, curators and conservation scientists. Dated back to the First Intermediate Period, 11th dynasty (2080-1980 b.C.), the twenty-nine wall painting fragments from the tomb of Iti and his wife Neferu, have long been considered as some of the masterpieces of the museum collection not only for their early datation, but also in reason of the impressive overview of ancient Egyptian everyday life and culture they portray.

The project, developed by the Centro Conservazione e Restauro "La Venaria Reale" in collaboration with Turin Museo Egizio and Piedmont Archeological Soprintendenza[1], was intended to enhance the knowledge of the fragments, focusing on the investigation of historic, technical and conservative issues, before preparing them for new exhibition at the Museo Egizio.

Preliminarly to the conservative treatments, a multianalitycal protocol was set up: at first, non-invasive analysis have been carried out in order to investigate ancient techniques and materials, clarify conservative criticalities and recognize previous treatments. Therefore, every fragment has been observed and photographed in UV light fluorescence, then images of IR reflectography were captured and false colors were processed. IR images revealed a number of details about execution technique, especially related with the preparatory drawning and the outline, such as two "pentimenti". Instead, UV fluorescence and false color images showed a heterogeneous map of materials, only partially recognizable as originals: characteristic fluorescence of modern materials, beside the ones of pigments attested in ancient Egyptian wall paintings, shed new light on documented and unknown remedial treatments occurred after paintings discovery in 1911.

The collected results led to a second step of analyses that have been carried out to characterize the different materials observed, including fiber optic reflectance spectroscopy (FORS), Fourier transform IR spectroscopy (FT-IR) and EDX analysis with scanning electron microscopy (SEM-EDX). The analytical results, compared with the historical information[2], helped to distinguish original plasters and pigments from the ones, such as Zinc white, applied during modern intervention. Furthermore, analytical investigation allowed to identify overlaid materials used in various treatments, from a preliminary *in situ* protection of the painted surfaces with sheets of "yellow paper" and local soils[3] to the modern superficial consolidation with paraffin by Lucarini, or an undocumented re-adhesion of painting chips with alkyd resin[4].

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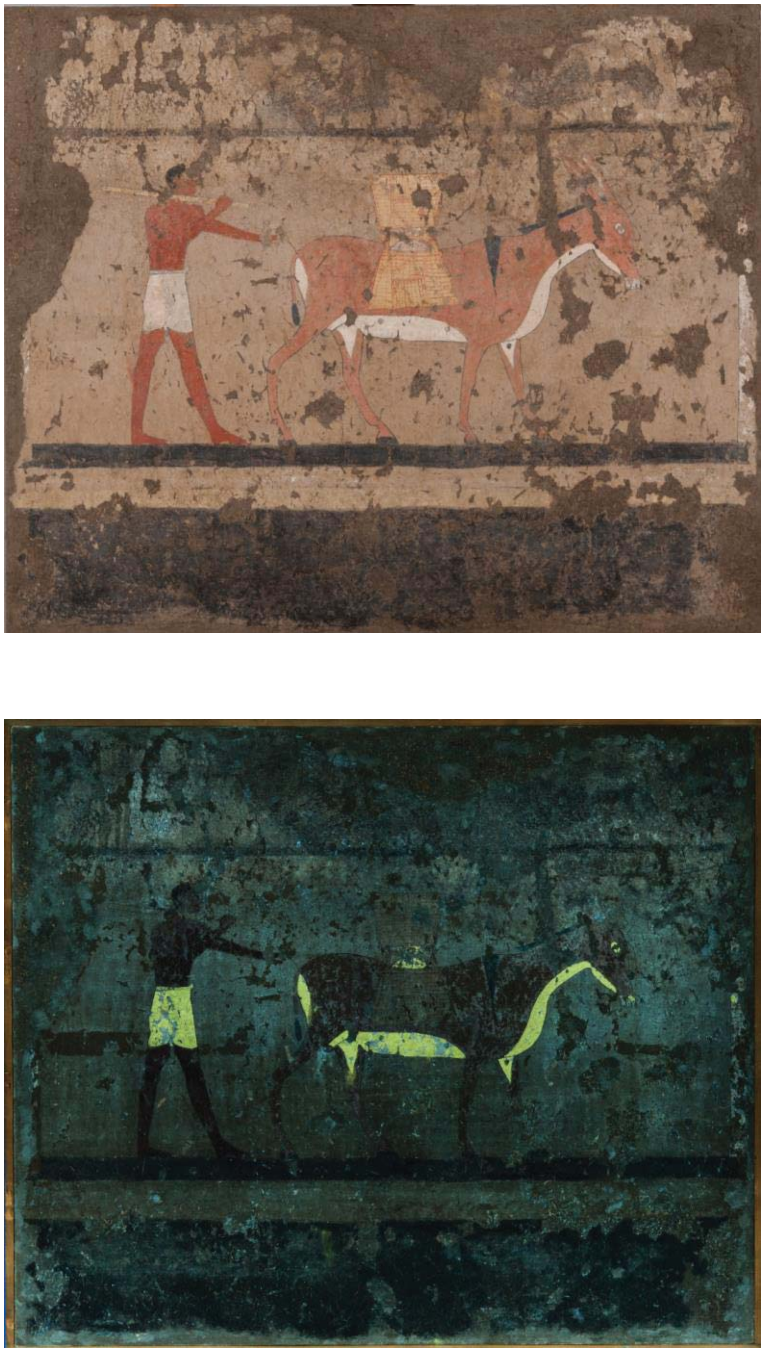
[1] In the person of Dr. Matilde Borla, archeologist, official in the local board of the Italian Ministry of Culture.
[2] G. Marro, L' esplorazione della necropoli di Gebelein (dai lavori della Missione Archeologica Italiana in Egitto) Estratto dagli Atti della Società italiana per il Progresso delle Scienze, XVII Riunione- TorinoSettembre1928, Pavia 1929, pp. 36-43.
[3] F. Bertelli, E. D'Amicone, L. Vigna, OPD Restauro 25, 2013, pp. 363-376.
[4] Personal Comunication by B. Moiso.



Fragment n° 14354/05 in visible (above) and UV (under) light. The areas showing a yellow UV fluorescence (typical of zinc white pigment) have been further analysed with FT-IR and XRF, obtaining the evidence of a natural resin as binding and the presence of zinc as white pigment in the latest overpainting.

# The identification of a red lake pigment in the wall paintings of Härnevi church

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In 2016 a previously unidentified red pigment with characteristic elongated fibres was found in the 15th century wall paintings of Härnevi church, Sweden. This investigation set out to identify the pigment, working from the hypothesis that it might be a madder lake pigment made from wool shearings. The paintings in Härnevi church have been attributed to the workshop of Albertus Pictor (~1440-1509) who is the most well-known mural painter in Sweden. However, he was also known as an embroiderer. This gives a possible connection between Albertus Pictor as a painter and as an embroiderer as he would have had access to cloth scraps that could be "recycled" into pigment.

The investigation utilised the technical art history methodology where observations in situ was supported by contemporary sources, scientific analysis and through reconstructions.

Samples of the pigment were investigated with the use of optical microscopy, Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy coupled with Energy Dispersive X-Ray analysis (SEM-EDX) and High Performance Liquid Chromatography (HPLC). The result supported the hypothesis that the pigment was made out of wool shearings dyed with madder root. The identification of both the wool substrate and the lake colorant has to the author's knowledge not previously been made on a pigment sample from a wall painting.

The pigment was reconstructed according to a contemporary recipe from the Nürnberg kunstbuch and tried with three different binders; rabbit skin glue, linseed oil and egg. The binder that had the best working properties with this type of pigment was egg. Binding analysis on a sample from the wall painting made by Mass spectrometry nano-LC-ESI-Q-TOF also suggested that egg proteins had been used.

The investigation additionally led to a partial revision of the wall painting technique used by this workshop and demonstrates the complexity of these paintings where a combination of techniques and organic materials has been used. Furthermore, the reconstructions led to a deeper understanding of the material and provided information on why one binder might have been chosen over another.