

C U R S O S   E   C O N G R E S O S

**INTERNATIONAL CONGRESS ON  
Science and Technology  
for the Conservation  
of Cultural Heritage**

**Santiago de Compostela, Spain,  
2-5 October 2012**

**BOOK OF ABSTRACTS**

# **Research Advances for the Conservation of Cultural Heritage**



**EDITED BY**  
Massimo Lazzari  
Sophie Rochette

UNIVERSIDADE  
DE SANTIAGO  
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# Research Advances for the Conservation of Cultural Heritage

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## **PREFACE**

The European Cultural Heritage is an invaluable legacy. Europe's cultural heritage is the product of many cultures that have contributed over centuries to its development. We recognise the potential for the cultural heritage to play a proactive role in enriching and enhancing quality of life, in delivering answers to basic questions about our historic origins, in providing solutions to environmental and construction-related problems, and in interacting with other internal social, economic and political drivers.

Europe has shown itself skilled at turning pure scientific research for cultural heritage into innovative products, giving it a lead over other parts of the world where there is a demand for new European technologies. However, having established that universal solutions are not the answer and that deterministic approaches and an eagerness for standardisation have oversimplified reality, we can admit Europe has the knowledge to be able to scientifically validate answers to concerns over the sustainability of our current approaches to heritage conservation. In this sense, Europe has been, and is still today, the world leader in these kinds of initiatives and studies. In the context of the economic crisis in which the European Union is involved, and in particular some of the richest countries in terms of Cultural Heritage (i.e., Greece, Italy, Spain, Portugal), the present situation is a challenge for the institutions and the scientists concerned with the conservation of Cultural Heritage and, therefore, the application of imaginative solutions would allow to fully exploit the synergies generated through an international cooperation.

The Spanish Network on Science and Technology for the Conservation of Cultural Heritage, funded by the Ministry for Science and Innovation (HAR2010-11432-E), began its activities in March 2011. Currently in the Network participate seventy five groups, including Spanish National Research Council (CSIC) and Spanish universities teams; cultural institutions, foundations and museums; and private companies. The Network aims to foster the collaboration between the elements of the science-technology-enterprise system to ease the sharing of ideas and experiences helping in the resolution of problems and should allow the transfer of technology with the common goal of contributing to the conservation of Cultural Heritage.

One of the activities of the Network is the organization of annual meetings. This International Congress on Science and Technology for the Conservation of Cultural Heritage has as a main goal to create an interdisciplinary forum for discussion on all aspects of cultural heritage conservation, providing at the same time an up-to-date and comprehensive picture of the state-of-the-art of investigations.

The ultimate aim is to promote networking among European research teams and strengthen the foundation of scientific and technological research. In the hope of achieving this goal I welcome you to this International Congress on behalf of the organizing committee.

Cesareo Saiz-Jimenez  
Network Coordinator

The Conference is organised on behalf of the Spanish Network of Science and Technology for the Conservation of Cultural Heritage (**TechnoHeritage**) by the Universidade de Santiago de Compostela (USC, Spain).

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- T2.** Agents and mechanisms of deterioration of Cultural Heritage (physical, chemical, biological), including deterioration of modern materials used in Contemporary Art and information storage
- T3.** Development of new instruments, non invasive technologies and innovative solutions for analysis, protection and conservation of Cultural Heritage
- T4.** New products and materials for conservation and maintenance of Cultural Heritage
- T5.** Preservation of industrial, rural and archaeological heritage
- T6.** Security technologies, Tele-survey and Geographical Information Systems for protection and management of Cultural Heritage
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**Environmental assessment and monitoring of changes in  
air pollution, climate change, natural events on Cultural Heritage**

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Our heritage has always been under threat from the environment. The Great Sphinx was buried by sand and it was cleared several times. Herodotus (484 BC–425 BC) further wrote that “Ahmose II... for restoration of colossal statues and man-headed sphinxes he brought other stones of monstrous size”. Earthquakes, war, flood and storms can cause immediate and catastrophic damage, but the affects are often more subtle than this and accumulates over time. It is only after much of value is lost that there is an awareness of the damage caused by this slow impact of the environment. The nature of these impacts and the forces that drive them have changed over time. This makes monitoring and assessment of the damage important so management strategies can mitigate the impacts. In past centuries the colder climates of northern Europe caused much damage to porous stone, and then industrialization and the use of high sulfur fuels was a key factor in damage. These pressures may now be lower, but they are likely to be replaced by enhanced impacts of a more oxidizing urban atmosphere, salt weathering, surface flooding and wind driven rain. Climate change can also propagate indoors and here there is the potential of damage through increased mould growth or insect pests. The shifting nature of this threat requires new tools to measure and model the risk over long timescales.

## **Agents and mechanisms of deterioration of Cultural Heritage**

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Over the last decades considerable attention has been devoted to the role played by atmospheric deposition in the damage processes induced on the materials characterising the cultural heritage exposed to the outdoor atmosphere (e.g. archaeological, architectural and modern built heritage). Most of the initial work relating to this issue has focused on the effects due to gases, mainly SO<sub>2</sub>, NO<sub>x</sub> and ozone. However, since the outset, atmospheric particles have been considered to play a key role in the damaging processes, even if their investigation is more difficult because of their variety in size, shape and composition.

The presentation will provide an overview of the work performed on the characterisation of atmospheric particulate found on building materials of historical and archaeological interest. In addition, it deals with evaluating their effects, focusing particular attention on building materials, such as stone and mortars, in view of the evidence of their increasing rates and levels of damage over the last decades, especially in urban areas.

How climate change will impact on the deterioration of cultural heritage will also be considered through the presentation of the main output of the EC Noah's Ark Project summarised in the "Atlas of climate change impact on European Cultural Heritage", which includes European-based maps related to various degradation processes under future climate scenarios.

## **Development of new instruments and application of non invasive technologies and innovative solutions within the CHARISMA project**

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CHARISMA (*Cultural Heritage Advanced Research Infrastructures: Synergy for a Multidisciplinary Approach to Conservation/Restoration-7th FP n.228330*) is a consortium of 22 European institutions, that develop and promote advanced research in conservation/restoration. (<http://www.charismaproject.eu>). The consortium combines research laboratories with leading technology institutes on cultural heritage, to facilitate profitable interactions among scientists, conservators-restorers and curators. Final perspective is the creation of a future common European Research Infrastructure in the field.

Within CHARISMA, three different types of activities are jointly carried out by the consortium partners, as: research, networking and transnational access.

Within the *research program* six new instrumentations for *in-situ* non invasive 2D and 3D measurements, have been designed and are in development, including Confocal IR Microscopy, OCT, THz Imaging, Single-sided NMR and others.

Through *transnational access*, facilities of the consortium are open to European scientists, conservator/restorers and curators, in order to let them carry out their research exploiting advanced tools. Access opportunities include:

a. the consultation of the data archives of: The National Gallery and The British Museum in London, UK; the *Opificio Pietre Dure* in Firenze, IT; the C2RMF in Paris, FR; the *Museo del Prado* in Madrid, ES; and the RCE Agency in Amsterdam, NL; b. the exploitation of instrumentations and competences of small (MOLAB), medium (AGLAE, Paris, FR, and ATOMKI, Debrecen, HU), and large scale facilities (Synchrotron SOLEIL and Budapest Neutron Centre).

Among the access facilities, MOLAB offer European researchers a unique set of portable instrumentations for non invasive *in-situ* multi-technique measurements, to develop diagnostics or to monitor materials and cleaning techniques before, after or during restoration. The integrated MOLAB portable techniques include multispectral high-resolution IR imaging (*CNR-Istituto Nazionale di Ottica*, Firenze, IT), X-ray diffraction (*CNRS*, Paris, FR), X-ray fluorescence, near- and mid-FT-IR, Raman (both micro- and macro-), UV-Vis absorption and emission and others (University of Perugia, IT).

Examples will be given of applications which demonstrate how *in situ* multi-technique applications can lead to excellent characterization of painting execution techniques (Cezanne, Renoir, Memling, Van Gogh, Burri, etc.), to significant tests of innovative restoration methods (Pontormo, Munch, etc.) and to useful monitoring. Examples will be also given on how the combination of *in situ* non invasive and laboratory micro-invasive investigations permits detailed information on alteration processes to be achieved, even at microscopic level, when the alteration is at the first stage of development.

## **New products and materials for conservation and maintenance of Cultural Heritage**

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Works of art and artifacts 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 if protective coatings (mainly acrylic and vinyl resins polymers), applied in previous restoration treatments, are present.

In the past years we pioneer the synthesis and the application of several advanced systems for the cleaning and consolidation of works of art. Two main systems have been developed: nanoparticles, microemulsions and chemical/physical gels.

a. **Nanoparticles.** Calcium and barium hydroxide nanoparticles offer versatile and highly efficient tools to invert the degradation processes altering wall paintings, or to de-acidify and protect cellulosic materials (paper, wood). An illustrative example of the efficacy and potentiality of nanotechnology is represented by the rescue, *in situ*, of Maya wall paintings in the archaeological area in Calakmul (Mexico) and several other paintings all over the world. Inorganic consolidants are highly chemically stable and preserve the wall painting ensuring long-lasting consolidation effects without the side effects produced by polymers coating. Calcium hydroxide nanoparticles ensure the highest physico-chemical compatibility with the work of art and it should be preferred when degradation results from the loss of calcium carbonate. The presence of sulfate salts as a contaminant can inhibit the consolidation effects. Innovative formulations based on calcium and barium hydroxide nanoparticles overcome these limitations thank to their synergistic action, which confers to the paintings a stable consolidation.

b. **Micelles, microemulsions and chemical/physical gels.** The cleaning or the removal of coatings from pictorial surfaces can be achieved by using very efficient colloidal systems as i) microemulsions and micellar solutions optimized for the removal of acrylic, vinyl and alkyd polymers; ii) chemical, physical, and smart gels with embedded microemulsions or micellar solutions.

With illustrative examples, I will report on the applications of these systems in recent restoration workshops.

**The Preservation of industrial and rural heritage from  
the 19<sup>th</sup> and 20<sup>th</sup> centuries: a UK perspective**

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This paper will look at a variety of approaches to preserving industrial and rural heritage in the UK, with some comparative material drawn from elsewhere in northern Europe. A number of case studies will be used to highlight the range, scale and conservation problems in preserving the built heritage from this period. These sites include textile mills, railway buildings, cornmills and agricultural buildings. The legislative and planning framework will be reviewed, along with strategies for encouraging the adaptive re-use of buildings. The paper will also look at the archaeological techniques being used in the UK to record industrial and rural heritage threatened by redevelopment.



## **Challenges of GIS for Heritage Management**

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In this paper I will discuss the role that GIS plays in heritage management and protection within the context of the US NPS. The U.S. National Park system contains over one hundred thousand historic, archaeological or ethnographically significant sites. This talk will focus specifically on how GIS may be used to mitigate the impact of climate change on these resources and the challenges surrounding this task.

Protecting the physical vestiges of cultural heritage requires taking action. The decision making questions that inform action are all represented by the papers presented: Which sites are at risk? From what threats? How soon is action needed? What action would be helpful? What sites are the most important? GIS, remote sensing and geospatial data play fundamental roles in meeting this need. A basic model for protecting heritage is to identify heritage sites, model the risk to those resources and take protective action. Protective action might mean altering the forces of change, moving the resource to avoid the destructive force or hardening the resource such that it will not be adversely affected.

GIS can help us:

- establish baselines, risk thresholds and monitor change;
- analyze risks and vulnerabilities;
- convert physical resources into digital ones (digitally curate spatial models of destroyed resources);
- communicate with each other and the general public about places and heritage at risk.

In this paper I will discuss several major challenges in implementing useful tools to meet this need.

- Issues regarding quality and representation of spatial heritage data. How does our confidence in our knowledge vary spatially and temporally? How can we communicate these uncertainties without overwhelming users?
- Challenges and perils integrating spatial heritage information. How can we integrate spatial data sets from various paradigms and technologies? For example, much archaeological or historic research in the past was recorded in narratives. How can this information be integrated with modern GPS or LIDAR based data?
- GIS models and tools to guide action. What analyses can GIS offer to guide action?

## **Significance and Social Value of Cultural Heritage: a Critical Approach**

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This presentation analyzes some of the factors that are part of heritage-making processes (or heritagization processes): on the one hand, economic factors and, on the other, those dealing with the politics of identity, belonging and exclusion. Heritage is a metacultural process in the sense that artefacts, buildings, landscapes, festivals or any other heritage element are not by themselves heritage unless there is social value attached to them. From this point of view, heritage is a peculiar type of cultural process because it implies a metacultural reflection about culture. Heritage implies “adding value to culture.” It is a value-laden concept with no neutral ground of connotation. Therefore, heritage-related projects need to incorporate critical research on the instrumentalizations of heritage policies and the conflicts that arise. In addition, scientific projects and technology for the conservation of heritage –the theme of this conference– face the challenge of how to incorporate local actors in the heritage regime to build a more democratic heritage model. The analysis presented here is based on case studies of the 7FP CRIC project (Cultural Heritage and the Reconstruction of Identities after Conflict), which focuses on the impact of the selective destruction and reconstruction of cultural heritage and on the project “Processes of Heritagization along the Camino de Santiago” (INCITE09606181PR). Both projects have been conducted at the Institute of Heritage Sciences (Incipit).

**Multidisciplinary approach for the identification of the environmental risks and the assessment of the preventive conservation strategy for the *Portico de la Gloria*, Cathedral of Santiago de Compostela (Spain)**

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In the framework of the "Santiago de Compostela Cathedral Program" funded by the *Fundación Pedro Barrié de la Maza* a multidisciplinary investigation of the Portico de la Gloria was carried out between 2009 and 2011 to identify the main environmental (natural and antropic) risks and to develop a preventive conservation strategy and restoration plan.

In order to characterize the materials, investigate their state of conservation and identify the most relevant damage processes, a complete study of the Portico was performed. This study included historic and archivist research, structural studies, mineralogical analyses, biological sampling and cleaning tests.

At the same time a microclimatic monitoring was carried out following a specific methodology to understand the interactions between the atmosphere and the stone surfaces of the tympanum. With this approach, the main factors affecting the microclimate of the Portico were identified and consequently those having a greater impact on the observed weathering phenomena.

The main deterioration processes related to the environmental conditions were identified and the environmental phenomena playing an important role were prioritized. Nevertheless, the results obtained have shown that the main responsible for the observed damage was the infiltration of rainwater through the roof, due to cracks in the structure of the Cathedral. In fact, water soluble salts (mainly nitrates and sulfates) were detected in high concentrations in the south side of the Portico, causing efflorescence and sub-efflorescence driven by the thermo-hygrometric conditions and by the impact of solar radiation. These phenomena in synergy with biological growth (algae) and thick surface deposits represented a remarkable weathering factor especially for the polycromy.

The identification and evaluation of the most important environmental risks affecting the Portico allowed establishing the main conservation and intervention measures to be taken. Besides the repair of the roof to stop external water penetration, other solutions were suggested to improve the microclimatic conditions of the Portico, especially those addressing the atmospheric stability, thus reducing any further damage. The proposed interventions have to be integrated in the general management strategy for the conservation of the Cathedral and pooled with the unavoidable presence of huge quantities of devotes and pilgrims.

## Basic descriptive statistical methods for monitoring and evaluation of microclimates in Cultural Heritage

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The aim of our studies is to undertake the preventive conservation actions required and increase the knowledge about the conservation of different indoor Cultural Heritage (CH) (Metropolitan Cathedral of the city of Valencia, Spain) and open-air archeological sites (Ariadne's House in Pompeii, Italy). Preventive conservation requires knowledge of a set of parameters connected to a specific CH site, including microclimatic conditions. Thus, monitoring environmental parameters such as temperature and relative humidity (RH) is required. In order to evaluate the state of conservation of that CH different basic descriptive statistical methods are applied (mean daily trajectories, bivariate plots, etc.). We use a type of plot (figure), used in several fields of science, but rarely applied in microclimate monitoring where trajectories of a few days randomly chosen are usually presented. Descriptive tools have been effective for highlighting the dissimilarities among sensors and for knowing how their location, orientation, ventilation or height can influence the microclimate they, and consequently CH, are exposed. Those conclusions allow us to take appropriate decisions.

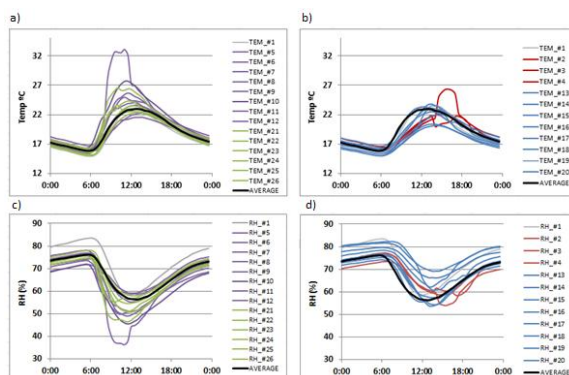


Figure. Mean daily trajectories of temperature and RH recorded in 2008-2009 (07/24/2008 to 07/29/2009) in Ariadne's House (Pompeii)

## Long-term weathering of glass and stained-glass in the changing environment of Paris from 16<sup>th</sup> to 21<sup>st</sup> century

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Dose-Response Functions established for the Si-Ca-Na modern glass haze [1] and for Si-Ca-K mediaeval stained-glass leaching [2] reveal that the first one depends only on pollution parameters (PM, SO<sub>2</sub>, NO<sub>2</sub>), while the second one, on both pollution and climate parameters (RH, T°, SO<sub>2</sub>, NO<sub>2</sub>).

In this study past temperatures in Paris were available from instrumental records since 1800. Past air pollution concentrations were estimated from fuel use statistics from 1875 to 1943 and from measurements that started in the 1950s.

Future temperatures and relative humidity in Paris through the 21<sup>st</sup> century were simulated *via* the Hadley model HadCM3 using the A2 IPCC scenario. Future pollutants concentrations were estimated from the GAINS model.

This study revealed that the increasing use of coal in Paris through the 19<sup>th</sup> century and the enhanced SO<sub>2</sub> concentration made a rapid increase in haze formation which reached a peak around 1950. The likely damage to mediaeval stained-glass follows a similar pattern. The damaging period from pollutants appears later and for less time in Paris than in London [3].

The less polluted conditions projected for the urban atmosphere of Paris will most likely simplify the cleaning of windows glass and large glass façades, as well as protect stained-glass windows.

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**Evaluation of environmental conditions of  
the *Museo del Ejército* (Toledo, Spain) by means of  
Sol-Gel optical sensors**

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Evaluation of environmental conditions is the key factor for preventive conservation in museums. Gaseous pollutants, especially acid species combined with moisture, arise as dangerous threats for conservation of most of materials (metals, textiles, papers, glasses, leathers, etc.). Despite the development of new technologies for monitorisation of temperature, humidity, lighting and others parameters, no device can be found in the market able to measure the air acidity/basicity, i.e. pH.

In the present work pH chemical sensors based on Sol-Gel technology, synthesised and calibrated by the TechnoHeritage groups C02 and IC2 have been used to evaluate environmental conditions in the *Museo del Ejército*. This is a state-owned museum holding a wide variety of items and materials from fifteenth century AD, distributed over 8.000 m<sup>2</sup>. The museum indoor arrangement, show cases, lighting, air conditioning, security systems, etc. correspond to the most advanced exhibition conditions.

Sol-Gel pH sensors with optical response were installed inside show cases, as well as exposed to the air of exhibition halls. In addition, reference sensors were exposed outdoor, distributed by the façades of the building. The sensors' response was recorded throughout 7 months. For this purpose a portable device designed and produced by the team C02 was used. Average pH results indicate that indoor pH is about 7.1, very close to theoretical neutral conditions, while outdoor pH is as low as 4.9, which could induce acid shock. These results are discussed in terms of pollutants' concentration and relative humidity percentage, both indoor and outdoor, as well as considering the architectural characteristics of the museum building (*Alcázar*, a fortified palace rebuilt upon Arabian, Medieval and further Renaissance castles). The positive role of conditioning, preservation and security systems of the *Museo del Ejército* is addressed as the main factor to provide the optimal conservation conditions recorded.

## Analysis of the hygrothermal behavior of Baroque Church: case study of the church of San Francisco de Asís in Morón de la Frontera

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Traditionally, the indoor environmental conditions of churches have been determined by their external climate conditions and their great thermal inertia. However, the recently comfort society requirements, join to energy efficiency and savings and air quality regulations, demand an environmental adequacy of these buildings. Furthermore most of these buildings, as well as their traditional liturgical use, have been rehabilitated to be used as cultural buildings.

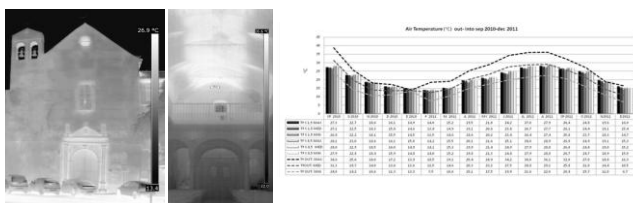
The lack of data about environment properties that support the cultural assets, hinders an adequate evaluation to decide on the design of control techniques for human comfort and the implications that certain fluctuations of air temperature and relative humidity have on the degradation process.

The work here presented is a part of an extensive research project named: “Study of the implantation of the technologies of hygrothermal conditioning in the refurbishment projects of Baroque churches”. A case study is the church of San Francisco de Asís, located en Moron de la Frontera, (Seville, Spain). This church is part of the city’s architectural ensemble and province’s rich immovable heritage and was declared Asset of Cultural Interest in Monument category.



In this study, was performed a characterization of microclimate parameters, expecting to find a normal hygrothermal performance of a building with high thickness and thermal inertia walls and with different temperatures and relative humidity depending on their height and location.

However, after studying the results of different parameters obtained in the monitoring campaign of the church, we observed there was not such difference between walls, at least to degree enough. After a detailed analysis of possible causes of this anomaly, it is determined the main reason was changes in urban environment. Also the results show the needed of some control of environmental conditions to reduce fluctuation, especially on relative humidity and to improve human comfort and preservation of church’s heritage.



## Microclimatic assessment and computational fluid dynamic modeling for salt crystallization control

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Ancient cultural buildings are often exposed to the risk of being damaged by soluble salt crystallization. This physical process can be activated and accelerated in building structures within specific microclimatic intervals for different chemical compounds. Therefore the importance to monitor the microclimatic parameters is widely recognized for identifying rapidly the conditions that can lead first to an increasing of the process and then to the building damage. Here we study the indoor microclimate of the Crypt of the Duomo of Lecce (South Italy), with a special focus to the environmental conditions of a particularly salt damaged area. In that area the salts efflorescence diffusion was graphically monitored over one year, in order to obtain damage maps for the same period. The decay mapping and the in-situ observations highlighted two important periods during the year for salt crystallization, so a possible connection between the microclimatic conditions and soluble salt crystallization was addressed. Once the indoor conditions have been assessed, a 3 dimensional Computational Fluid Dynamic (CFD) simulation was used to model a number of possible microclimatic scenarios, especially regarding the influence of ventilation, through the nine windows of the Crypt (Figure). The simulations permitted us to establish the most suitable microclimatic scenario in a preventive way, allowing us to control the salts' crystallization in the structure and to preserve the building.

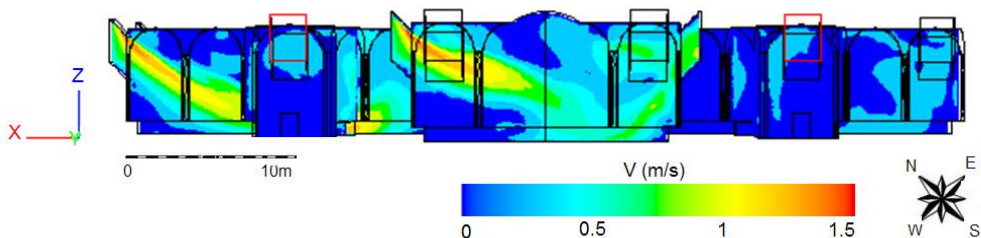


Figure. Airflow velocity in the Crypt (simulated scenario with four opened windows).

*Keywords:* microclimate monitoring; damage maps, soluble salt crystallization; computational fluid-dynamic (CFD) modeling; cultural building conservation



## Microclimatic studies in Paranhos water galleries, Porto (Portugal)

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*Paranhos* constitutes one of the main water galleries of the ancient shallow underground network excavated in the granite substratum of Porto City (Portugal) to gather the groundwater for public use during the past six centuries. The primary gallery has c. 3.2 km long and stands at a maximum depth of -20 m.b.g.l. Nowadays, due to aquifer degradation, groundwater is not used. The current interest of these galleries is double:

- a. Cultural Heritage and scientific value; aquifer vulnerability to pollution and urban speleological mapping applied to groundwater and geo-engineering studies have been developed in the *Paranhos* galleries. In addition, unusual mineral formations and microbial communities have been recently described. The microbiological study of these environments represents an approach to the discovery of the large bacterial diversity, the understanding of the role and functioning of these microorganisms and their implications on the conservation of the geo-sites.
- b. Underground geotourism; as economical resource because the potential capacity to attract tourists and produce income and investment. Artificial and stable underground spaces such as aqueducts or water galleries can be suitable for underground geotourism, previous establishment of safe conditions for visitors.

A multidisciplinary research to study the microclimatology, geochemistry, mineralogy and geomicrobiology of the *Paranhos* catchwork galleries is currently in progress. The characterization of the main environmental parameters (air-rock temperature, relative humidity, CO<sub>2</sub>, <sup>222</sup>Rn, etc.) in the internal atmosphere would allow:

- a. Establishment of fluid-rock interactions and development of a physical-chemical model of air-water-rock, as a base to define their relations with unusual microbial communities and mineral formations.
- b. Establishment of microclimatic parameters and determination of effective radioactive dose for visitors based on <sup>222</sup>Rn studies, as potential use as underground geotourism site under safe conditions.

## **Bio-susceptibility of thermal insulation systems used for historical buildings**

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In historical buildings of Northern countries high levels of energy are necessary to reach comfortable temperatures especially during the cold season. For this reason historical buildings are now also included in country specific regulations and ordinances to enhance the “energy efficiency”. Since an exterior insulation - as it is commonly used for modern architecture - is incompatible with monument protection, several indoor insulation systems based on historical and ecological materials, are on the market that should improve the thermic performance of a historical building. However, using organic materials as cellulose, loam, weed or wood, bears the risk of fungal growth and thus may lead to health problems in indoor environments. For this reason five different ecological indoor insulations systems were tested for their bio-susceptibility against various fungi both under natural conditions - after 2 years of installation in an historical building - and under laboratory conditions with high levels of relative humidity. Fungal growth was evaluated by classical isolation and cultivation as well as by molecular methods. The materials turned out to have a quite different susceptibility towards fungal contamination. Whereas insulations made of bloated Perlite (plaster and board) did not show any fungal growth after 2 years of exposition, the historical insulation made of loam and weed had high cell counts of various fungi. In laboratory experiments, wooden softboard represented the best environment for fungal growth. As a result from this study, plaster and board made of bloated Perlite are presented as being the most appropriate materials for thermal insulation at least from the microbiological and hygienic point of view. For future investigations and for the monitoring of fungi in insulation and other building materials we suggest a molecular biology approach with a common protocol for quantitative DNA-extraction and amplification.

**Biological crust contributes to the protection of  
Neolithic Heritage in the Mediterranean region.**

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Neolithic temples form part of the cultural heritage; they are built with different stones that provide colonizable surfaces to biological crusts, in addition to other substrates like soil. The structure and composition of biological crusts depend on the sort of substrate and environmental conditions such as light, water and temperature. Two main substrates have been studied: soils and walls. Soils are colonized by crusts composed mainly of bryophytes, lichens are also an important component, and some cyanobacteria and fungi are found. The structure of those communities rely on physical characteristics of soil and availability of water, among others. The importance of biological soils crusts comes from their important role as binding agents, reducing the release of dust. Biological soil crusts also interfere with water dynamics, they provide surface detention, increase net infiltration and reduce net runoff.

Walls are colonized mainly by lichens, and secondarily by cyanobacteria, bryophytes and fungi. The composition of wall communities depends on the orientation of walls, which determines changes on availability of light, temperature and humidity. The role of biological crusts on walls is controlled by its successional stage. While some primarily stages have a deteriorating role; later stages provide a protective activity. The equilibrium between both roles relies on environmental conditions and characteristics of the substrate. The importance of bioprotection becomes obvious when buried stones are excavated, and weathering by atmospheric agents is faster than biological growth. The deterioration by thermoclastism, wind abrasion or rain is almost negligible when biological crusts are well developed.

Any change in environmental conditions will modify growth conditions (light, water, temperature) and would determine the loss of biological crusts. Their disappearance would increase the risk of deterioration of the heritage and lead to aesthetical changes on stone surfaces.

## **The influence of substrate texture on early biological colonization**

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Biological colonization of stone is a major concern in the preservation and presentation of cultural heritage. Algae and cyanobacteria in particular can lead to the development of green, black or red biofilms on façades, with inappropriate cleaning techniques potentially causing damage to the stone, or promoting further growth. Whilst some examples of biological growth such as certain lichens can have a protective effect on stone, colonization is typically associated with varying degrees of biodeterioration related to the production of organic acids and other metabolic products, and the physical pressure of fungal hyphae and lichen rhizines extending between stone grains. A better understanding of why organisms grow where they do, will aid in identifying preventative measures against, and treatment methods for, bio-soiling of cultural heritage.

Sandstone exposure trials were set up at nine different locations across Northern Ireland to investigate the influences of local climate (rainfall), local environmental (marine/non-marine, urban/rural, aspect-related differences) and micro-climatic factors (substrate characteristics, smooth/tooled stone surfaces) on the early stages (up to 21 months) of biological colonization.

Peakmoor Sandstone was used as the main stone type for the experiment with Blaxter Sandstone and Portland Limestone blocks for comparison, both sandstones are Carboniferous, non-calcareous buff sandstones, Portland Limestone is a white, oolitic, Jurassic limestone. All three are commonly used across the United Kingdom. Substrate characteristic results showed that, contrary to expectation, biological soiling was heavier on smooth stone surfaces in preference to hand-tooled, textured stone, and that green algal-soiling was dominant on sandstone surfaces, whereas red-coloured algal-soiling (most likely of the green algal genus *Trentepohlia*) occurred more commonly on limestone.

It may be that a tooled surface provides a larger surface area for evaporation; therefore holding less moisture, or that a textured surface is less stable and therefore less suitable for colonization than a solid and stable surface.

**Ten years in controlling the phototrophic biofilms in  
the *Ocean's Cubiculum* at the St. Callistus Catacombs (Rome)  
*In memory of Patrizia Albertano***

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Roman Catacombs suffer significant biodeterioration due to the growth of multispecies biofilms on valuable stone and mural surfaces. These biofilms are composed of cyanobacteria, sometimes associated with microalgae, chemoorganotrophic bacteria and fungi. These communities develop on exposed surfaces by illuminated for touristic purposes. Such was the case in the *Ocean's Cubiculum* at the Catacombs of St. Callistus (Rome, Italy), a site totally covered by frescoes most of which were spoiled by microbial colonisation. For this reason it was chosen as one of the sites studied during the EU project CATS that started in 1999. The microbial communities present inside the Cubiculum were identified by non-invasive microscopy, laboratory cultures and the characterizing of exopolymeric substances of some cyanobacterial species within the biofilm. In 2003 a new lighting system was developed to control this type of biodeterioration. It consisted of monochromatic illumination of the cubiculum, emitting in the blue band, which was shown in the laboratory to hinder phototrophic growth. After installation of the system the biofilm has been monitored (to the present day) to determine the effect of the lamps. The discolouration of a green-blackish biofilm was actually shown to recede from the painting due to the inhibition of cyanobacterial growth, a result of insufficient light energy, with no other treatment necessary. A white covering all over the painting is still visible testifying the presence of bacteria that are most likely responsible for the degradation of the inactive phototrophic biofilm. Also, confocal imaging of strip samples taken from the site revealed that some cyanobacterial cells were still alive emphasizing the need for continuous monitoring and continuous use of the new lighting system. Therefore it is still vital that development of novel approaches continues in order to abate problems associated with phototrophic and heterotrophic growth without resorting to aggressive biocides treatments.

**Vivianite:  
a historic blue pigment and its degradation under scrutiny**

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Vivianite is a monoclinic mineral with chemical composition  $\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$ . It has been used throughout the centuries as a painting pigment (with documented occurrence between 1050 and 1780). As a pigment, it usually possesses a subtle blue color with violetish, greenish or grayish undertones (Figure). Its usage is relatively rare and it is described mainly in the works of old Dutch Masters from 17th century (e.g. Rembrandt, Vermeer, Cuyp) and in polychrome sculptures of German and Austrian provenience.

In some of the works, it has been observed that vivianite dramatically changed its color from blue to gray or even yellow. Therefore, the color impression of the artwork is severely harmed. To this day, the mechanism of this alteration has not been sufficiently explained. In mineralogical literature, the degradation of vivianite is described as a result of its oxidation – in its pristine state, vivianite is white and contains only bivalent iron, therefore is prone to oxidation with subsequent changes in structure and color. However, the resulting phase is of brownish yellow color, which does not explain the degradation to gray. The alteration of vivianite has never been studied in the context of painted artworks.

With the aim to explain these degradation processes, laboratory experiments have been carried out. First, we started with non-routine preparation of synthetic vivianite to ensure its unoxidized state before experiments. Subsequently, mixtures with different binders were prepared and subjected to artificial ageing processes. X-ray diffraction as well as infrared, Raman and UV-VIS spectrometries were used to monitor chemical, mineralogical and color changes and to describe the mechanism of the reaction.

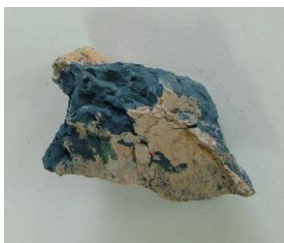


Figure. Vivianite from Ronneburg, Germany

## **Works at Olivés church in Zaragoza**

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Context: The Olivés Church is a three naves basilica ground building. From its construction in 1767, of the previous church only the ancient tower and the chapel remain as the church suffered important damages and successive reparations. At the moment the church is on the imminent point of collapse.

The church is built on a clayey hillock on top of the village with very fort slopes. The retaining walls that surround the church have suffered movements. The village's population is decreasing and the mud walls of the church's neighboring houses are collapsing.

The old cemetery is on the side of the church. The rain water comes in the cemetery and passes under the church inducing the the clayey hillock's and also the church's movements.

Nearly thirty years ago, the last works to stop the church movement were made and from then the church is closed even though there are walls to hold it in place. The walls nearby the slope have a lean of roughly twenty seven centimeter.

Method: A soil study was done to know its properties and the reason of the movement. The efforts on the walls and over the soil were calculated and compared with the soil bearing capacity and its water influence.

Results: The high slopes around the building, the water entrance bellow it and also the collapsed houses nearby are causes of building movements. Also, the structural roof is broken and it is not fixed to the walls that can move. The church state is critical.

Conclusions: As the church is not a property of cultural interest, there is a short amount of money to repair it. Now first phase over is done, with a paved square over the cemetery. The next phase is a new roof structure to support the lean walls. After that done, the repair inside can start.

**Black fungi and biocides:  
the case study of the Monumental Cemetery of Cagliari (Italy)**

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Fungi, because of their wide metabolic abilities and distribution, are among the most problematic biodeteriogens involved in the decay of inorganic and organic materials. Their presence on stone monuments is associated to aesthetic damage consisting of chromatic changes and biopitting, as well as to the loss of material due to lesions and surface exfoliation [1,2]. Black meristematic fungi are probably the most important biodeteriogens of stone monuments in the Mediterranean area in reason of their ability to cope with a wide range of physical and chemical stresses such as high and low temperatures, low water and nutrients availability, high UV irradiance, osmotic and acidic stresses [3,4,5], and not last biocides [6]. Moreover, the rock itself represents a further protection since most of them grow endolithically.

Chemicals used in restoration treatments are detrimental for the operator and the environment and it is of high interest to find a customized and effective protocol to reduce their use. In this perspective this study focused on 6 marble sculptures of the Monumental Cemetery of Cagliari, 3 of which treated 18 months before with the biocide Biotin®. The monuments were sampled using non-invasive techniques and 26 isolates of black meristematic fungi were obtained and identified by molecular methods. Agar diffusion test was applied to 12 different strains in order to evaluate their response to 4 biocides of common use such as Preventol® RI 50, benzalkonium chloride, Lichenicide 264 and Biotin® at various concentrations. The different sensitiveness recorded to biocides gave new insights on the possibility to obtain a more effective treatment to control these organisms, known to be problematic in the restoration treatments, using a more targeted biocide or a combination of them or by varying concentrations of the chemicals used.

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**Microbiological and molecular investigations at  
the Capuchin Catacombs of Palermo, Italy:  
microbial deterioration risk and contamination of the indoor air**

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Mummified human remains can be regarded as an independent “ecosystem” in which highly specialized microorganism can thrive and be involved in degradation processes. The crypt of the Capuchin Convent of Palermo (Italy) contains over eighteen hundred mummies, dating back from the late 16<sup>th</sup> to the beginning of the 20<sup>th</sup> century, standing in line at the walls of subterranean corridors carved out of deposit of tuff. Today, many of the mummies show serious signs of fast and recent biodeterioration.

Within the framework of the "Sicily Mummy Project", a research project aimed at studying and preserving these remains, an extensive microbiological and molecular biological investigation was performed. A sampling campaign was carried out to investigate the microbiological status of the mummies as a basis to prevent further biodeterioration. Samples were taken from different materials including skin, muscle, bone, hair, clothes, straw used as stuffing material as well as material from the surrounding walls, showing massive rosy discoloration. In addition, air samples were taken to investigate the impact of this microbial contamination on the indoor air quality.

Microbiological results showed that the mummies are heavily contaminated with moulds. Thirty-three fungal species were isolated from the mummy materials, some being common airborne fungi and some originating from the stuffing material or the clothes. In some areas of the crypt the fungal spores in the air reached more than 2000 spores/m<sup>3</sup>. This amount must already be classified as a potential health risk for visitors.

Molecular analyses showed complex microbial communities colonising the mummies and the surrounding walls, consisting of bacteria, archaea and fungi. Halophilic archaea were found on the wall material, being the main responsible of the rosy discoloration observed. Fungal sequences revealed the presence of pathogenic fungi that may be related with the deterioration of the mummies.

**Lichen-induced mechanical weathering of schist in  
the Côa Valley Archaeological Park  
(Vila Nova de Foz Côa, Portugal)**

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Concern about all aspects of biodeterioration of schist has increased with the discovery, in the Côa Valley (Vila Nova de Foz Côa, Northeast Portugal), of one of the most important sets of Palaeolithic engravings, today protected under UNESCO as World Heritage. Most engraved surfaces are highly covered with lichens, whose deteriorating effects are still poorly-known, but expected to depend on the weathering ability of the colonizing species and surrounding environment, as well as on the physical and chemical properties of the substrate. Hyphal penetration is an important component of lichen colonization of rocks and is known to play a crucial role in lichen induced chemical and physical alteration. This study aimed to characterize the penetration patterns of lichen hyphae and quantify the extent of hyphal spread within schist in the study area using five locally abundant species (*Aspicilia hoffmaniana*, *Caloplaca subsoluta*, *Lecanora pseudistera*, *Peltula euploca* and *Rinodina oxydata*).

Two 3 cm long polished sections perpendicular to the lichen-rock interface were prepared for each species and stained using the periodic acid-Schiff method (PAS) to highlight the hyphal penetration component (HPC). Microphotographs of the stained sections were analysed using free and open-source software packages namely: *ImageJ* for pre and post-processing procedures and generation of calibration points, *MaZda* for texture analysis and *R* for colour feature extraction, data analysis and classification. Image classification returned good to excellent results depending on the species with best scores for *C. subsoluta* (ME= 4%), and worse for *A. hoffmaniana* (ME= 24%).

The analysis of lichenized schist samples revealed a unidirectional pattern of hyphal penetration, up to 5 mm deep, following lichen produced and/or expanded intermineral voids, and appearing to be related with the lamellar nature of schist minerals. Therefore the effects of hyphal penetration on schist spread beneath the surface and should also involve the minerals in the deeper layers.

## Physical and aesthetic decay of built heritage from biological films developed on joint mortars

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Porous stone materials can be affected by litobiontic communities' colonization responsible for physical-chemical processes that give rise to their biodeterioration, also contributing to the loss in aesthetic value of built heritage. Thus, in urban areas with high levels of atmospheric pollution, in the aesthetic decay that occurs in façades due to soiling by particulate matter deposition, the development of biological films that in many cases have an intense dark color must be taken into account.

This paper focuses on biodeterioration processes affecting the joint mortar used on the limestone façades of the Formerly Workers Hospital of Maudes (Madrid, Spain). This type of material is very susceptible to biodeterioration processes, because of its high porosity. The mortar is characterized by Polarization Optical Microscopy, X-ray Diffraction and Mercury Intrusion Porosimetry, and special attention to the interaction with colonizing microorganisms by means of SEM-BSE technique (Scanning Electron Microscopy with backscattered electrons *in situ*) is given. Besides, how the joint mortar biological colonization contributes to limestones façades soiling is quantified, through the comparative analysis of the chromatic parameters of the limestone with respect to the mortar by means of Spectrophotometry.

The study reveals that lichen thalli are directly involved in the material disruption, leading to the decohesion of its components. They also contribute significantly to the degree of darkening that the building façades show. While the limestone soiling is very heterogeneous and responds to its interaction with air pollutants, for the joint mortar it is much more homogeneous and, in areas of higher humidity and with no direct pollution exposure is due to a biofilm development. In all other areas where joint mortar show darkening, this is mainly due to its interaction with air pollutants.

This paper provides information on the effect of biological colonization in mortars, entailing the implementation of the SEM-BSE technique in such materials, widely used in built heritage.

## **Indoor pollution and metal corrosion by organic acids: case study of the Oteiza Museum**

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Organic acids, mainly acetic and formic, are known to be significant pollutants in the museum environment, especially in closed spaces such as display cases and storages. These acids are emitted from the construction materials, such as wood or manufactured wood panels, paints, varnishes, sealers, etc., and cause degradation of calcareous and cellulose based materials and corrosion in metals such as lead or copper. Measurements of these acids and assessment of their effect on metallic heritage have been carried out in museums in northern Europe, UK and the USA, but to the best author's knowledge, no studies have been made in museums in Spain or in southern Europe in general.

This communication presents a case study of the measurements of these acids in the Oteiza museum in Navarra, Spain. Two display cases (OT1 and OT2) were selected by the museum conservator to identify possible conservation risks. Measurements of the acetic and formic acids were carried out by passive sampling using Palmes diffusion tubes, which were exposed for 14 days and analyzed using ionic chromatography. To evaluate the corrosivity of the atmosphere, copper and lead metal coupons were exposed for 8 weeks, and the corrosion was quantified using gravimetric and colorimetric techniques.

Results showed that the concentration of acetic and, especially, formic acid were elevated both cases, being higher in OT2. Significant corrosion was measured in lead coupons, resulting in the formation of a visible white layer of corrosion products that were identified as copper formate by XRD.

Based on these results, the museum conservator has implemented corrective measures (based on controlled ventilation of the display cases) to reduce the concentration of these dangerous organic acids. The reduction of the pollution attained is currently under evaluation.

This work is an example of how an adequate knowledge of a museum environment and its interaction with the objects help to identify the collection risks. This collaboration between conservators and conservation scientists is the base to take simple but efficient preventive conservation measures to arrest those risks, assuring an adequate conservation of museum collections.

## **The conservation of polymeric design objects: novel applications of molecular spectroscopy and analytical imaging**

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Polymeric materials have been used extensively in works of art and in 20th century design objects. A large number of handmade and industrial objects, made of polymeric materials, represent today the development of 20th century society, and are conserved in museums and private collections. If not suitably protected, polymeric materials may rapidly deteriorate: knowledge regarding the stability and condition (deterioration, restoration and treatment) of such objects is still limited and only few examples of protocols for the investigations of objects in plastic are available [1, 2].

This paper presents the Fourier Transform Infrared and fluorescence spectroscopy for the investigation of the condition of a series of design made of polyvinyl acetate, cellulose acetate and ABS. Various 20th century lamps – coming from the Triennale Design Museum in Milan and private collections – have been analyzed and compared through analysis of micro-samples, combined with multispectral imaging and fluorescence spectroscopy directly on the surfaces [3]. The use of different methods and different sample preparation techniques allows the identification of the bulk polymers, and the detection of some additives, and can be used for an assessment of the condition of the objects. By combining results from complementary techniques, a localized characterization of the polymer has been achieved and heterogeneity in plasticizer content and level of degradation have been highlighted.

This work aims to establish a non-invasive or micro-invasive protocol for polymer characterization. The paper focuses on the investigation of different polymeric blends which have been naturally aged and from different real objects, compared with polymeric standard material. Sample treatment, microscopic and spectroscopic analyses will be presented and discussed, highlighting the distinct of the combination of the analysis of micro-samples and imaging techniques. Finally, prospects for future research will be given.

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## Characterization of decay products and building materials on the ancient wall of Vitoria-Gasteiz using micro analytical instrumental techniques

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Knowledge of the chemical composition of the building materials of our monuments may help us to preserve and protect them from the pollution of our cities. In fact pollution causes irreversible damage in the building materials: cracks, efflorescence salts, black-crusts, etc. Many of this salts and crusts can be dissolved and washed by rain water, causing a loss of material and, consequently, weakening the structures. If the loss of material is large, the structure may collapse, like in the recent events in Pompeii.

The aim of this work is to make the characterization of the building materials of the ancient wall of Vitoria-Gasteiz and the decay products that could be present caused by the action of pollution. The interest of the work lies in the history of the wall, which was “hidden” until 2001. Since then, the wall materials have been impacted by several environmental agents, such as, soot, acid gases, mainly SO<sub>x</sub> and NO<sub>x</sub>, infiltration waters, etc.

Several hand-held spectrophotometers (Raman, FTIR and EDXRF) were used to determine qualitatively which compounds were present on the wall. Detached materials were used to take micro samples for ionic chromatography. Nitrates are already present on the wall (Figure 1). The presence of these compounds may be linked to groundwater as well as to the attack of acidic NO<sub>x</sub> gases. A Raman peak in the common band of nitrates (1040-1060 cm<sup>-1</sup>) and a peak at 1384 cm<sup>-1</sup> (N-O stretching band) in a FTIR transmittance spectrum are the proof of this presence. Especially worrying is the presence of mirabilite (Na<sub>2</sub>SO<sub>4</sub>·10H<sub>2</sub>O) in the modern restoration of some parts of the walls (Figure 2). All soluble salts were quantitatively determined by using ionic chromatography.

In conclusion, the presence of nitrates and sulphates in the wall suggests the high impact of the urban environmental pollution in the monument.

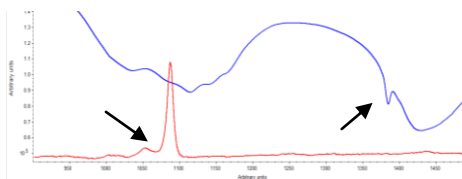


Figure 1. Peak in Raman nitrate band (red) and peak in IR nitrate band (blue) [peaks marked with arrows]

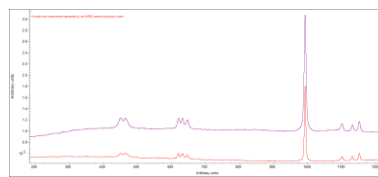


Figure 2. Raman spectrum of sample (purple) and Raman spectrum of mirabilite natron (red)

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## **VARIM 2.0: non-invasive NIR hyperspectral imaging for analysis of cultural beings**

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Nowadays, the contribution of non-invasive techniques to the analysis of artworks represents a valuable advance in the field of restoration and conservation of Cultural Heritage due to the preservation of original work. NIR hyperspectral imaging systems provide lots of wavelength-discriminated data hidden to the human eye without any sampling. Nevertheless, most of the existing systems are suited to analyze only singular regions and the extension of the studies to larger areas requires a long and heavy procedure.

As a result of the collaboration between the Visual Telecommunications Application Group of the *Universidad Politécnica de Madrid* and the Physics Analysis Department of the *Instituto del Patrimonio Cultural de España*, a whole system for the automatic acquisition and formation of the reflectographic mosaic, called VARIM, was developed. This system provides the underdrawing of big altarpieces *in situ* without dismantling. Currently, the system has been expanded with hyperspectral lenses and two precise mechanical positioning devices. Hence, a set of narrow wavelength images, around 2 nm, between 1000 and 1700 nm can be obtained in an easy-to-use way along a region of the painting, providing detailed spectral images as well as discrimination of materials.

In this paper, besides VARIM description, first results of this imaging system are shown together with an overview of the potential applications of our novel system.

**Non-invasive recording technologies for  
the study and conservation of prehistoric rock art:  
the dolmen de Dombate**

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The work presented here describes the methodology used for the recording of the megalithic art (painting and engravings) preserved in the Dolmen de Dombate (Cabana de Bergantiños, A Coruña).

The latest recording tasks have been carried out during the year 1992, when the Dolmen was protected with a provisional wooden cover, and the paintings inside were cleaned and consolidated. After that intervention, no further registering or cleaning and consolidating treatments were undertaken, even when the paintings revealed different changes in its state of preservation that suggested the need to update this documentation.

The plans for the construction of a permanent canopy over the mound raised again the need to undertake direct interventions inside the chamber, especially on the paintings. Therefore, it became essential to obtain an accurate recording of the preserved art, thus allowing to verify the present state of the paintings, as well as assessing any possible damages and alterations throughout the implementation phase of the project and the processes involved in conservation and restoration activities.

These recording tasks were always carried out by means of non-invasive and indirect techniques, mainly consisting in the digital tracings and alteration maps from orthophotographies of the stone slabs obtained by close-range photogrammetry and 3D Scanner based on structured light. A series of detailed three-dimensional archives was also created, which represents the paintings and engravings with great detail and accuracy. This makes the digital preservation of the paintings possible, but it also gives access at any time to this three-dimensional information, thereby enabling us to handle it: supervising the state of preservation, automatically comparing it with previous and subsequent recording works and so on. We suggest the interest of applying indirect technologies as a necessary part of a conservation and evaluation methodology for this kind of art.



**Modern methods of documentation for conservation:  
digital mapping and automated 3D object documentation in  
software metigo®**

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Several years of experience of heritage documentation has given the author a background to develop methods of cartography and digital evaluation. The outcome of which is the development of a 2D-mapping software with integrated image rectification over a period of more than 10 years.

Based on true to scale mappings quantity surveys of areas and lines can be calculated automatically. Digital maps were used for the documentation of damage types, for the planning of required action and for the calculation of costs. The combination of image processing and CAD-functionality makes the programme's operation user-friendly, both in the office and on-site. Metigo MAP was developed in close cooperation with conservators and restorers. Based on simple equipment consisting of digital camera, laser measuring instrument for measuring distances and standard notebook the mapping software is used in many restoration companies.

Digital stereo-photogrammetry allows users an automatic evaluation of the spatial dimension and the surface texture of objects. The integration of image analysis techniques simplifies the automation of evaluation of large image sets and offers a high accuracy. In a first step identical points are detected in a set of images to combine pairs of them to stereo models and to calculate the photogrammetrical orientation of each image. An adapted expansion, and matching algorithm, offers the possibility to scan the object surface automatically. The result is a 3D point cloud for each stereo model coloured by the images. With the integration of the iterative closest point, algorithm (ICP), these point clouds are fitted to a total point cloud. After creation of the triangulated digital surface models (DSM) the texturing can be made automatically by using the images that were used for scanning the object surface. This textured surface model is the basis for calculation of true to scale ortho photos or digital 3D mapping.

## **Innovative testing solutions for safeguarding architectural heritage**

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The paper presents several innovated or newly developed techniques for testing historic materials which enable acquire material characteristics not achievable in another way due to specific constraints posed by the conservation policies. It will show a family of methods - from very simple and affordable to rather sophisticated and available with a special equipment only.

As an example of the affordable methods let us present one for *in situ* testing of surface quality and material sorption of liquids, which represents one of the very basic and indispensable techniques in the conservation practice. For the measurement the so called Karsten tube has been used for several recent decades. However, the application of the Karsten tube method *in situ* brings about some difficulties, e.g. problems with fixing a heavy glass tube on vertical surfaces, problems with sealing the contact ring area, a need for two operators and soiling of surface with the sealing putty. Therefore, an innovative device has been developed within the research programme of the EC FP6 STONECORE project. The system is based on a micro tube outlet and takes advantage of electronic continuous measurement of water infusion into the surface with storage of digital data, which enables semi-automatic long term measurements and recording of the water sorption from the very beginning. The measurement reduces the number of operators, it is more precise, effective and faster. Further, non-standard testing of surface cohesion, strengths of materials and strengthening effects of various consolidation agents will be described and illustrated.

In contrast, the presentation includes also modern equipment supported methods, e.g. digital image correlation measurements, x-ray microtomography and methods where rather simple physical principles are combined with numerical analysis which gives to them an enhanced power.

## **Assessment of laser treatment on dolostones colonized by microorganisms and lichens**

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The Redueña stone is a Cretaceous dolostone traditionally used as a building material in the architectural heritage of Madrid (Spain). This study is a multi and interdisciplinary research in which geologists, biologists, physicists and chemists have been already developing [1,2], analyzing the material itself, both in the quarries and on site in the monuments and buildings, determining its decay patterns, analyzing the microorganisms that colonize the stone surface and possible remediation treatments (biocides), as well as performing tests in the laboratory with different laser conditions radiation to assess efficacy in removing microorganisms and evaluating the effects on stone. We present here the preliminary results of the assessment of the laser technique to remove the biofilms on the rock surface, onsite, in the quarry, results that could be extrapolated to the monuments stone surface, thus avoiding any damage to monumental stone.

The procedure consisted of laser irradiation [3] (Nd:YAG, 1064nm, 10 ns, 350 mJ) on selected rock surfaces, with well known microorganisms (cyanobacteria) and lichens. Before and after this laser irradiation, samples were taken to assess the effectiveness of treatment on both the lichens thalli and microorganisms, using SEM-BSE and TEM, and also on the stone substrate by means of SEM-SE+EDS.

The preliminary results show that laser fluence applied in the field was not enough to efficiently eliminate and/or damage lichen thalli, as observed by TEM and SEM-BSE. This is in accordance with previous laboratory results, where it was demonstrated that a higher fluence is necessary to clean and make inactive lichen symbionts. It was also proved that no severe damage was found in the dolomite crystals after laser radiation. Some measurements were also recorded before and after laser treatment, such as roughness readings by means of an optical roughness-meter (general decrease on roughness parameters with laser cleaning), and color measurements by a spectrophotometer (color parameters were closer to those of the fresh cut of the rock after cleaning). Continuous monitoring of the thermal processes during laser irradiation with an infrared microbolometer-based videocamera was performed, working within the 7.5 to 13  $\mu\text{m}$  spectral range. While maximum temperatures attained hardly exceed 55°C, thermal gradients can be extremely high (5°C/0.01s), especially in dry conditions and in low albedo lichen species such as *Verrucaria nigrescens*.

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## Effect of wavelength and pulse duration on the laser cleaning of paints

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The application of laser cleaning methodologies on light-sensitive cultural heritage substrates (paintings, documents on paper and parchment, textiles, etc.) requires the study of the physicochemical effects that may be induced upon laser irradiation on the constitutive materials. In this study, we present work carried out to analyze the influence of laser wavelength and pulse duration on the modifications induced on paint constituents by using pulses of femtosecond, picosecond and nanosecond duration and wavelengths in the ultraviolet and the infrared spectral regions (213, 248, 266 and 1064 nm) [1-6]. The study was carried out in aged model samples consisting in shellac varnished and unvarnished traditional artist's pigment temperas, and also in pellets of raw pigments. A multianalytical approach was chosen to assess possible laser induced physicochemical changes, based on the use of optical microscopy, colorimetry, spectrofluorimetry, laser induced fluorescence, Raman spectroscopy and X-ray photoelectron spectroscopy. Comparison of the obtained results using different pulse durations and wavelengths illustrates the participation of mechanisms of diverse origin according with the pigment, binding media and varnish chemical composition, and highlights the importance of the optimization of the laser parameters by using laser wavelengths efficiently absorbed by the binding media. The reported investigation also shows the specific advantages of using ultrashort pulses for the safe laser processing of painted artworks.

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## LA-gf-ICP/MS (Laser Ablation-great format- Inductively Coupled Plasma/Mass Spectrometry) applied to the study of the influence of aqueous treatments on manuscripts integrity or the problem of calibration on heterogeneous samples

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The content of this study can be presented from two different points of view: the applied, by using a quasi non-destructive technique to monitor the changes produced by the application of aqueous treatments to manuscripts and the methodological, focused on how calibration must be performed on these heterogeneous samples in order to get comparable results.

**Applied.** Manuscript conservation includes the application of aqueous treatments that may produce changes on their composition in a different extension than the visual appearance may suggest.

The main problem to follow these potential changes is the lack of non-destructive analytical techniques with high spatial resolution. The use of LA-gf-ICP/MS overcomes this limitation by applying successive laser pulses to extract material from different positions producing a non-observable 100 microns diameter crater. A network of points around the ink line permits us to build concentration distribution maps before and after any treatment application.

Experimental design includes the study of the influence of two aqueous treatments on two types of samples. Samples: 16<sup>th</sup> century paper and synthetic iron gall ink, and 17<sup>th</sup> century paper and ink. Aqueous treatments: two solvents (water or water + alcohol 20%) and two application procedures (bath of a fragment of manuscript or addition of a solvent drop onto the surface).

Before and after aqueous treatment application, a net of 27 points around the ink line was analyzed by LA-gf-ICP/MS. The reference isotopes used were <sup>56</sup>Fe, <sup>57</sup>Fe (Ink), <sup>44</sup>Ca, <sup>24</sup>Mg, <sup>27</sup>Al, <sup>55</sup>Mn and <sup>137</sup>Ba. A preliminary analysis was also performed by SEM-EDS.

In order to compare the results obtained with those obtained for the classical ICP/MS approach, after LA-gf-ICP/MS analysis, total dissolution determination was also performed.

The results obtained show that iron concentration decreases by half after both aqueous treatments for the synthetic ink, whereas this remains constant for the 16<sup>th</sup> century ink. This behavior is only observed in the bath treatment and not in the drop approach. These results coincide with the total dissolution analysis data.

The conclusion indicates that aqueous treatments produce a clear effect on the manuscript integrity and that this effect depends on the ink nature. A second conclusion is that drop essay to evaluate solubility behavior does not yield useful information.

**Methodological.** The above results are based on a calibration process of the signal obtained for the different matrices analyzed. Calibration for such heterogeneous materials, where the amount of material analyzed is of the same order as the heterogeneity distribution, is complex. In this study, several calibration approaches have been essayed: a. the addition of a drop of a standard solution of Mn and Ba (results obtained across the drop surface yield an intensities dispersion of 40%); b. the addition of a drop of matrix conditioner (gelatin) together with the standard solution (the material conditioner + standard was physically unstable and drop off during the ablation process); c. the use of an element, not affected by the aqueous treatment (Al), as an internal standard to normalize the intensities and compare the different situations (this was the procedure used for the study presented above).

## **Application of DESI-MS to the study of graphic art materials**

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Desorption electrospray ionisation-mass spectrometry (DESI-MS) is a non-sampling surface analysis technique. During DESI-MS analysis a stream of charged solvent droplets is directed at a sample of interest resulting in the desolvation of analytes at the sample surface and the formation of analyte ions which enter directly into the mass analyzer. Analysis is performed under ambient conditions and it is not necessary to excise a sample from the object.

DESI-MS has been used in environmental analysis, quality control/assurance, archaeometry and forensics applications. DESI-MS has several advantages over related MS techniques in that it requires no sample preparation, can be used in a high-throughput manner and importantly, it can be used to create chemical images of the sample of interest.

We will present our applications of DESI-MS in the study of graphic art. In this work we have focused on two major classes of artist's materials, coloured papers and biro pens. We have used DESI-MS to identify dyes used in the manufacture of both coloured papers and pen inks. In some cases we have been able to elucidate the degradation pathway of some classes of colourants by identifying degradation products.

In addition to presenting our results we will also present a short discussion of the problems associated with DESI-MS. While the technique is technically non-sampling, it is not, non-destructive because the solvent stream wets the sample surface which can result in the smudging of inks and in extreme cases the etching of the sample surface. These factors present a distinct limitation on the application of the method and must be considered when selecting regions of interest on a heritage object.

## **Pigments and painting preparations of Gonzalo de Bilbao analysed by non-destructive XRF technique**

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In the frame of the preparations of an important exhibition dedicated to the Spanish painter Gonzalo de Bilbao organized in the Museo de Bellas Artes of Seville opened on the 25<sup>th</sup> of November 2011, several of his paintings have been analysed in a non destructive way. The aim was to identify pigments used by the painter through different periods of his artistic activity, as well as to find out what kind of preparation did he apply on canvases. There was a major interest in finding out, whether his palette and the system of preparing the painting ground were changing through time. He was active in the period between the end of the 19<sup>th</sup> and the beginning of the 20<sup>th</sup> centuries, when many new pigments were invented, especially synthetic ones on the bases of chrome, cadmium, cobalt, zinc and barium.

In order to obtain reliable results, 14 paintings from different periods of his artistic activity have been chosen, from his early, more realistic stage, to his final artworks that already show impressionist brushstrokes. Among these, some of his most important works, like *Las Cigarreras*, have been chosen, as well as several bozzetti. All the paintings have been analysed with a portable XRF equipment, composed by X-Ray generator RX38 with W anode and a SDD detector with 140 eV of energy resolution. This non-destructive analysis offers identification of inorganic materials on the basis of their characteristic chemical elements.

The results showed that Bilbao was changing his painting preparations. In his early works he applied exclusively lead white (denoted by the presence of Pb peaks). Entering the 20<sup>th</sup> century, this one was gradually replaced by zinc white (Zn), while in his late works a new material, litopon (Zn, Ba), was introduced. Pigments showed even more complex development. Bilbao was introducing new pigments almost as they were appearing on the market, combining them with traditional ones. In his early works he used lead white (Pb), yellow and red ochres (Fe), umber (Mn, Fe), vermilion (HgS), copper based green pigment (Cu), and bone black (Ca). Later on, he started to include gradually zinc white (Zn), chrome green (Cr), cadmium yellow, orange (Cd) and red (Cd, Se), cobalt blue, violete and green (Co), prussian blue (Fe), among the most important ones. On the bases of these results, it was possible to confirm several dates of paintings and to place them in the right period of Bilbao's artistic activity.

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## **A novel approach for micro FTIR reflection absorption analysis of artworks' surface**

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Non invasive reflection FTIR measurements provide indispensable information about the chemical composition as well as degradation processes of the surface of works of art. However, band assignments and the identification of components can often be complicated by the fact that the IR reflection process of artworks' surface is complex. The morphology of the paint layers as well as their thickness give rise to both diffuse and specular reflection phenomenon that may result in band shifts and changes in the shape of the IR peaks. A novel approach of  $\mu$ -transflection analysis of artworks' surface is presented, the technique that gives the opportunity to overcome these problems. The obtained transflection spectra are very similar to the transmission spectra that offer an easier interpretation. Although micro sampling is required (see Figure), the sample removal leaves barely visible traces. In addition to the identification of the components present at the surface of the work of art, the technique can also be applied for monitoring of the chemical cleaning.

Some examples of the identification of the surface of the Baroque easel paintings as well as the chemical cleaning utilizing  $\mu$ -transflection are presented.

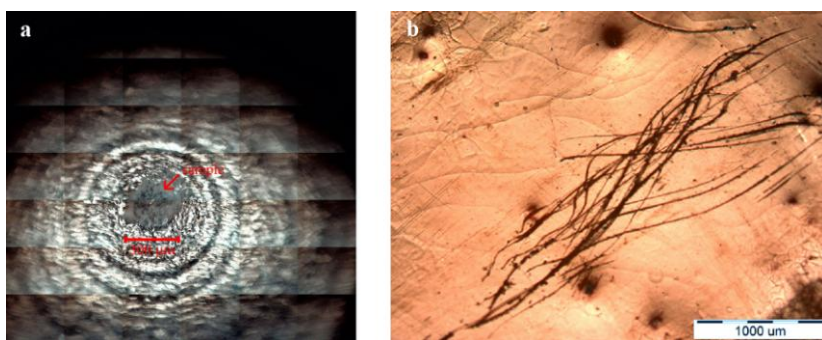


Figure a. Photomicrograph of a sample on a diamond holder recorded with FTIR microscope, b. surface of a model painting after sample removal.



**Methodology for the study of the walls of the *Patio de Santo Tomás, Colegio Mayor de San Ildefonso* (Alcalá de Henares)**

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The *Colegio Mayor de San Ildefonso*, original architectural set of the Alcalá University, has undergone many transformations and changes of use since it was built in the 16<sup>th</sup> century. Since 2010, substantial restoration works in the main College buildings are being carried out. During these works, the wall renderings of the main courtyard, *Patio de Santo Tomás de Villanueva*, were removed, showing the building materials of the walls. This exceptional event allowed a direct study of the historical evolution occurred to the building in the last 500 years, through the analysis of the materials and the construction techniques used, because it was observed that the historical building works were made on the same plane of the wall. Taking advantage of this opportunity, an experimental and analytical research was carried out in order to achieve three main goals: first, finding out the shape and size, building techniques and materials of the original *Patio*; second, identifying the main elements and construction techniques of the different historical stages of the buildings; and third, surveying the successive building works undertaken in the building over the past five centuries.

To achieve those objectives, the methodology of the study combined different researching approaches. The first approach was based on a planimetric survey, obtained by photogrammetry, and complemented with historic and graphic documentation, searching documents, bibliographic references, photographs, paintings and plans in historical archives. At the same time, material samples of brick, mortar and rammed earth were extracted from the walls and were characterized by scanning electron microscopy and elemental analysis (SEM / EDX). Then, the materials' data were combined with the geometric information, which allows identifying the different masonry techniques present in the *Patio* and performing a morphological analysis. Due to the high accuracy of the planimetric survey, it was also possible to carry out a metric analysis of the wall. As a result, a qualified data set, with direct information through the identification and classification of materials and construction techniques, was obtained.

The original construction techniques and materials were found out: rammed earth (tapial) between brick piers, without any horizontal brick layer between each lift. The rammed earth *boxes* were 3 x 9 Castilian feet and the piers 3 to 6 Castilian feet wide, made of bricks of 4 x 9 x 17 cm. The height of the different buildings which constitutes the original *Patio* and the dimensions of the openings were also identified.

This study is part of the Program “Geomateriales. Durabilidad y conservación de geomateriales del patrimonio construido” (S2009/MAT-1629) funded by the Comunidad de Madrid.

**The altarpiece of the Church of Freixo de Espada-à-Cinta:  
a study on its artistic materiality**

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The Altarpiece from the Church of Freixo de Espada-à-Cinta, in Portugal, is a remarkable work from the 16th century attributed to workshop of Viseu. However, some questions have been raised about the true attribution of the altarpiece, and art historians have pointed out different hypotheses about the painters and the workshops involved in its production. Some have suggest that it was painted by the great Portuguese renascence painter Vasco Fernandes, others attributes to Vasco Fernandes's pupil António Vaz, and still others attribute the panels to Henrique Fernandes, also his pupil.

In this work we present the study of the 16 paintings that constitute the Altarpiece of the Church of Freixo de Espada-à-Cinta, using a multi-analytical approach for the characterization of the painting technique and materials applied in the paintings, with the purpose to answer to some of the problematic questions that have been puzzling art historians for some time about the attribution of this altarpiece. Several micro-samples were collected from each painting and then analysed by optical microscopy, FTIR, and SEM-EDS. Data obtained through the combination of these analytical techniques, along with infrared reflectography, bring to the light new evidences that give an important contribution to the problematic questions about the altarpiece's attribution. Surprising results on the composition of the preparatory layers and on the painting technique used in the production of the panels were obtained, which allow new interpretations about the possible influences and workshops involved in the altarpiece's production.

## **A novel instrument for light-stability testing of originals**

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A prototype of a device for micro-destructive light-stability testing of cultural heritage materials was constructed. The instrument is based on the idea proposed by Paul Whitmore, where light from a high-power light-source is focused on a sub-millimeter spot on the tested object and the reflected light is analyzed by a spectrometer, giving information on the induced colour changes.

The new design has been optimized for the needs of a conservation workshop. It allows an easy and intuitive operation, as well as supports both: performing of the light-ageing tests and interpretation of gathered results. The now available Fading-Test-System from Newport Corp. (USA) is targeted towards research community and requires specialist skills to set up the instrument, the measurement's plan and the obtained data's interpretation. The new system, constructed in collaboration between the University team and a SME specialized in construction of scientific instruments, has a: a. light-stabilized short-arc xenon lamp with IR and UV radiation excluded (with an optional UV inclusion); b. retro-reflective optical head mounted on motorised stage allowing for automatic focusing of the light beam projected onto the sample; c. UV/VIS spectrometer with a system ensuring correction of a possible drift from the light source and/or spectrometer itself.

All listed components are integrated in a single housing, forming a small foot-print instrument resembling an optical microscope. The software developed for this instrument allows the user to specify a total dose for which the sample in question should be tested (also expressed in years of exposure on a museum wall at a given lighting conditions), it also allows for semi-automatic reciprocity principle testing and outputs results in ready-made reports with visual representation of the color changes for the tested object - digital image showing *before* and *after* state for specified points on the downloaded image shifted according to the result of the performed light-ageing test.

## Optically Stimulated Luminescence dating of roman mortars in Braga (N Portugal)

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Building materials provide valuable historical information on the past of ancient and Heritage buildings. Their characterization provides information on the origin of raw materials, manufacture, building technologies and sometimes information on different building phases and periods (chronology). Chronological information can be obtained from written historical documents, but they are unusual or detailed information is absent. As an alternative, relative dating methods are the study of building stratigraphy, chronotypology, mensiochronology and chemical analysis of building materials.

Among stony materials, mortars are very interesting for chronological studies, as they cannot be reused (as usually occurs with rock ashlars or bricks). The use of absolute dating methods (based on ionizing radiation) has been explored in the last decades to be applied on different kinds of mortars. Radiocarbon has been used to date organic matter (e.g. charcoal, bones, vegetal fragments) contained on mortars, and different protocols have also been tested to date the lime component of lime mortars. Such method has been successfully applied in some cases, although some methodological problems have limited its use [1,2]. Luminescence dating has been commonly used to date other building materials (bricks). Optically stimulated luminescence dating (also called OSL) has also been tested on some mortars, including lime, mud mortars and Portland cement. Early works have provided promising results [3-8].

In this work we attempt OSL dating procedures to date ancient mortars from the Roman Theatre of *Bracara Augusta* (Braga, N Portugal). Three mortar samples from the theatre foundations have been collected and OSL was tested to get the absolute age of the building and assess dating procedures on different mineral fractions.

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## Analytical studies of 19<sup>th</sup> century photographs by non-destructive techniques

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The late 19<sup>th</sup> century photographs are chemically a multilayer material of several inorganic and organic compounds. The observed composition variety is a consequence of the large number of photographic products and processes that were used in those days as well as result of ageing effects. The data about the chemical composition of a photographic material can be very useful in determining its age and authenticity as in searching for appropriate restoring techniques or storage protocols. Most of the conservation work has been done based on artistic evaluation. Nevertheless, during the last decade, non-destructive analytical techniques have been associated with microscopic and visual methods for the identification and conservation of photographs and photographic emulsions.

In this work, analytical studies were performed on three selected 19<sup>th</sup> century photographs: a multi-technique non-destructive approach was used to determine the composition and degradation status of the selected photographic samples. Reflectance Fourier-Transform Infrared Spectroscopy allowed the identification of a protein material as well as the chemical nature of the protective material layer. The surface morphology and homogeneity of uncoated samples were analysed in a variable pressure Scanning Electron Microscope (SEM-EDS) coupled with a Bruker X-Ray Energy Dispersion Spectrometer used for elemental composition estimation. X-Ray Fluorescence Spectroscopy (EDXRF) was also used for the *in-situ* analysis of the samples.

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## **Overview of non-chemical treatment methods against insect pests in museums**

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Since the 80s, Integrated Pests Management (IPM) is becoming an important aspect in preventive conservation in museums as in the last years some very effective pesticides like Methyl bromide and Hydrogen cyanide have been banned and alternatives had to be found. Today the most wide spread non chemical methods against insect pests applied in museums are anoxic treatments (mainly with Nitrogen, but also with Carbon dioxide or Argon), freezing and controlled heat treatments. Many museums have build their own Nitrogen chamber or make use of air tight bubbles and reducing the Oxygen level with Oxygen scavengers, Nitrogen bottles or with the use of Nitrogen generators. Other methods also used for museum objects today are Nitrogen treatment under pressure, heating with microwaves, high frequency radiation or gamma radiation. Still quite new in the application in museums and storage sites is the use of parasitoid wasps against pests like clothes moths, biscuit or tobacco beetles. All methods are described and, advantages, disadvantages, costs and time needed for each treatment method compared and discussed.

## Consolidation of archeological gypsum plaster by conventional and bacterial treatments: a comparative study

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Gypsum plasters have been used since ancient times to cover masonry, to support paintings and as decorative carved pieces (e.g., “mocarabes” at the Alhambra, Granada, Spain). Due to its softness (Mohs hardness of 2) and relatively high solubility ( $pK_{sp}= 4.62$ ), such a type of plasters and decorative surfaces are easily degraded specially when exposed to humidity (rain, condensation and/or rising damp). The consolidation of decorative historical gypsum-based materials by conventional organic and inorganic consolidants is a subject of controversy, mainly because many of these treatments are nonreversible and show limited efficacy. For these reasons a new method based in the biconsolidation capacity of carbonatogenic bacteria inhabiting the material was assayed. Our research group developed this methodology [1] and demonstrated its high efficacy for the consolidation of porous limestone [2]. Here we report on the consolidation of historical gypsum plasters from an archeological site (Alcázar de Guadalajara, Spain) using both conventional treatments [ethyl silicate (Bioestel); methylacrylate-polyethylmethacrylate (Paraloid B72) and polyvinyl butyral (Mowital)], and the carbonatogenic bioconsolidation methodology. Scanning electron microscopy (SEM) observations reveal that conventional products do not penetrate into the plaster, thus forming an impervious surface layer which blocks the pores (Figure c). In contrast, the bacterial bioconsolidation treatment produces a new cementing material, identified as vaterite ( $\text{CaCO}_3$ ) by X-ray diffraction, both on the surface and in depth, without pore blocking (Figure b). Drilling resistance measurement system (DRMS) analyses show that the bacterial treatment produces a good level of consolidation both at the surface and in depth, whilst the other treatments show limited consolidation efficacy, and this is limited to the surface (first 2mm). As a conclusion, the bacterial carbonatogenesis bioconsolidation methodology is proposed for consolidation of this type of materials.

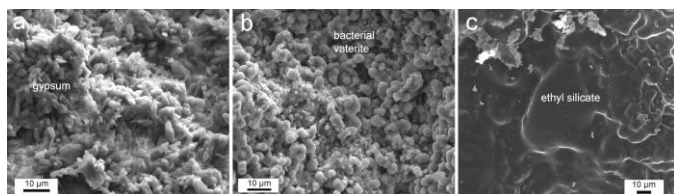


Figure a. SEM photomicrographs of gypsum plasters before and b. after bacterial bioconsolidation treatment, and c. consolidation with ethyl silicate.

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## **Novel protease from marine organisms with potential interest in restoration procedures**

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In the last decades molecular biology allowed the development of innovative protocols in the field of conservation/restoration of cultural assets. In this work we present novel hydrolysates isolated from marine invertebrate organisms, whose protease activity was previously tested in the laboratory by zymography on polyacrilamide gel (in presence of 0.1% gelatine).

Notably, these enzymes are active in the temperature range of 4 to 37°C. In this study, two sets of proteases were applied to bio-clean art surfaces at room temperature (19-25.5°C). Before removal, the water-soluble components of the layers were analysed by size exclusion high-pressure liquid chromatography (SE-HPLC, BioSuite 250 to 10µm SEC 7.5x300mm Waters), followed by electrophoresis on acrylamide gel (SDS-PAGE 15%) with bands' silver staining. The results revealed the presence of protein molecules in concentrations between 24 and 110µg.ml<sup>-1</sup>, and molecular weight between 20-35 and 60-90 kDa.

The enzymatic cleaning showed skillful results, without providing for the heating of the enzyme solution or of the surface on which they were applied. This particular feature makes these proteases more appropriate than others, which are usually activated at temperatures ≥ 37°C. Our hypothesis is that these enzymes will improve the efficiency of enzymatic cleaning protocols, according to the conservative restoration procedures.



**Nanostructured materials for stone consolidation in  
the Temple Valley of Agrigento:  
*in situ* evaluation of their effectiveness**

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The present study, performed in the context of the Master on “Nanotechnology and Nanomaterials for Cultural Heritage”, aims to test new nanostructured products for the consolidation of the stone blocks from the Roman-Hellenistic quarter discovered in Contrada San Nicola, close to the Temple Valley of Agrigento (Sicily). The quarter, constituted from about twenty houses unearthed on the sloping terraces, arranged within a regular urban plan in three blocks (*insulae*), was developed starting from the 2nd-1st centuries B.C. and lasted till the 4th century A.D. The houses are of various kinds, including the Hellenistic type with large courtyards surrounded by a colonnade (*peristyle*) and the Pompeian type with an atrium and central basin for collecting rainwater.

The stone used to build the houses is a biocalcarenite, constituted by calcareous shells and micritic limestones fragments cemented by calcium carbonate.

The study regarded the colorimetric and chemical characterization of the collected stones., before and after the consolidation treatments. *In situ* measurement methodology was developed for testing the different nanostructured products. The consolidation effectiveness was validated by not destructive tests able to monitor, after the treatment, the absorption capacity and the colour change of the samples.

## Thermodynamic modelling of sulfo-resistant cements with addition of barium compounds

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Sulfur trioxide (SO<sub>3</sub>), contained in the atmosphere or in the underground waters, is one of the most important factors in the chemical deterioration of a different type of calcareous-based material which is one of the constituents of our Cultural Heritage, *e.g.* fresco and mural paintings, lime mortars, marbles, limestones and even concrete (a more recent building material which is part of much of the 20<sup>th</sup> century's built heritage). Barium hydroxide solutions have been used to convert the products of sulfate attack, *e.g.* gypsum, ettringite and thaumasite (the last two being found in concrete artefacts), into more stable phases, directly or indirectly (Ferroni-Dini's method in wall paintings). However, their toxicity is a great disadvantage.

The aim of this study was to evaluate the behaviour of two different barium compounds (BaCO<sub>3</sub> and BaO) in the hydration of a Portland cement (where gypsum is present as a setting regulator) and their role against sulfate attack (increasing amount of a Na<sub>2</sub>SO<sub>4</sub> solution (44 wt%)) through thermodynamic modelling with the GEMS program. The results of this study would then be used to design sulfo-resistant restoration mortars made with Portland cement.

Thermodynamic modelling of cements containing BaCO<sub>3</sub> and BaO predicted the precipitation of barite (a very insoluble sulfate) and the inhibition of ettringite. The latter occurred when the Barium compounds were added at concentrations of  $\geq 6\%$  and  $\geq 4$  wt%, respectively. It is clear that the higher the amount of barium compounds, the better the protection against sulfate attack, although this protection is limited to a certain amount of sulfate solution. To summarize, ettringite precipitates when more than 46 ml of a Na<sub>2</sub>SO<sub>4</sub> solution (44 wt%) is added to a mixture that contains 20% BaCO<sub>3</sub>. In the same way, monosulfoaluminate precipitates in cements with 20% BaO when the sulfate solution is higher than 40 ml.

## **Titania-silica nanocomposite photocatalyst: application for stoneware self-cleaning**

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Titania-silica composites are promising materials considering self-cleaning properties. Nowadays, they are widely available as commercial glass coatings. Our objective in this paper is to optimize these composites in order to be used as restoration materials. Recently, we have synthesized a mesoporous titania-silica composite with photocatalytic activity by mixing silica oligomers and titanium dioxide nanoparticles in the presence of *n*-octylamine [1].

In this study, this product was applied on stoneware tiles from a building of the 60's in the city centre of Palermo. This stoneware is a vitrified ceramic building material, consisting mainly of kaolin and feldspar. It is extensively used as floor pavement and wall covering in indoor and outdoor applications. The stoneware selected has low water absorption (<0.5%) and high bending strength (>35 MPa).

The treatment was performed on 2x2x3 cm samples by brushing. For comparison, other stoneware specimens were treated with a popular commercial photocatalytic product, E-503 (Nanocer), under the same conditions.

The adherence to stoneware was evaluated by performing a peeling test, adapted from the literature [2], combining a conventional test with SEM imaging and EDX analyses. We also investigated self-cleaning effectiveness of the coatings by studying the total colour change ( $\Delta E^*$ ) of stones stained with methylene blue and orange and exposed to UV irradiation (365 nm).

Our nanomaterial gave self-cleaning properties to the stoneware under study. In addition, this coating presented effective adhesion and was free of cracks. The commercial material produced a cracking coating with a poor adhesion on the stoneware. Concerning to self-cleaning test, the two products evaluated showed a significant reduction of the stain.

From the results obtained, we can conclude that the new coating material developed in our laboratory is capable of: (a) adhering firmly to the stoneware to ensure that the conservation and self-cleaning properties of the coating have a long-term effect; (b) providing self-cleaning properties to the stoneware surface. We have also shown that the commercial product do not create an effective coating that adheres to the substratum; therefore, such product is of no practical use for protecting stonework.

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## **Semi-interpenetrating p(HEMA)/PVP hydrogels for the cleaning of water-sensitive canvas paintings**

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Cleaning of cultural heritage artifacts enables to fight the natural effect of time by restoring the original appearance of the artwork. Nowadays, aqueous cleaning is usually preferred to organic solvents mainly because it is environmental friendly. Unfortunately, easel paintings present specific characteristics that make the usage of water-based systems invasive. The interaction of water with wood support or linen canvas favor mechanical stresses between the substrate and the paint layers, so that often detaching of the pictorial layer are observed. The usage of water-based detergent systems offer several advantages in terms of selectivity and gentle removal, layer by layer, of soil materials or aged varnish, which are known to alter the readability of the painting. In order to benefit of this advantages it is necessary to confine the detergent system in a gel with very high retention capability to minimize the effect of water.

In this contribution, the confinement and release control of the water-based detergent system is achieved through the synthesis and application of innovative chemical hydrogels specifically designed for cleaning water-sensitive cultural heritage artifacts. These are based on semi-interpenetrating p(HEMA)/PVP networks with suitable mechanical strength and rigidity to avoid gel residues after cleaning treatment. Two different compositions were selected. Water retention and release properties have been assessed. The amount of free and freeze-bound water was quantified by Differential Scanning Calorimetry (DSC) measurements, while mesoporosity was investigated by Scanning Electron Microscopy (SEM). To demonstrate both the efficiency and versatility of the selected hydrogels in confining the most appropriate cleaning system (pure water and oil-in-water microemulsion) two representative case studies are presented.

## Materials made from polyolefins used in tasks of preventive conservation: a comparative study of their long-term behaviour

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The use of synthetic polymers is widely widespread in the Conservation of Cultural Heritage and their presence is usual in the field of Contemporary Art. Thanks to the great advances developed by the chemical industry, it has emerged a great range of products that can be used in the shape of sheet, supports, foams, etc. into the tasks of Preventive Conservation (handling, packing, storage and exhibition). Usually, these products have been initially developed for other industrial uses and the information available concerning their composition is quite limited and, in some cases inaccurate. On the other hand, all the materials used in artworks or in their conservation treatments should have the appropriate characteristics to ensure their long-term behavior. For these reasons, a research Project is being developed in order to study the synthetic polymers used in the field of conservation of Cultural Heritage and in Contemporary Art. This research arises from the collaboration between the IPCE and the Painting and Restoration Department of the UCM. Several materials are being studied to identify their composition and long term behaviour. The results corresponding to the study of different materials used in the field of Preventive Conservation are presented. They are sheets, supports, foams and corrugated plastics. All of them are polyolefins, but show differences related to the type of polyolefin, the nature of additives and the fillers. Their long-term behaviour has been evaluated by performing accelerated artificial aging (T, T and humidity, light) and changes in their original composition and properties have been determined. The analytical techniques used have been: FTIR-ATR, Py-GC-MS, SEM-DEX, DSC, TGA, GPC and TREF. The figure shows the FTIR-ATR spectra corresponding to Cellaire®, a low density polyethylene, and Propore®, a polypropylene, after having being exposed to arc-xenon aging. In both materials, very important changes can be appreciated due to the formation of different oxides compounds. These compositional changes are connected to important variations of molecular weight. The results obtained have allowed us to propose a mechanism of reaction focus to know which kind of products are formed and their effects on the heritage objects.

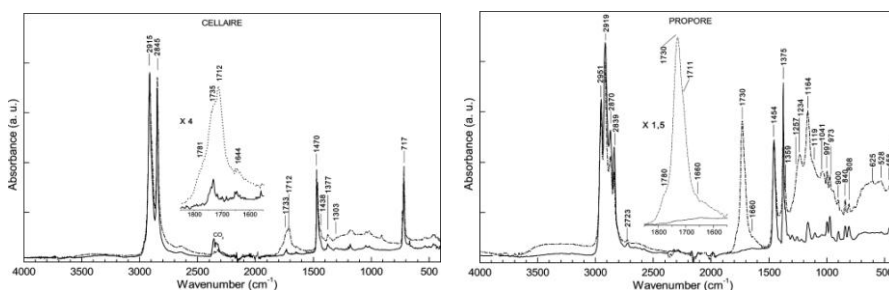


Figure. FTIR-ATR spectra of polyolefins before and after having being exposed to arc-xenon ageing for 1800 hours: a. Cellaire® (LDPE): b. Propore® (PP)

## **Application of new organic-inorganic materials as consolidants for the deteriorated plasters**

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The external plasters based on lime mortars often suffer some degradation phenomena such as detachment, lacunae and loss of cohesion. For these reasons different approaches and technologies, innovative or linked with the local traditions, should be used depending on the type of intervention needed. These considerations are the bases of an actual extensive research program about the conservation of ancient plasters at the Sacro Monte of Varallo Sesia, an Unesco site in Piedmont (Italy). Considering the disadvantages of the common consolidants, the first goal of the research is to use hybrid materials where the limits of organic and inorganic products offset themselves because the inorganic particles are compatible with the support and stable over time, while the organic resins improve the adhesion. Two organic-inorganic hybrid materials as consolidants have been studied: both the formulations were synthesized from an inorganic precursor (Tetraethoxysilane, TEOS) added in different percentages (up to 60% per hundred resin) to a polysiloxane epoxy formulation (TEGO RC 1411, Degussa), and to a cycloaliphatic epoxy resin (3,4 Epoxycyclohexylmethyl -3,4-epoxycyclohexane carboxylate, Aldrich), cured in the presence of ytterbium as acid catalyst. The liberation of the acid supports the deposition of the silica clusters starting from the inorganic precursor through a sol gel reaction. The TEOS not only contributes to increase the mechanical properties of the films but also to reduce the viscosity of the resins avoiding the use of solvents.

First of all, the curing process of the two formulations was verified. Thanks to the homogenous deposition of silica clusters with nanometric dimensions, the obtained coatings are transparent to visible light and harder. Both the formulations were applied by brush on plaster's sample. A good penetration was achieved after the addition of TEOS and the morphology of the plaster was respected as evidenced by SEM observations. The porosity and the vapor transmission were maintained while, on the contrary, the water absorption was reduced. In particular, the hydrophobic property of the polysiloxane formulation was maintained, even in the presence of a large amount of TEOS added. These properties were also verified during artificial ageing with soluble salts: no detachment at the interface between the treated and the untreated parts were observed. Thanks to the inorganic phase the color changes and the yellowing are minimal also after the photo-oxidative artificial ageing. In recent years, sustainability and green chemistry issues are also requested in the field of conservation. For these reasons, new solvent free organic-inorganic materials as consolidants for lime plasters have been studied to be applied where the consolidation of the surfaces is the main request. Moreover, the cationic polymerization reaction allows to obtain at the same time the deposition of the silica clusters and the curing of the epoxy resins without using amines and avoids all the drawbacks of the direct interaction with the nanometric particles.

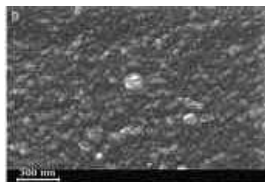


Figure. FE-SEM micrographs of cured TEGO RC 1411 + 40% TEOS. The homogeneous deposition of silica nanoparticles is visible.

## **Multidisciplinary approaches for the investigation of the hypogean environments of the Etruscan tomb "Della Scimmia", Chiusi, Italy**

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A general survey of the state of conservation of the painted walls of the Tomba della Scimmia in Chiusi has been made considering different aspects. The microclimatic monitoring and the surface pattern (composed by the colour analyses and the topographic rendering) have been investigated in two campaigns. Furthermore, an attempt to control biological growth has been made using a new portable microwave instrument.

The climatic data are quite constant apart when a group of tourists visit the tomb. For all measured areas, colour variations of the surface after 8 months are quite low and within the variability of the measure, confirming the stability of the painted surface. The selected areas controlled by the microphotogrammetry system at  $T_0$  and after a time step of 8 months ( $T_8$ ), have shown no meaningful changes in the z axis. The new methodology that control the biodeterioration phenomena which develops on cultural heritage surfaces, once set up in laboratory tests, was applied on a painted figure contaminated by biological white patches. The efficiency of the treatment was evaluated on samples collected (before and after) with the Plant Cell Viability Kit (Sigma Co), while the possible influence of microwaves on the substrate has been controlled with the microphotogrammetric system.

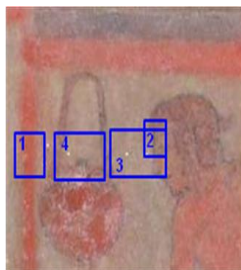


Figure. Selected areas, on the painted surface of the Etruscan "Tomba della Scimmia", Chiusi (IT), for the surface pattern analysis

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## **New nanomaterials for stone restoration**

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The sol-gel process has been found to be successful when applied to the protection and conservation of stones and other building materials. However, a well-known drawback of sol-gel materials is their tendency to crack while drying. Our research group has developed a novel synthesis [1-3] in which the sol-gel transition occurs in the presence of a surfactant. This provides an efficient means of preventing cracking of the gel in two ways: (1) by increasing gel pore radius; (2) by reducing solvent surface tension. Recently, we modified the process in order to avoid the use of volatile organic components (VOCs) in the starting sol [4,5]. The synthesis is simply carried out by mixing a silica oligomer and an aqueous solution of *n*-octylamine under ultrasonic agitation. With this procedure, we prepared materials with different applications: (1) stone consolidants; (2) hydrophobic products by adding an organic component (polydimethylsiloxane) to the starting sol; (3) self-cleaning materials by mixing a photocatalyst (TiO<sub>2</sub>) with the silica precursor; (4) superhydrophobic materials by adding colloidal silica particles to the hybrid sol.

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## **Critical aspects in safeguard valorization and recovery of local architectural heritage: an emblematic example about rural buildings between Ossola (IT) and Ticino (CH)**

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### **Aim of the work**

The public interest in preserving the rural stone architecture in the Val d'Ossola is now universally recognized: roofs of stone slabs of great depth and steep slope, stone masonry, stone balcony supported by stone modillions, are some of the most significant and emblematic image of local diffuse architectural heritage that in border regions between Ossola (IT) and Ticino (CH), has underlined a very common cultural root. Here, the wide diffusion of some recurrent modes to build in spontaneous architecture has recently addresses to start up the research program, Interreg Italia Svizzera 2007-20013, ID 27462783. mis. 3.1, in order to promote, support and lead actions for congenial, compatible and vivifying recovery and preservation.

The recovery and preservation of this heritage are hampered by the disintegration of culture in general and constructive culture in particular. Furthermore, the preservation requisites must harmonize with the current performance and functional ones: the obtained frame may be considered as a reference base to face the several problems emerging from the different local situations.

The main purposes of this research are, for example, to promote the assimilation of lost culture, and to set up practical actions for conservation or compatible refurbishment of these ancient buildings.

### **Essential results**

We foresee to focus on “intrinsic” problems and inconveniences, and then focus on “driven” ones, mainly caused by use and operative rules, bypassing the reference to the specific research and project. We also foresee to analyze a certain number of significant local situations, in order to obtain precise indications to qualify local materials and to regulate interventions.

Different levels of action will result through (a) the realization of exemplary pilot sites, (b) actions for dissemination of knowledge, (c) direct actions to preserve architectural heritage, (d)

### **Conclusion**

The ongoing research will seek to achieve two main outcomes:

- to promote a deeper sensibility through reappropriation of culture to conservation and recovery of traditional houses in Ossola and Ticino
- to draft a set of binding rules and regulations by code of practice taken by local governments as a mandatory administrative tool.

**The protection of the baserri as an organizing system for the rural landscape in the context of the urban sprawl's process: the "SLaM" model versus the utopia of "smart cities"**

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The baserri, the vernacular farm of the Basque Country, is above all a singular and efficient agricultural productive system that has given shape to the landscape of our country. In the mid-twentieth century, as the industry was massively expanding, many farms were abandoned or turned into a source of additional income, while the urban areas underwent a process of high-density urban sprawl. After the industrial crisis, the value of the bucolic farm rose. At the same time, its profitability as agricultural and forestall exploitation decreased. This resulted in the farms becoming a dwelling surrounded by forests and abandoned pastures, which were often urbanized during a second wave of a low-density urban sprawl. The resulting landscape has begun to be perceived as a continuous metropolis that, according to predictions, will host the 75% of the population by 2050. This will make the current consumption and performance model obsolete. The concept of neoliberal "smart cities" gives priority to the prompt economic profitability and the technology, and they are applied only to the most booming neighborhoods of the metropolitan areas that have greater financial capacity, dispossessing them of their identity. Therefore, this concept is not useful for these rururban areas. Alternatively, we regard the "smart landscapes of memory (SLaM) as patrimonial districts of a high cultural level and generators of a sense of identity and membership. They are subject to a coordinated management and urban planning project in order to achieve a physical, social, cultural, environmental and economically sustainable development of the territory and especially of its inhabitants.

## **Petrology contribution to the study of the Roman gold mines of “Pino del Oro” (Zamora, Spain)**

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The Roman gold mines of Pino del Oro and its environment (Zamora) form part of the mining operations that took place in the Northwest of the Iberian Peninsula during the Early Empire (I-II AD). The fieldwork developed since 2006 has located more than 70 sites associated with mining operations throughout the area. Gold mineralization was exploited by various kinds of open works, mainly short trenches and opencasts. To obtain the gold, the extracted ore was subjected to a special treatment of ground in mortar sets made in the surface of the local granite rocks. These mortars are known in the area by the name of “cazoletas” (hereinafter grinding mortars).

The grinding mortars are located on two kinds of granite outcrops. The main aim was to characterize both stones and to determine their state of deterioration in order to provide analytical information that may help to support various hypotheses related with the uses of the grinding mortars. Sampling was done in both kinds of granite, inside and outside the grinding mortars. The research is ongoing and it includes the samples' petrographical analysis and the stones' petrophysical properties study, both *in situ* and in the laboratory. For the petrographical analysis a polarized light optical microscope and a fluorescence microscope is used to allow the study in depth of the fissuration rate of the samples. The petrophysical characterization is done using ultrasonic wave propagation velocity ( $V_p$ ), taking into account the indirect transmission method (in the field) and the direct transmission method (in the laboratory). The surface hardness measurement is done using the sclerometric method, and the measurement of water saturation and the characterization of the rugosity are done by means of a 3D roughness meter. Preliminary results will be presented.

## **Valorization of the “Royal Mercury Pathway” between Almadén and Seville (Spain)**

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Applied research to valorize the “Royal Mercury Pathway” (XVI-XIX) between Almadén and Seville is in progress. Almadén, Ciudad Real, the largest cinnabar mines in the world, produced about 250,000 MT of mercury until the mine closure in 2002. Although Almadén was famous during the roman epoch because the use of cinnabar as valuable pigment, its more flourishing period is related to the introduction of amalgamation in the Spanish Central America silver mines since the mid XVI century. After destillation of cinnabar, the obtained mercury was used to extract the metals from silver ore. Consequently, the demand for mercury increased, and Almadén became an important mining and industrial center. Most of the production was sent to Seville, via a Royal Pathway (“Camino Real del Azogue”) and later, to Cádiz via fluvial way to be loaded in galleons and transported to Central America. Silver was essential to fund the conquest campaigns of the Spanish Royal Crown.

Our research has been focused on finding evidences in old maps and historical libraries, together with fieldwork reconnaissance and relief analyses to locate the original pathway. All the data has been managed with GIS. The route crosses Ciudad Real, Córdoba, Badajoz and Seville provinces and allows the discovering of distinct construction and maintenance elements (bridges, fountains, etc.) or other important Cultural Heritage figures that provide additional value to the pathway. Bullock carts and mules were used in the transport of mercury across three variants, two roads, and a carrier, which were used between XVI century until the final introduction of railway in mid XIX. Nowadays, the Mining and Cultural Heritage of Almadén is available for visitors in the Almadén Mining Park & Museum. Almadén together the Slovenian Idria mercury mine expect to be declared Human Heritage by Unesco in 2012.

## **Studying the origin and evolution of the agricultural landscape in NW Iberia using terraced soils**

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We sampled and analyzed with high-resolution a polycyclic terraced soil located in the surroundings of Santiago de Compostela, looking for the imprints of the different ancient agricultural practices. To this aim a combination of techniques were applied (AAS, XRF, IR-MS) together with selective dissolution extractions (for Al, Si and Fe) and the determination of more traditional physico-chemical properties (soil reaction, pH in NaF, phosphorous retention, etc.). The aim was to identify the signals of land use changes and the different agricultural management techniques applied since the beginning of the agricultural use of the soil. The sequence contained a buried paleosol, with strong andic character, which is considered to exemplify the soil properties prior to the construction of the terraces. In the upper anthropogenic soil layers the relative amounts of soil components responsible for andic properties decrease, presumably as a consequence of the introduction of new agricultural techniques that lead to changes in the chemical stability of organo-metal complexes, thus influencing its accumulation. Variations in acidity, P and Ca contents, and the isotopic composition (<sup>13</sup>C, <sup>15</sup>N) of the organic matter, point to the use of fertilization and liming practices and/or the introduction of new agricultural species. The radiocarbon dating of soil samples indicates that the intensification of agricultural use of this soil and its strong anthropization started in the Early Middle Ages. Our research suggests that the current configuration of this agricultural landscape is mainly inherited from those early modifications, and that the application of several techniques to proper archives (like terraced soils) may help to reveal the history of the build up of the present cultural landscape.

## **Geomatics applied to the monitoring of the damage and stability of the Heritage**

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In this text, we go over some relevant results obtained at the Laboratory of Geometric Documentation of the Heritage -UPV/EHU- about the use of geomatics (surveying, photogrammetry, laser scanning, etc.) in order to refine a methodology for detecting and monitoring the degradation of historic elements.

Based on the acquisition of measures for the definition of shape, dimensions and spatial layout of objects, geomatic techniques can suit almost any need of size or accuracy; therefore, they are most versatile and applicable in a great variety of cases. To begin with, examples of 3D modeling of buildings at risk from collapse are shown; these models can help us to track the evolution along time. Secondly, we present some in-house software created for the quantification of the loss of material on stone and the automatic detection of pathologies. To finish off, we will look through a case of how to optimize a recording methodology for the geometric monitoring of a historic building done exclusively with surveying techniques.

**The restoration of  
the *Pont del Diable* or Aqueduct bridge *de les Ferreres*,  
Tarragona (stage 1)**

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The aqueduct bridge of *Pont del Diable* (Devil's Bridge) or *de les Ferreres* (s.i. AD) is part of the water supply system of Tarraco, catalogued as BIC and World Heritage Site. In 2009 its comprehensive and interdisciplinary restoration was undertaken by a wide interdisciplinary team. The aims were the rational cleaning, structural consolidation and stability, safety, reversibility and innocuousness of the materials used.

Scientific studies for historical and archaeological knowledge and deterioration patterns diagnosis were conducted: archaeological excavation, static analysis (stability on the edge of the structure capacity, building process), lithological analysis, mechanical behaviour (damages due to inadequate removing of centerings); ground-penetrating radar (internal structure and damages), biological analysis (lichen's consolidant effect, removing of vegetation); geological analysis (different materials and repairs on the building work, by limewater applications, chromatic patinas, reposition of ashlar contact areas ), etc.

A detailed orto-photogrammetric mapping served as the base for archaeological, deterioration patterns and treatment maps, that allow an "ashlar to ashlar and joint to joint" documentation. This information is the basis for a GIS for the study, data management and maintenance program of the monument.

The restoration works provided the suitable framework to deepen into the knowledge of roman construction and the development of new tools aiming to Heritage conservation sustainability.

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**CSI: Sittingbourne –  
Conservation Science Investigations in a town centre shopping  
mall**

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This paper discusses the public response and participation in Anglo-Saxon CSI: Sittingbourne - an investigative conservation lab working on finds from a 6<sup>th</sup> to 8<sup>th</sup> century Anglo-Saxon cemetery site in Sittingbourne, Kent. It is a unique community led heritage conservation project. It allows public access to the conservation techniques involved in treating objects from an archaeological dig. The project has been a local initiative involving a Sittingbourne-based conservator, the archaeological excavation organisation (Canterbury Archaeological Trust) and a voluntary local museum (Sittingbourne Heritage Museum), combined with the support of local businesses, history enthusiasts and the wider community. The project opened in late 2009 and has had more than 5,000 volunteer hours contributed to it and nearly 20,000 visitors. Conservation volunteers have been trained to work under supervision and discuss the conservation project with visitors.

The project and its relationship to the community has been used as a case study for two different MA student projects focusing on social values of cultural heritage. We will review these works, examining public engagement with archaeological conservation both before and after the project opened. Reportage from a resident artist reflecting on public interactions with the shopping mall exhibition, an examination of communications from visitors to the exhibition and social media sites will reflect on a variety of levels of public engagement with the process of archaeological conservation science. Subsequently, this paper will interrogate how the project and the opportunities it presents to the community have been, and continue to be valued.



## **Built heritage cultural significance in the conservation of historic school buildings**

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International guidelines on the conservation of historic buildings suggest that preserving the heritage values ascribed by people contributes to the improvement of everyone's quality of life. Historic school buildings have this capacity to join people from different ages with different interests, to share the same social and cultural values associated with the buildings.

Today, conservation of historic schools promotes debates worldwide among architects, who face a major challenge of designing in the context of buildings that no longer provide the physical requirements for the new philosophy of education, which is shifting from teaching to learning. They also face this theoretical shift in Conservation theory, moving from provider to user.

The literature recognizes the impact that conservation can have on cultural significance. However, there is a lack of empirical research to support this assumption.

By building on heritage-values based conservation theory and using heritage impact assessment tools, this research answers the question 'how does conservation impact on historic school buildings heritage values?'

An evaluation is currently being conducted of the process of change, with qualitative analysis of design projects, interviews with architects, owners and school boards, and site observations.



Figure. Liceu Passos Manuel, Lisbon (2009)

## **Neomudejar Architecture in Seville: urban and social background, interventions in the Patio House**

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Since the second half of the 19<sup>th</sup> century, Spanish cities were forced to grow out of its walls, creating extensions, which was the 19<sup>th</sup> century's solution to urban expansion. This formal expansion responded to the needs of wealthy bourgeois society, seeking for a clean, attractive and comfortable city. Industrialization in turn caused a massive influx of immigrants from the countryside who demanded affordable housing. However, speculation had excessively driven up land prices of the extensions. In Seville, however, the city grew inward, there were new alignments, interior plots were built and the urban grid was filled. However, this phenomenon was not observed before the second decade of the 20<sup>th</sup> century when the population undertook a major quantum leap. This population's increase was due to the soaring of rural immigration to the city, as well as to the preparation for the Latin American Exhibition of 1929, requiring additional labor.

Moreover, the crisis of 98 induced a neglect of foreign architectural styles in favor of national ones, seeking in popular architectures for inspiring models, revealed in the forms of Plateresque Herrera, Mudejar and Baroque Hispanic. In the case of Seville, one of the styles that gained greater prominence in the physiognomy of the city was the Moorish Revival style inspired in the Arabic forms.



Figure. New alignment Av. de la Constitución (1910).  
Reform of the Countess of Lebrija house, located on 8 Cuna St. Courtyard.

The started urban regeneration process also affected existing patio houses, in which the renewal was done from within, where the key was the courtyard while the façade had still little representative value. Soon thereafter, coinciding with the urban transformations that occurred in the city and the beginning of construction of dwelling houses, mostly rentals, the existence of the court had a unique function: ventilating the rooms. Design of the interior courtyards of the great Sevillian Palace House would come to the exterior façades resulting in the emergence of a significant amount of façades inspired by Moorish style that still remains in the city, currently known as Sevillian neo-Mudejar style.

## **Industrial glazed tiles, values and intervention**

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The glazed tile is one of the most characteristic coating materials of the Portuguese civil architecture from the mid-19th century until the beginning of the 20<sup>th</sup> century, however the roots of the use of ceramic materials used for decoration dates from the 16<sup>th</sup> century. The glazed tiles are one of the most striking Portuguese media arts over the last five centuries as serial products (productions of the 17<sup>th</sup> and 19<sup>th</sup>) and as individualized products (18<sup>th</sup> and late 20<sup>th</sup>).

The tiles, as integrated heritage, are present in façades of buildings constructed during the industrial revolution or in earliest times. The tiles were produced in plants using manual (for periods further back than 1860) and industrial (>1880) processes to shape the ceramic body. The decor undergoes similar evolution with the application of manual, semi-industrial (stamp) and mechanical (printing) processes. The Portuguese legislation lists different classes of assets -historical, paleontological, archaeological, architectural, artistic, ethnological, scientific, social, industrial and technical- and for each class there is a need for identifying each value(s) -memory, antiquity, authenticity, originality, rarity, uniqueness and exemplary. It is intended to focus on the plastic and the grammar of the ceramics' patterns in order to highlight the rarity and originality that brings this heritage to artistic, social, industrial and technical classes. It is intended to substantiate the theme through the following relationships - art/industry, artist/worker, public/private and public art. This analysis will be centered in the reality of the cities of Porto and Ovar (northeast Portugal).

**Iron Age goldwork as cultural heritage:  
building strategies for its research,  
conservation and social valuation in NW Spain**

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The protohistoric goldwork from the northwest of the Iberian Peninsula is among the most outstanding in Western Europe. However, our knowledge of it and its social appreciation have been hindered by various factors. Among them we can mention the hackneyed subject of its apparent “decontextualisation”, as finds are often made by chance during farm work, as well as the burden of a tradition of investigation and conservation that considers the gold items as untouchable “works of art”. As a result, the recent patrimonial history of Castro Culture goldwork is generally invariable and monotonous, with its exhibition being limited to museum display cases and with little generation of social value.

In this paper we present a strategy aimed at remedying this situation. In contrast to the idea of “decontextualisation”, we maintain that all contexts are significant and that in most cases it is possible to recover relevant contextual information. Secondly, we propose a “biographical” focus that takes into account all the life stages of the object, from its manufacture to the present day, including its discovery, its journey through private collections, the conservation treatments applied to it and its exhibition in a museum. To meet these needs we need to apply a strongly interdisciplinary methodology that combines, among other procedures, fieldwork, the collection of oral information, the use of archival and bibliographical sources and the application of diverse archaeometric techniques (XRF, SEM, AMS C14 dating of organic remains, the characterisation of interior fillings, etc.). This leads us finally to suggest that the best way of promoting social appreciation of Castro Culture goldwork is to integrate it into a cultural heritage value chain that links said appreciation to the work of research and conservation.

Our proposal is illustrated principally through two examples studied within the framework of a research project in progress, the “treasures” of Recouso and Calvos de Randín. The former consists of 16 gold earrings, 4 ingots and other smaller fragments and the latter is made up of 17 ingots.



## **Las Médulas: the social valuation of a cultural landscape**

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The aim of this paper is to present the work carried out by Las Médulas Foundation on this cultural landscape in the area of scientific and heritage dissemination, as well as the methodological criteria used and the results obtained.

The actions carried out so far by the Spreading and Dissemination Area of this organization have focused on the implementation of a complete educational program. Its aim is the transmission of knowledge of Las Médulas in the schools as a mean for its social valuation at the earliest ages.

This ambitious aim cannot be fulfilled without the interaction and active participation of its target audience: teachers, pupils and families. Thus, and with the aim of enhancing heritage education in schools, courses for the continuing training of teachers have been underway. Teaching work has been supported in turn, with the creation of a range of educational resources that allow transferring archaeological research to the classroom from the official curriculum and facilitates the use of the landscape as a learning tool.

Apart from formal education, this organization has focused its effort on the design and implementation of a set of educational activities, such as experimental workshops and educational itineraries. They promote direct contact with the different elements that form Las Médulas cultural landscape and the interaction with the methods of research that have developed around it.

Finally, this work has extended to the families that, together with schools, are necessary to bring the cultural landscape to children in order to foster their knowledge around it.

Ultimately, all these initiatives have been fundamental to promote the communication between heritage and society; a communication that must be carried on in order to strengthen new proposals for the social valuation of our cultural heritage.



**Documenting the architectonic heritage:  
the best way of preserving it**

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Architectural heritage is generally built in the natural stone sourced from nearby quarries. We can say that for over 10.000 years our ancestors selected the proper kind of building stone, taking into account that at that time the strength of the stone was not quite as important as we could think. However in most modern buildings, although built with natural stone, the outer stone wall is, in most cases, only a cladding consisting of thin sheets of stone fixed with concrete of the building with corrosion resistant metal fittings. If load building properties are required, the majority of building stones have compressive strengths at least as great as bricks or concrete. Still, capilarity absorption is very different from one type of stone to other, and this characteristic is important because nowadays the surroundings of the historical buildings experience different conditions such as acidic rain and atmospheric contamination. A clear example is shown in historical buildings using sandstone in their base course. In historic times, the streets were covered with pebbles in earth. All the subterranean water draining underneath the cities could evaporate or come out in some way through the permeable material. But most of the historical city centers are today paved with granite or similar material. The subterranean waters cannot come out easily and they escape using the porosity of the sandstones, creating the deterioration of these rocks. It is easy to see how buildings that used granite (or other non porous material) have been preserved until the present, while buildings that used the porous sandstones or other local natural stone that at the time seemed appropriate, are quickly deteriorating. A general practice in restauration is to clean, repair or even replace the damaged part of the buildings with similar rocks. However, the restoration work is not always done properly, either because the repair is poorly done, causing a major damage, or because the natural stone used for the replacement is not appropriate. The only way to deal professionally with replacement work is to know the original stone and use the same one in order to avoid contrasts in the building, or if the stone has proved to be unsuitable under present conditions, choose the right replacement following the righ criteria. This is extremely important when dealing with historical towns or monuments that have been recognized as heritage by UNESCO. Several projects attempted to deal with registering documentation about ornamental stones. So far none of them were succesful in time and in achievements. This is why national and international networks have been created to document all data on historical natural stone and historical quarries. It is the case of the Spanish network CONSTRUROCK, made up by research teams from universities, research and development institutions and natural stone related companies. Its aim is to start cataloguing all natural stone and quarries in Spain, focused on new and historical buildings. Another one is the Global Heritage Stone project (within a task group inside the International Union of Geological Science) whose aim is to introduce a new formal international designation for natural stone materials that have achieved widespread use as well as recognition in human culture. It also aims to formalize specific characteristics of a dimension stone in an internationally accepted context. As a consequence of these projects, some specific and up-to-date databases will be created and maintained so we, as experts, can offer advice on the important issue of restoration of the architectural heritage based on a real situation.

## **Quantitative research underpins heritage management: preserving ferrous metals**

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Predictive preservation of metal heritage relies upon understanding corrosion mechanisms and generating quantitative corrosion rate data that relates corrosion to environment and object variables. This rate data can be used to design, assess and implement treatment strategies. In doing so a management tool is created that can match finance and resources to evidence based preservation linked to estimation of object lifespan. This would be of immense use for producing cost-benefit and management structures that optimize use of the inadequate resource base on which conservation must operate. Currently, there is limited availability of data to develop evidence based management and no international standardization for producing comparative data.

Cardiff University is actively developing methods and protocols for assessing corrosion rates of ferrous metals and is examining how the data produced can be applied to management of heritage metals. The concept of developing evidence based management is illustrated by discussing a current AHRC/EPSRC Heritage Science funded research project, which is quantitatively defining the corrosion rate of chloride infested archaeological iron. This is determined as a function of chloride in the corroding object, physical change to its structure and environmental relative humidity. Quantifying corrosion as a function of oxygen consumption and the challenges of qualitatively measuring corrosion via physical damage to predict object longevity are discussed. The broader application of the quantification concept and its research methodology is illustrated using quantitative evaluation of chloride extraction methods for archeological iron and an ongoing Historic Scotland funded project quantifying the impact of surface preparation on historic wrought iron. This offers evidence for the claim that successful management of heritage budgets and resources rely upon quantitative research generated in science laboratories.

**Winter covering for marble statuary of  
the Schlossbrücke (Berlin, Germany)**

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Protective structures for works of art or antique artefacts have a long architectural tradition and have been known in Germany since the 19<sup>th</sup> century. The effect of such covers on the microclimate around artworks of natural stone and hence their protective effect are documented and understood insufficiently.

In 2007 an inter-disciplinary model project as part of a pilot project of the Berlin State Office for the Protection of Monuments that was planned with the aim of developing an innovative winter covering system for marble statuary located on the Schlossbrücke in Berlin. Such a system would need to fulfil the various requirements for structural stability, aesthetics, climate and practical use. This applied research represents the first complex scientific study of the sustainability of a winter covering system. A climate monitoring system was designed to create a dense database for the numerical prediction of the effect of protective systems and to compare the given climate conditions to the known factors influencing the marble deterioration. Based on these findings a prototype of an innovative shelter was designed and tested.

The project shows that besides a temporary covering, regular inspection and maintenance combined with regular cleaning ensures an effective and sustainable protection of marble sculptures. Such a maintenance program is the precondition for preserving the sculptures of the Schlossbrücke as a historical ensemble.

Important scientific results of the project are transferable to similar objects of Carrara marble. The results throw a new light on the conventional protection of such objects and lead to a discussion on the necessity of an all-season protection.



**New protocols for  
built heritage protection in the Basque Country:  
towards an automatic analysis tool for built heritage**

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In 2011 the Basque Government commissioned Fundación Zain Fundazioa (Zain) and the University of the Basque Country's Built Heritage Research Group (GPAC) to develop built heritage analysis and protection protocols for the objectivisation and standardisation of the analysis and decision making process through the *Plan estratégico para la gestión del patrimonio construido* project. This project includes the development of an ICT tool to help in and speed up the application of these protocols in practice. This paper presents this tool and its two distinguished parts: the analysis component and the decision making component. The decision making component applies the criteria established in the protocol and is implemented as an expert system. The analysis component aims to automate the analysis process through the use of data in different formats (such as digital images, maps, plots, historical documents, etc.). The feature information revealed through the analysis component is the information fed into the decision making component. The analysis component is the centre of current research. This paper presents the past and current research work carried out in the development of this tool as well as an analysis of the possible impact and consequences of such a tool for the protection of built heritage in the Basque Country.

**A methodological approach to  
evaluation of shelter effectiveness for  
the conservation of archaeological sites**

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Environmental factors may damage or alter stone if archaeological sites are left exposed after excavation. Shelters are structures that cover archaeological sites and may modify environmental conditions in order to retard deterioration; however, some shelters negatively affect the remains they were meant to preserve. A method to evaluate shelter effectiveness is being developed based on monitoring weathering processes on a wide range of specially selected ‘indicator’ materials situated both inside and outside shelters.

Preliminary results of changes to the indicators’ physical and chemical properties associated environmental monitoring data and the decay patterns observed at case study sites will be presented. This approach provides important benefits, including: 1. indicators can be analysed with both destructive and non-destructive testing methods, 2. indicators can be placed in different environments and sites in order to obtain information about common weathering processes, and 3. easily weathered indicators can provide weathering information within a short exposure period.

The result of this study will be the development of a protocol to assess the effects of open shelters (structures that provide partial cover) on stone remains at exposed archaeological sites. This scientific-based methodology could be applied extensively by heritage professionals in order to support their decisions regarding future interventions at archaeological sites.

## **Environmental damage risk assessment and mitigation strategies for sustainable preservation of cultural heritage assets in the city of Granada (Southern Spain).**

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Monitoring and assessment of environmental risks related to tangible cultural heritage assets (CHas), in the context of *preventive conservation*, is a key strategy to safeguard them. Here we summarize atmospheric aerosol composition and its impact on CHas in Granada. Investigations include: 1. indoor and outdoor air pollutant identification and effects on materials in close and semi-open monuments, 2. field exposure tests to determine black soiling of carbonate stones, and 3. laboratory sea-salt ageing tests to learn about interactions between marine aerosols and differently finished stones.

Granada urban contaminants are mainly composed of soot and soil dust particles that darken stones and artworks and form gypsum black crusts. Blackening of indoor artwork is fostered by particle suspension due to improper cleaning habits, cultural events and relief. Identified marine and secondary inorganic aerosols suggest sea salt transport from the coast. Indeed, reactions between marine aerosols and polychromes promote fading of Alhambra paintings. Levels of pollutant gases inside monuments are low except for O<sub>3</sub> in the Alhambra, where climatic conditions were less aggressive than expected. Inside the Alhambra and at the Pomegranates Gate (original access now closed to traffic), black carbon concentrations reached 15µg.m<sup>-3</sup>, but are expected to reach 23µg.m<sup>-3</sup> as for a similarly steep street with dense traffic. While closing the Alhambra palaces to outdoor air would avoid soot deposition, catastrophic decay would result due to an aggressive microclimate. Therefore to minimize this problem traffic must be reduced around the Alhambra.

On stones exposed to urban air, black soiling and gypsum crusts developed after one year of exposure. Stones surpassed 2% effective area coverage (limit perceptible to the human eye), and soiling coefficient was comparable to other urban exposed limestones. Laboratory ageing tests revealed that stone polishing helps protect against salt decay.

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**Microclimatic and Ground-Penetrating Radar surveys for  
damage diagnosis:  
the case of the Crypt of the Duomo of Lecce (Italy)**

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The presence of particular microclimatic conditions inside monumental buildings is responsible of deterioration processes. In many cases, efflorescences and moulds are visible on the façade or the interior of several monuments of historical importance. In other cases, the effects of decay processes are not visible. So, the diagnosis and the consequent set up of effective interventions for conservation are difficult, especially in presence of complex geometry and large variability of construction materials. The Duomo and its Crypt is one of the most important buildings in the city centre of Lecce (South-Italy). Especially in the Crypt, salt damage is evident, enhanced by the hypogeum position and incorrect interventions too. In order to identify the conditions that favour crystal growth, we performed both a microclimatic monitoring and a sub-surface investigation and characterization, by using Ground-Penetrating Radar (GPR) technique. The microclimatic conditions that allow the salt variations over time are given. The spatial variation in GPR signal attenuation permits us to assess the physical and hydrological nature of the pore fluids and associated damages. The analysis of that data in form of “frequency maps” highlights absorption losses, probably linked to high moisture content. Moreover, stratigraphically complex layers of archaeological remains under the Crypt were revealed.

*Keywords:* microclimatic survey; GPR survey; environmental monitoring; the crypt of the Duomo of Lecce

**Entry and dispersion of microorganisms in Altamira Cave:  
new evidences from aerobiological and atmospheric gases surveys**

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Altamira Cave (North of Spain) contains one of the world's most prominent Palaeolithic rock art (World Heritage Site, UNESCO). The conservation of the paintings is threatened by microorganisms (bacteria and recently fungi). Evidences of remarkable microbial activity have been mainly located in the area near the cave entrance, but already reached the Polychrome Hall. Previous studies revealed that entry and dispersion of microbes (and nutrients) on the cave depends on the exchange rates between the cave atmosphere and the exterior through the entrance. Therefore, so far one of the main objectives of the corrective measures implemented in recent years has been focused to minimize the exchange rates through the entrance and reinforce the isolation of Polychrome Hall, limiting the dispersion of microorganisms and the supply of nutrients by airflow. Nevertheless, the data obtained in an aerobiological study combined with a multiparametric survey of atmospheric gases have shown that there is another possible source of entry and spread of microorganisms in the innermost area of the cave (the Well Hall), far from the unique and most elevated entrance. On the one hand, an extensive aerobiological sampling all over the cave was conducted to quantify the level of airborne microorganisms (bacteria and fungi). An elevated level of airborne microorganisms in relation to nearby sampling sites reveals a higher connection degree with the outer atmosphere at this cave site. On the other hand, a spatial-distributed sampling and measurement of carrier (CO<sub>2</sub>) and trace (CH<sub>4</sub>) gases and isotopic signal of CO<sub>2</sub> (d<sup>13</sup>C) reveals a direct connection (active gas-exchange processes) with the outside atmosphere at this cave site. The discovery of an unknown input source of external airborne microorganisms is a threat to the rock art and should be taken into account in future conservation measures in the cave.

## **Canonical Biplot as tool to detect microclimates in the inner and outer parts of Salamanca Cathedrals**

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Salamanca is a city located on the Central Meseta of Spain. Its climate can be defined as Mediterranean with a continental trend and strong daily fluctuations in temperature (as large as 30°C), that produce stresses in exposed materials owing to processes of dilation/contraction (thermoclasty and freezing-thawing), specially in heterogeneous materials such as Villamayor sandstones (skeleton of the quartz and feldspar into a palygorskite, smectite and illite/mica). These decay processes lead to microfissures, plates, flakes and surface arenization. The different degrees and types of decay observed in exposed and protected materials in the Salamanca Cathedrals (New and Old Cathedrals) microenvironments are largely due to the above phenomena.

In the present work, the data of relative humidity and temperature from different sensors in the inner and outer parts of the Salamanca Cathedrals are analyzed to characterize different microenvironments in it from March 2008 to March 2010.

We analyzed values of the sensors every two hours as month-year-localization, to detect the different microclimates present. To avoid the effect of seasonal time, series have been carried out of four different analyses (spring, summer, autumn and winter). The sensors were placed on the outside (environmental station) and inside (different heights inside of the two Cathedrals and museum adjoining the cloister).

The Canonical Biplot is similar to MANOVA (Multivariate Variance Analysis), which permits simultaneous plots of the different groups to be compared, and the different variables being analyzed to be obtained by also involving the specific Biplot characteristics.

When comparing the data from external sensor of the old Cathedral (Dome), with respect to the data of internal sensors of the building, the fluctuations in relative humidity and temperature were found. In summer and winter, there are clearly microenvironments (exterior side and the museum adjoining the cloister). In spring and autumn these differences are less evident.

## **Polar compounds in diesel soot and historic monument surfaces**

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Research on the chemical composition of atmospheric aerosols is essential for understanding aspects related to global climate, cloud formation, effect on human health, etc. A large part of the organic compounds from aerosols and particulate matter can be recovered in a water soluble fraction, which may represent up to 75 % of the total organics. However, a very limited knowledge on the organic composition of aerosol and the water soluble fraction exists and this derives mainly from the fact that organic compound speciation has traditionally been carried out based on gas chromatography-mass spectroscopy analysis. With this approach, a considerable portion of polar (oxygenated) organic compounds remained unanalysed, and the resolution of the complex mixture containing a wide range of different organic molecules is poor.

Diesel exhaust, an important contributor to atmospheric aerosols, consists of a complex mixture of compounds. After emission, these compounds undergo chemical and physical transformations, or aging, in the atmosphere or in the deposition sites. It has been stated that there are myriad of unknown organic species and its associated transformation products in diesel exhaust, and that additional analyses are needed to further elucidate the composition of the polar fraction, which is a significant gap in the knowledge of the atmospheric science community.

Black crusts are repositories of urban aerosols, as the monument surfaces passively entrap particulates in a gypsum matrix and, to some extent, the compounds were preserved. In this work we propose a fractionation protocol that provided a high degree of molecular resolution and clues for understanding the nature of the polar fraction of diesel soot and their components. The same fractionation scheme was adopted for black crusts from a historic monument. Both polar fractions were compared and their molecular features discussed.

**MHS (Monitoring Heritage System) quantification,  
evaluation and control of the influential parameters on  
the degradation of cultural heritage as an active tool of  
preventive conservation**

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The MHS Project (Monitoring Heritage System) is conceived as a monitoring system adapted to the historic and artistic heritage that has been installed and tested since 2005 by Santa Maria la Real Foundation - Romanesque Studies Center, through its department for Heritage Preservation.

Related to the issues offered 1 and 2, the system is developed to quantify, record, evaluate and control a wide range of conclusive and influential parameters in the conservation of immovable heritage in order to ensure the sustainability of its management as well as an ideal maintenance and of the goods that it could hold.

Today the project has become one of the reference systems in the cultural sector, a powerful tool to control efficiently and in real time the status of historic preservation, thanks to an innovative sensing technology and wireless data transmission, and to an intelligent and dynamic management of the results.

System components:

- **Specific monitoring system**, consisting of equipment for measuring and recording environmental parameters, structural and safety, especially developed to overcome the problems of installation in heritage.
- **Specific system of data transmission**, to generate an effective and standardized codification in data transmission.
- **Database**, as the result from the applied investigation study, based on the characterization of the different objective materials from the record data registered by the system.
- **Predictive Diagnostics Tool**. Software based on the implementation of mathematical algorithms developed by Statistical Process Control (SPC) and Pattern Recognition.
- **User's Application**. It is the interface that interacts with the final user or manager, providing relevant information and possible modifications and adjustments in the system.
- **Actuators**. Devices that can be operated by the system or by the user to control and regulate the incidence of certain parameters.

The MHS intelligence lies in the system capacity to detect and predict risks or potential damage and activating action devices automatically or making specific recommendations for action, in order to maintain the optimal preservation of cultural heritage.



## **Environmental exposure of the Seville Cathedral altarpiece: a microbiological and chemical survey**

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The altarpiece of the Seville Cathedral was built between 1481 and 1565 and depicts the life of Jesus Christ on carved wood which are gilded and decorated with gold. The huge scale of the work, which has a total perimeter of 20.10 m and 23.41 m height, makes this altarpiece the largest in the world. Several artists were involved in the execution of the altarpiece, such as Pyeter Dancart, Pedro Millan and Maestre Marco, as well as others of unknown identity. However, most of the altarpiece work seems to have been performed by Jorge y Alejo Fernandez Aleman.

Before the restoration in 1977, serious concerns emerged about the structural condition of the altarpiece, including wood parts in danger of collapse, as well as accumulation of dust on the surface, flaking and lack of adherence of the polychromy and gilding. The intervention in 1977 was centered on ensuring its structural stability, comprising the consolidation of structures and flaking paint and gold.

In 2012, a new intervention to appraise the state of conservation of the Seville Cathedral altarpiece is currently in progress. Our study is centered on the detailed assessment of the dust accumulated on the surface and the survey of significant alterations of biological origin. The scientific approach carried out combined molecular biology methods and analytical procedures. The following methods of analyses were performed: X-ray diffraction (XRD), X-ray fluorescence (XRF) and Fourier-transform infrared spectroscopy (FT-IR). In addition, field emission scanning electron microscopy (FESEM) was conducted to examine different morphologies and chemical microanalysis.

According to our preliminary results, the composition of the dust samples is very heterogeneous, comprising different components of airborne particles, fragments resulting from the altarpiece deterioration, particularly gold leaf from the gilded wood, products from candle combustion and probably from air pollution (soot), as well as biological remains of insects and arachnids.

## Risk of decay detected through wireless sensor networks

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As it is well-known, new outlook is focused on preventive conservation in architectural heritage, reducing the risk of deterioration before it has occurred. To tackle a whole decay evaluation it is necessary to monitor a large number of variables related with contributing factors. The introduction and development of wireless sensor networks rest with data acquisition and monitoring in the long term in order to detect decay phenomena or presence of harmful compounds like dampness, salts, etc., this minimally invasive technique being the required way to achieve preventive conservation. The current project presents different wireless sensors networks (WSN). The main sensors were used to monitor deterioration and study the best technology to deploy in architectural heritage. The project is being carried out in a Renaissance church of the 16<sup>th</sup> century in the north of Madrid (Spain).

Different parameters over different time periods were studied, relating them with activity inside the church, e.g. heating system, ventilation, etc. Thermohygro-metrical parameters such as temperature (T) and relative humidity (RH) were registered by means of a wireless network, detecting noticeable differences between these parameters, depending on the sensor location. Sensors have been positioned inside the wall's construction material (brick, stone, etc.) or on its surface. The obtained results have made it possible to establish behavior guidelines of the microclimate inside the walls.

Finally, outdoor conditions were also registered by a weather station in order to get a complete monitoring system. This system was equipped with different developed graphic user interfaces for data processing, including a complete data acquisition and back-up module.

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## Microclimatic analysis in Galician churches decorated with 16<sup>th</sup> century wall paintings: case study of *San Lourenzo de Fión*

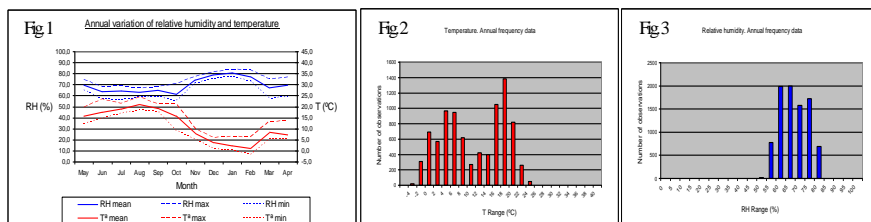
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**Introduction and aim:** Galician wall paintings have remained forgotten under plasters or behind Baroque altarpieces for the last four centuries. In recent years a project to recover and preserve this heritage has been launched, focusing on *A Ribeira Sacra*, a region rich in religious architecture with wall paintings. One of the main aims is to characterize the indoor microclimate in the churches, to evaluate the importance of the fluctuations of environmental factors on the conservation of the paintings and to establish measures for preventive conservation.

**Methodology:** Firstly, the climate of *A Ribeira Sacra* was studied based on the climatic data registered in the nearest official stations during the last decades. Secondly, the main thermo-hygrometric parameters were measured every hour, during the annual period May 2011-April 2012, by means of climatic stations installed in three churches in regular use. Each station was equipped with four probes STHx-10 (with thermo-resistances Pt-100 and humidity capacitor sensors) to measure temperature (T), relative humidity (RH) and to calculate dew point spread, both from the indoor environment of the chapel and from the surface of the murals at different heights, to study a vertical profile. The fourth probe was installed outdoor as a reference.

**Results and conclusions:** Results from the Romanesque church *San Lourenzo de Fión* are presented as an example. Mean and extreme values, frequencies, range and speed of the fluctuations of the thermo-hygrometric parameters are analysed on an annual, seasonal and daily basis. Figure 1 shows the annual evolution of the mean, maximum and minimum values of T and RH. The annual mean temperature is 12.0°C, with a minimum of 1.0 in February, and a maximum of 21.1 in August. The absolute range of fluctuation is 29.8°C, from February (-2.3) to June (27.5). Regarding relative humidity, the annual mean value is 70%, with a minimum of 61 in October, and a maximum of 81 in January. The absolute range of fluctuation is 30%, from October (54) to January (84). Figures 2 and 3 present the annual frequency data of T and RH, showing the predominance of occurrence of T values from 16 to 20°C and of RH from 60 to 70%. Special attention was paid to the stability of the indoor environment versus the outdoor, to evaluate the isolation capability of the building, and also to the influence of the use of the building on the indoor microclimate, that explains the hourly maximum variations registered. To conclude, as fluctuations are higher and sometimes faster than expected, it would be recommendable to implement environmental control measures to reduce them, trying to eliminate the extreme values of the histogram and to establish an optimal range adapted to this particular context, achieving a compromise between human comfort and good conservation conditions for the artworks.



## **Thermographic study of the influence of natural lighting in temperature variations on the *Portico de la Gloria***

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The present work deals with the influence of natural lighting in the temperature changes of the sculptures of the Portico de la Gloria in the Cathedral of Santiago de Compostela. The Romanic sculptures of Portico de la Gloria receive sunlight which raises their temperature such that humidity changes and mineral salts damage the sculptures. The solar energy which pass through the big baroque style windows in front of the inside sculptures has been characterized. A series of thermographs at different times on one of the sculptures has been taken (Figure) and it has been found that UV and IR filters which have been set on window glasses contribute to reducing this negative effect.

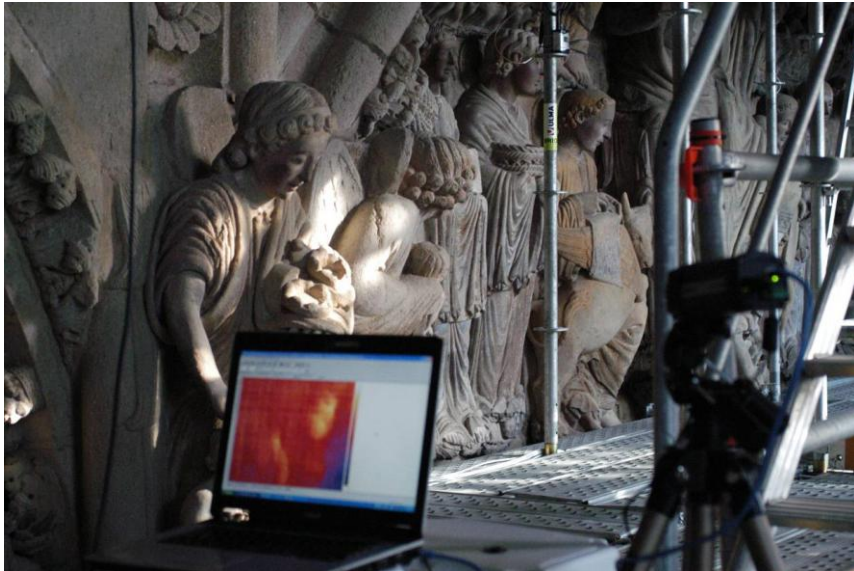


Figure: Experimental setup of the termographic camera.

## **Alterations of materials at the façades of the church of San Pedro de Mezonzo (A Coruña, NW Spain)**

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The Church of San Pedro de Mezonzo is located in the A Coruña city center and its main façade is exposed to the east. It is mostly made of granite stones but there are other stony and metallic materials applied. The outside of the church is comprised mostly of ashlar and plastered walls but there are also some examples of carved stone (statuary) on the main façade that are mostly made of granite.

An observational study based on visual detection of alteration features showed the presence of:

- diverse stains;
- erosive features with loss of material.

The dark brownish/reddish stains are related to the presence of ferrous elements on the main façade. The whitish efflorescences detected on the granite ashlar of the main façade are mostly composed of alkaline sulphates. There are also some widespread darkish coatings on the granite ashlar that might reach the thickness of a black crust. This also occurs on other materials and on the carved statuary.

The erosive features affect the plastered walls and seem to mark water infiltration points as well as the granite ashlar. The proximity of the efflorescences to the erosive features suggests a causal association between the erosive features and salt weathering.

These decay features indicate that the decay of the materials results from exogenous agents (e.g. water, atmospheric materials) and also from the materials that are used in the construction of the church. Of particular relevance are the ugly brown/reddish stains associated with the metallic elements and the intense erosive features observed on the granite ashlar that seem related to the alkaline sulphates (usually related with cement mortars), features that indicate the contribution of the materials used on the built structure.

## **Decay of building materials in the Circular Mausoleum, Necropolis of Carmona, Spain**

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The Necropolis of Carmona (Seville, Spain) is one of the most significant Roman burial sites in southern Spain used during the first and second centuries AD. Of its more than 600 tombs, the Circular Mausoleum is one of the best examples of a tomb affected by different decay mechanisms. The alteration patterns are varied and abundant, including host-rock fragmentation, loss of materials (disintegration, arenization), surface modifications (efflorescence, crusts of various typologies) and biological colonization (mainly bacteria, algae and lichens). As a result of the numerous interventions and restorations since its discovery, the tomb presents a high RH degree (78.9%, on average) and a general overheating near roof surface (mean temperature of air-rock interface remains 1.2°C above average air temperature). Moreover, vapor condensation is highly enhanced due to porous structure of stuccos, mortars and host-rock, thus condensation is registered during more than 20 days per month and it reaches monthly amounts up to 1.6 kg/m<sup>3</sup> air (January and February). These factors produce a thermal gradient in the tomb and, therefore, a stratification of the tomb air. Ventilation is restricted and the intense thermohygrometric gradient induces decay mechanisms through the tomb. Thus, biological colonization is mainly produced in areas near the ground, crusts in the intermediate zones and efflorescences and breaks out in the upper zones and roof of the tomb. Crusts and efflorescence are mainly composed of gypsum and are distributed in all kind of substrata. Crusts present different forms from thin, smooth and cryptocrystalline to globular crusts. Efflorescences show mainly acicular habit. Evidence of microbial activity is varied and widely extended. In the entrance and corridor walls, lichens, algae, cyanobacteria and heterotrophic bacteria are found. Inside the tomb the distribution of the microbial colonies depends on the orientation of walls and its distance to the entrance. Microbial colonization is more intensive in holes and rough substrates and presents a greenish color due to the growth of phototrophic microorganisms. In flat substrates, violet, and discrete black (spotted/mottled) colonies and dispersed green biofilms are found. The different pathologies observed are discussed to the light of environmental parameters.

## **Drying and oxidative degradation of Shellac used as protective coating for wooden artifacts**

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Shellac is a resinous secretion of lac insects of the genera *Laccifer*, mostly cultivated in the host trees in the forests of India and Thailand. The purified resin is widely used in the food industry and, to some extent still as an adhesive or protective after being used extensively in art and conservation. The resin is a complex mixture of several polar molecules such as mono- and polyesters of hydroxy aliphatic and sesquiterpenoid acids, which are the responsible of its characteristic adhesion properties and, at the same time, the cause of its instability.

This paper is devoted to a detailed investigation of the polymerization (drying) process and of the subsequent oxidative degradation of commercial shellac, exposed to accelerated weathering conditions. To this end, two different types of shellac in form of thin films were exposed to the following simulated conditions of ageing:

- constant temperature of 120°C in a forced-air circulation oven;
- accelerated photo-ageing in a high-speed exposure unit equipped with a Xenon-lamp; a special UV glass filter was used for limitation of radiation at wave lengths greater than 295 nm, corresponding to outdoor solar exposure.

Structure and property changes during the different treatments were mainly followed by Fourier transform infrared analysis, thermogravimetric analysis, differential scanning calorimetry, insoluble and weight-loss determination. Finally the degradative behaviour was compared with that of old, naturally aged samples.

**Study of the armor covers deterioration processes in  
the High Palace of Pedro I in the Alcazar of Seville**

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Mudejar armor covers from the Palace of Pedro I have been the subject of our investigation since 2000, when the restoration works on the ceilings in poor conditions started. They are located within the boundaries of the Alcazar of Seville. From the start of the intervention, there has been a constructive and comprehensive analysis of the reinforcement structure. This structure itself has historical and heritage value and this intervention allowed us to study first-hand the main processes of deterioration suffered through time.

In each part of the armor it is easy to find highly degraded areas due to poor conservation, linked in most cases to erroneous construction solutions and to biological factors triggered by wet conditions.

The deterioration of ceilings, so often mentioned in the original documents reviewed, has been a constant over the centuries. The need for servicing, cleaning and rebuilding has been repeatedly stressed.

Some cases of damage also arose from mechanical processes that led to the emergence of stresses not supported by armor or to the deterioration of the structure in general, i.e. load-bearing walls.

We present the results of these studies in order to create a foundation upon which to base future conservation work and maintenance of the architectural heritage.



**The erosion of granite surfaces:  
the Cathedral of Évora as example**

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Nowadays, granites and similar rocks are considered very durable construction materials. Looking back into the past, several examples may show that they can be very fragile, justifying the need for urgent intervention and conservation works. Sand disintegration and scaling are frequent decay patterns on monuments made on this type of stone where large areas are in risk of loss.

The research done with the ultimate aim of contributing to the intervention plan of conservation in the Cathedral of Évora allowed to collect data on the degradation of the materials in specific but valuable areas where this problem is particularly relevant.

In this paper we present some results that allow us to evaluate objectively the loss due to erosion of the surfaces. Inside the monument it was possible to get logistical conditions that allowed the quantification of the process, certainly impossible in the outdoor of the monument.

## **Magnetite and bronze-magnetite coverings in pre-Roman weaponry**

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Many weapons of Iberian pre-Roman period have the peculiarity (of unknown origin and with no continuity along Roman period) of having surface magnetite and bronze-magnetite artificial coverings. The anti-corrosive properties of these layers allowed the conservation of several pieces in which the characteristics of these coverings can be recognized. Other pieces, nevertheless, cremated during funerary rituals, suffered a deeper corrosion due to the final thermal cycle.

Recognizing the original surface and the state of conservation of these iron objects of archaeological origin is usually problematic. This difficulty can lead to an infra-valuation of the reading of the corrosion layers. The study of the corrosion compounds is the key to the identification of the original surface, the formal identification of the object and the choosing of the most appropriate treatment in order to perform its restoration, cleaning or preparation of the altered or corroded surfaces.

In this work we present five pre-Roman iron pieces presenting both surface finishings (magnetite and bronze-magnetite). By means of their study and interpretation using optical microscopy and scanning electron microscopy, and the experimental reproduction in laboratory using steels of the same characteristics of the originals and a Carbolite oven, we have reconstructed their fabrication processes and the corrosion processes that can affect them, in order to offer the conservators-restorers community a method to work securely with these kinds of tools.

## Study of the long term stability of an industrial polyamide from a contemporary artwork

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Synthetic polymers were used for the fabrication of artworks since their introduction as industrial materials and, as a matter of fact, sculptures (including assemblages, collages and installations) partially or completely made of plastics are ubiquitous in art collections and contemporary art museums. On the other hand, it is well known that polymers may be much more prone to oxidation and more in general to physical or chemical ageing, than other materials traditionally used by artists, even under protected indoor conditions such as those found in museums during display or storage [1,2].

In the framework of a comprehensive project aiming to develop an analytical procedure to evaluate the degradability of polymeric materials in contemporary works of art [3], herein we focus our attention on the long term stability of a plastic-made sculpture (*Homo Felis* by *Esferobite DSk*) from the collection of the contemporary art museum of Santiago de Compostela. Recognition of the polymeric components was carried out by attenuated total reflectance – Fourier transform infrared (ATR-FTIR) analysis and differential scanning calorimetry (DSC), whereas their weathering was investigated under simulated conditions of ageing in which the processes of degradation occurring under natural conditions were accelerated through the irradiation of polymer samples in a photoageing device equipped with a xenon light source. Monitoring of structural and molecular changes was performed mainly by FTIR and UV-vis spectroscopy, DSC, thermo gravimetric analysis, and weight loss determination.

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**New materials in contemporary sculpture:  
analysis of MDF fibreboard**

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Connections among scientific research methods and those characteristic of artistic creation have developed in a parallel way, establishing connections in those contributions and solutions for specific matters concerning both matters. We should not forget that one's rigor cannot overturn the other's spontaneity and *vice versa*. Throughout this investigation we intend to carry out a deep analysis of the Medium Density Fibreboard (MDF) derived from wood to be analysed as an important sculptural material; establishing at the same time a parallelism among sculpture, new materials and traditional techniques.

Wood is a vegetable organic matter, whose main characteristic is its anisotropy and heterogeneity in its fibres, but it also presents a disadvantage concerning section sizes, surface, length and shape, which may not satisfy in some cases the requirements and necessities of our projects. The technological and industrial development offers some alternatives as the MDF board providing new faculties, in a constructive way as well as in an artistic creation, to the sculpture as this is a homogeneous material in all its directions and with plastic and procedural possibilities similar to natural wood.

In our research we have analysed the physical and chemical formation, as well as the mechanical characteristics and its behaviour facing adverse conditions, subjecting the MDF board to different laboratory tests: accelerated test in the absorption of humidity, accelerated test in oven-drying, accelerated test when exposed to extreme temperatures (freezing and high temperatures) and accelerated ageing test.

The exposition of the results we obtain shows us that MDF board suffers different physical and volumetric changes as it is subjected to quite extreme conditions. However, in steady environmental conditions, it provides an excellent behaviour, comparable to that in natural wood used in sculptures.

## **Study of the corrosion products of the lead blocks from the historical organ Jean Pierre Cavallé of Vinça, France**

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The pipe organ in Saint Julien and Sainte Basillise parish was built by the French organ builder Jean Pierre Cavallé, who finished its construction in 1765. After a series of transformations throughout the centuries, the organ was subject to a thorough restoration at the end of the XX century, being returned to its original stoplist and sonority. A very severe corrosion in the lead blocks of one of the reed stops was a problem that aroused during this restoration. The blocks are a fundamental component in these reed stops. They are made from a piece of pure lead that serves as a fixation for the different elements that form a reed pipe. On one end the wedge of wood fixes both the shallot and the reed tongue. The resonator made by tin-lead alloy (usually by means of welding) is fixed on the other end.

In the pipe organs, the blocks are kept in a closed environment for a long period of time; we found that the blocks' lead surface were converted into white corrosion compounds; the blocks were corroded in bulk through a progressive advance of the corrosion layer. Due to the severity of the corrosion it was essential to substitute them for new blocks since their recovery was impossible. The possibility to have at our disposal unrecoverable pieces, allowed us to be able to thoroughly study the components without having to worry about the possible destruction of the samples. It was possible to prepare cross-sections of different zones of the blocks to observe the growing lead corrosion crust. In this work, the alterations of these types of pieces are described for the first time. The following techniques were used: optical microscopy, electron microscopy with X-ray dispersive analysis, micro Raman and X-Ray diffraction, both in configuration of Bragg-Brentano as in glancing angle. The corrosion products found are plumbonacrite and hydrocerussite, two basic lead carbonates.

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## Evaluation of the biodegradative potential of bacteria and fungi isolated from an oil painting on canvas

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There are several reviews highlighting that microorganisms may be responsible for the degradation of different objects of art such as paintings, stone buildings, wood or paper. Paintings contain a wide range of organic and inorganic constituents which are a good carbon source for microorganisms, usually those which have high enzymatic activity and low nutritional requirements.

In this study we evaluate the biodegradative potential of a selection of bacteria and fungi previously isolated from the painting “Virgen de Guadalupe”, which showed visible signs of biodeterioration. For that purpose, the stratigraphic sequence of a cross-section corresponding to a sample taken from the painting studied in this work was identified. After that, mock paintings reproducing real layers of this oil painting on canvas were prepared, inoculated with bacteria and fungi previously isolated from the painting and finally, they were examined for potential susceptibility to microbial degradation using micro-FTIR spectroscopy. In micro-FTIR techniques, an infra-red spectrometer is linked to a microscope, so the sampling areas of interest can be visually identified in order to obtain the spectral data. We selected the bacterial and fungal isolates that showed a higher number of enzymatic activities related with deterioration processes.

FTIR-spectra revealed that, neither bacteria (*Arthrobacter* sp. and *Paucisalibacillus globulus*) nor fungi (*Eurotium* sp. and *Penicillium* sp.) separately, were able to cause chemical changes on the different materials used to prepare the “mock paintings.” When used together, *Arthrobacter* sp. and *Eurotium* sp. were not able to cause these changes either. Only when *Arthrobacter* sp. and *Penicillium* sp. were used together, the observed bands of the FTIR-spectra showed variability in position.

## **Identification of microorganisms that cause rot in wood by molecular biology techniques**

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The detection and accurate identification of microorganisms involved in biodeterioration processes of cultural property is a necessary first step for conservation. Traditional microbiological techniques, based on isolation and cultivation in the laboratory, have the disadvantage that not all microorganisms can be cultured, as is the case of wood-rotting fungi. Thus, the aim is to combine traditional microbiology with molecular biology techniques based on DNA extraction and analysis, in order to identify fungi that cause rot detected in the wooden support of various artworks of historical and artistic interest. Specifically, these techniques have been applied to the study of the vaults of the Sala de los Reyes of the Alhambra in Granada, and the processional paso of Jesus del Gran Poder in Sevilla.

The observation of several samples of wood rot by optical microscopy with polarized light showed the presence of fungal hyphae and spores that could not be identified. Therefore, DNA was directly isolated from samples of wood rot. This DNA was used as a template in a polymerase chain reaction (PCR) using oligonucleotides corresponding to conserved sequences of the gene encoding the eukaryotic 28S rRNA as primers. The resulting fragment was isolated and subsequently sequenced. (The sequence thus obtained was compared with those from different DNA databases by using the BLASTn algorithm).

**Preventative intervention on  
Eduardo Chillida's Monument to Tolerance in Seville (Spain)**

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The Monument to Tolerance was created in 1992 by the sculptor Eduardo Chillida (1924–2002). On the Muelle de la Sal (Salt Pier), next to the river, this work was raised in reinforced concrete around an inner steel framework using formworks and moulds in its construction.

Since the moment of its construction, this work has undergone weathering due to its own characteristics and to its exposure to high environmental humidity. This has impacted both its structure and the cohesiveness of the concrete. Consequently, it has been subjected to numerous prevention attempts that have nonetheless been unable to halt the decay process. With the aim of undertaking a definitive intervention on the monument, we have come up with a proposal for stabilizing its building materials without having recourse to isolating it. The study, together with a partial reconstruction, addresses both the composition of the materials and the pathologies affecting them. Restoration and maintenance are proposed.

Characterization consisted in determining the chemical composition by X-ray fluorescence, studying the mineral composition by X-ray diffraction, estimating the pH of the concrete and the carbonation depth by phenolphthalein tests, and determining its physical properties.

Basic study results include a high amount of chlorides, the inappropriate use of lime mortar in previous restorations, and decay due to the composition of the concrete.



## **Analysis of heat effects due to fires on calcareous stones**

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Fires are one of the frequent anthropogenic hazards for Cultural Heritage, these events occur usually during armed conflicts or may be due to poor maintenance of electric net or gas pipeline systems.

This work has recorded the historical analysis of the fire effects on different Churches in Seville (Spain). The fires destroyed most of the structures of these churches and only a little part of the walls or façades could be recovered. The main construction materials of these façades are limestones, calcarenites and sandstones.

The aim of this study was to analyze the behavior of similar limestone submitted to equivalent heat effects. The thermal tests have been studied on fresh samples of limestone from Jerez de la Frontera (Cadiz, Spain), Puerto de Santa Maria (Seville, Spain) and Pedrera (Seville, Spain), that could be the original quarry of the façade in most of the churches from Seville.

The heat tests have been carried out in an oven model 12-PR/200 BB series at different temperatures: 300°C, 400°C, 600°C and 750°C in order to evaluate the effect of the temperature generated from an inner fire in the monuments.

Several analytical techniques have been employed to determine changes due to heat effects:

a) For the mineralogical-petrographical study, we have used an optical microscope Kyowa with a digital camera and X-ray diffractometer brand Bruker (model D8 Advance), using CuK $\alpha$ .

b) Physical properties have been studied by ultrasound speed measurements with a PROETISA STEINKAMP equipment, model BP-5, at 55KHz, color changes has been followed by a X-RITE equipment Series SP60 and also loss of weight has been measured.

Specimens from the three quarries show color changes since 400°C, meanwhile the highest temperature (750°C) produce mineralogical and textural changes due to the presence of portlandite, which is accompanied by fractures, fissures and high loss of weight.

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## **Sulfur isotopic analysis. Application to the study of the origin of gypsum-rich crusts in granites**

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Gypsum-rich crusts are one of main deterioration forms of rocks used in monuments and art works exposed to environment ([1], [2] and references therein). The study of the origin of the sulfur of such crusts and salt deposits by means isotope ratio analysis has been yet conducted in the case of sedimentary rocks and marbles [3], [4], [5], but it has never been approached to clarify the origin of gypsum in sulfated crusts developed in granitic rocks.

This paper presents the results of a study that aims to identify the origin of sulfur in granitic crusts of historic buildings located in an urban environment with great coastal influence (Vigo, NW Spain). Firstly, a set of samples of black crusts developed in these buildings was taken in order to characterize them from mineralogical and chemical points of view. Secondly, a sampling of different sulfur sources was performed, determining their content of total sulfur and sulfate ion. The sulfur sources considered were: total atmospheric deposition collected at five different points of the study area during four months, sea water, soil and building foundations, mortars and cements form the buildings, commercial mortars and cements and combustion residues from diesel and gasoline vehicles. Finally, in all the samples (crusts and sulfur sources), the sulfur isotopic ratio expressed in  $\delta^{34}\text{S}_{\text{CDT}}$  was determined.

The results show that the main sources of sulfur in the study area are the atmosphere and the construction materials present in buildings; the sulfate content from the basements and foundations is negligible. Regarding  $\delta^{34}\text{S}_{\text{CDT}}$  values, the end members correspond to sea water (with the highest  $\delta^{34}\text{S}_{\text{CDT}}$ ) and to commercial cements and combustion residues (both with  $\delta^{34}\text{S}_{\text{CDT}}$  close to 0); atmospheric deposition samples show values very close to the reference value of the seawater. The isotopic ratio of the sulfur from black crusts is only slightly lower than atmospheric deposition values, and very far from the values obtained for commercial cements and combustion residues of vehicles. The values of  $\delta^{34}\text{S}_{\text{CDT}}$  of the crusts are higher on those facades oriented to the rainy depressions coming from the ocean. It is found, therefore, that the contribution of sulfur from natural sources (sea spray and rain) to the gypsum-rich crusts formation in this area is much greater than the combustion emissions. This result is interesting because in previous studies, marine sulfate is not found as a probable source in gypsum-rich crusts processes [4], [5]. In this sense, the impact of marine origin salts on granite rocks used in monuments, as established in the case of chloride [6], should be checked with regard to the role of sulfates, given its contribution to the formation of gypsum-rich crusts.

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## **Restoration of the Renaissance façade of the town hall of Seville**

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The restoration work on the renaissance façades of the town hall of Seville (Spain), constructed in stone, has presented a challenge due to the details of its magnificent sculptures and their deterioration.

Firstly it was necessary to perform a combined scientific-technical study before the restoration that included the following actions:

1. The stone was chemically characterized to find its intrinsic degradation factors.
2. The main signs of alteration were mapped and the deterioration factors were determined. The stone is profusely carved and to reduce the construction effort soft stones were used, showing low resistance to some external agents.
3. The main chemical mechanisms of degradation of the stone of this building were analyzed.
4. Samples of the stone's external layers were taken and analyzed. The stone of the Town hall of Seville had an original protection based on thin layers of lime mortar, a kind of stucco.

The results allowed us to select the actions to be performed on the façades. The intervention project consisted of:

1. Cleaning the stone of salts and harmful materials.
2. Reinforcing the structure of the sculptural elements with stainless steel rods and stone lime mortars of lime.
3. Waterproofing the areas affected by dampness with the traditional technology for the recovery of hydraulic lime mortars.
4. Consolidating with lime micro-mortar and protecting the stone using a technology used in construction in the 16th century: a thin layer of lime mortar, pigmented with minerals to get the color of the stone.

The results have been very good, achieving consolidation and protection with materials related to the stone. This was accomplished with great efficiency and is expected to well preserve the stone façade. In addition it has recovered the original brilliance of this Renaissance façade, one of the best of Europe Renaissance.

## Degradation of plastics artifacts: case study of a “drafting machine” made of different cellulosic plastics

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Since the beginnings of the 19<sup>th</sup> century, plastics have been used widely in the manufacture of technical instruments with different purposes. In the last few decades, plastics entered the art, ethnographic and history museums and now they have become the main object of relevant conservation research. As is well known, some of these plastics are susceptible to particular type of degradation -as it occurs in cellulose derivatives- and their degradation can lead to the complete destruction of the artifacts.

The Cartography and Geographic Studies Archive of the Spanish Ministry of Defence houses a relevant collection of topographic, geodesics and photogrammetric instruments. Some of them have been manufactured with plastics as it occurs in the case of certain instruments used in technical drawing. Figure 1 shows the image of a “drafting machine” manufactured with plastic and metals. Its nowadays condition is an excellent example of the plastic degradation and the synergies produced by the degradation products.

This paper presents the results of the analysis for the identification of the materials used in its manufacture and the relationship between its composition, the identification of the VOCs produced during its degradation and the conservation condition of the artifact. This study is an illustrative example of the consequences of the combined use of extremely unstable materials (cellulose nitrate, cellulose acetate and metals) (Figure 2) and the connection with the development of cracking, crazing, exudates, loss of transparency, deformation and yellowness of the plastic, as well as corrosion on metallic parts.

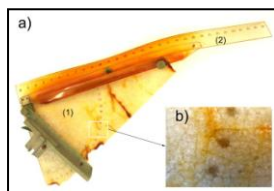


Figure 1. a) Image of the artifact, a drafting machine; b) degradation showed by the cellulose nitrate.

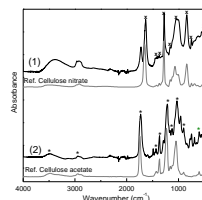


Figure 2. FTIR-ATR spectra of the plastics: (1) cellulose nitrate; (2) cellulose acetate.

## Evaluation of mural paintings biodeterioration by oxalate formation

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Microbiological deterioration, caused by microorganisms growing on the material surfaces, can alter and destroy polychrome surfaces, resulting in chromatic changes and hyphal penetration [1,2]. One of the pathologies detected in the mural painting is the crystallization of oxalate salts due to biological attack resulting from lichen, fungal, algal or bacterial metabolism. The oxalic acid produced by many biodegrading organisms acts as a strong complexing agent for the metallic cations present in the substrate, which would otherwise be toxic to the microbial species themselves. One degradation phenomenon that occurs on artworks is the formation of metal oxalates [3,4,5].

The aim of this work is the isolation and identification of the microbial communities involved in the biodeterioration phenomena affecting the wall paintings of the Convento de Nossa Senhora da Saudação (Montemor-o-Novo, Portugal) and the identification of a pigment deterioration product caused by oxalic acid, in order to plan appropriate restoration treatments.

For microbiologic assays the samples were aseptically collected from areas of the paintings with significant contamination. The microbiological study allowed the identification of several bacterial strains (e.g. Gram+ cocci/bacilli), yeast strains and filamentous fungi of the genera *Penicillium*, *Cladosporium*, *Aspergillus*, *Sporothrix* and sterile micelia were also isolated.

The combined spectroscopic approach using scanning electron microscopy coupled with energy dispersive X-ray spectrometry (SEM) and Raman microscopy allowed to evaluate the microflora proliferation and the presence of oxalates, respectively, and proved to be a useful tool for the biodeterioration assessment in mural paintings.

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## **Mural paintings biodeterioration: chromatic alteration of the lead white pigment**

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One of the pathologies that occurs in mural paintings is the chromatic alteration of the lead white pigment. Salt damage in wall paintings causes mechanical changes by crystallization pressure and also chemical and mineralogical alteration of its painted surface. Porous materials are suitable for migration of salt solution to the surface, where salt can crystallize and attack colour layers [1]. It was proved that oxidation of white lead resulting in the formation of brown-coloured lead dioxide is a biogenic process. Microorganisms isolated from the mural paintings are capable of oxidizing, along with white lead, other bivalent lead-containing pigments (massicot, minium) [2].

The main aim of this study is to describe the changes of white lead pigments in Igreja de Santa Clara (Sabugueiro, Portugal), to explain the mechanism of the blackening of lead-based pigments and to identify the different microorganisms involved in this process and the role of salt solutions. This information can be useful in decision of making for conservation and restoration treatments.

Samples from the most damaged areas of the paintings were collected, under aseptically conditions, in order to proceed with the microbiological study. Their isolation in selective nourishing medium allowed the identification of numerous bacterial strains (e.g. Gram+ cocci/bacilli) and filamentous fungi of the genera *Penicillium*, *Cladosporium*, *Sporothrix*, *Aspergillus* and sterile mycelium were isolated as well.

The characterization of the microbial communities on the painting was achieved by the resource of molecular techniques, such as DGGE [3]. The application of the denaturing gradient gel electrophoresis (DGGE) allowed the separation of fragments of the same size but with distinct sequences, a parental band is obtained in which it is possible to identify populations and more specifically individual members [4].

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**Investigate of CIE (L\*,a\*,b\*) and the total colour difference "ΔE\*" value of different banknote papers (Egyptian 5 pounds "EGP", Egyptian 10 pounds "EGP", 1 Riyal "SAR", 5 Dirham "AED", 1 Dolar "US\$", 5 Euro "€") upon CMC modification and accelerated ageing**

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Banknote papers include an extensive range of security features that involve secure complex processes such as watermark, security thread, micro printing, etc. Security features are very important elements integrated into paper banknotes for fighting counterfeiting as without the presence of security features within banknote papers how can we fight counterfeiting?

In the present paper, different banknote papers (Egyptian 5 pounds "EGP", Egyptian 10 pounds "EGP", 1 Riyal "SAR", 5 Dirham "AED", 1 Dolar "US\$", 5 Euro "€") are coated by different concentrations and different layers of carboxymethyl cellulose (CMC). Accelerated ageing speeds the natural ageing process of paper by subjecting it to extreme conditions.

We performed accelerated ageing; thermal ageing at 140 °C for 2 hours and UV-radiation ageing with two different wavelengths ( $\lambda_1 = 256$  nm,  $\lambda_2 = 336$  nm).

Change CIE (L\*, a\*, b\*) and the total colour difference (colour tolerance); AE\* values were investigated before and after CMC coating.

Change CIE (L\*, a\*, b\*) and the total colour difference (colour tolerance); AE\* values were measured and calculated before and after accelerated ageing.

The security features of banknote papers were examined through transmitted light, UV light and IR.

It can be concluded that the security features integrated into banknote papers are effective as the accelerated ageing have no effect even small on the security features after CMC modification which reflects in increasing banknote papers durability.

*Keywords:* Banknote papers, Security features, CIE (L\*, a\*, b\*), The total colour difference (Colour tolerance) "ΔE", Accelerated ageing, CMC.

## **Chemoorganotrophic community in the Ocean's Cubiculum at the St. Callistus Catacombs (Rome): ten years of monitoring**

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As already studied in the frame of the EU CATS project, different type of biofilms (green, greyish, white) were widespread on lithic faces of the so-called Ocean's Cubiculum at the Catacombs of St. Callistus (Rome, Italy). The microclimatic conditions (T°, RH% and irradiance) favoured the establishment and proliferation of very highly diverse microbial communities formed by cyanobacteria, bacteria and, to a lesser extent, by algae and fungi. Blue light (emission peak around 460 nm) was successfully applied in this site to limit the growth of phototrophic microorganisms, but no action was carried out against chemoorganotrophic microflora responsible of white patinas and greyish spots. Thus the studies concerning the microbial community were focused on their monitoring in term of species and on their role in the crystals precipitation on the surfaces. For this purpose a multistep approach was carried out by the use of different kind of tools (microscopy, laboratory cultures and molecular analysis) to analyse the microflora biodiversity and species identity. Some significant changes were found in the microbial diversity, especially due to the increase in number of bacteria and to the appearance of deteriogen fungi such as *Penicillium*, *Aspergillus*, *Cladosporium* and *Doratomyces*.

The present work reports on the results obtained during 10 years of studies and discusses critically the next steps to be carried out for a durable conservation of the "Ocean's Cubiculum".



## **Study of the influence of black dyes in the physico-mechanical behaviour of silk**

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The aim of this study is to understand the implications of the chemical structure of some natural dyes in the physico-mechanical behavior of dyed silk fabrics in order to establish their degradation as a consequence of certain dyes. More specifically, this study focuses on black natural dyes commonly used on dyeing procedures for silk fabrics during 18th century such as logwood (*Haematoxylum Campechianum* L.), and certain tannins. The reproduction of different recipes from the treatises of this century allowed to prepare dyed silk samples in order to characterize them physico-mechanical and chemically, after different accelerated ageing cycles.

A multi-method approach is proposed combining microscopy and spectroscopy techniques, traction tensile tests and colorimetric measurements in order to characterize the overall behavior of silk fabrics as a function of dyes present in their composition before/after ageing processes.

Stress strain curves helped to determine the stiffness and flexibility of silk as well as their elongation and strength to failure within specific environmental conditions and dyeing procedures. The studies conducted previously by this research group about the unaged and aged silk behaviour allowed the correlation between all results that demonstrated an increase of the silk rigidity due to the different pH of the bath solutions, as well as the difference in the colour depending on the dye.

## **Rheological analysis of some historical and commercial binders labelled as thixotropic in oil painting references**

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Some binders used in oil painting are supposed to have special properties because of their “thixotropic” behaviour: they would flow easily in contact with the brush, but they would be like a gel at rest. Time factor is not clearly established so there is a confusion between shear thinning and thixotropic behaviour that could be present when describing them.

Mediums labelled thixotropic, according to the literature, present a common composition based on: drying oil (linseed or walnut), stiffness elements (dammar resin, mastic, sandarac or arabic gum), plasticizers (beeswax and/or egg), solvent (turpentine or lavender) and optionally driers (litharge or lead white, now replaced by cobalt and zirconium driers).

The aim of this work was to analyse shear thinning behaviour and thixotropy in four different binders: two historical artisan recipes (“*Van Eyck according to Mayer*” and “*Rubens according to Mytens*”) and two nowadays commercial media (“*Venetian medium* by Le Franc et Bourgeois” and “*Liquin Light Gel* by Winsor and Newton”). Rheological measurements have been carried out with a controlled stress rheometer RS1 Rheostress (Haake), at 20°C. Before measurements, samples were kept at rest for 15 min.

Step flow curves in controlled stress mode were performed (shear rates from  $10^{-4} \text{ s}^{-1}$  to  $100 \text{ s}^{-1}$  aprox.) and thixotropy of the Non-Newtonian samples was analysed in Hysteresis loops and Weltmann model.

The results after physical tests revealed that “*Rubens according to Mytens*” had a newtonian behaviour but the other three binders were shear thinning fluids because viscosity decreased when stirring. Regarding to the time dependence, *Van Eyck according to Mayer* and *Venetian medium* recover part of their initial viscosity during this resting period, however, *Liquin Light gel* doesn’t recover at all, so an irreversible rheodestruction of the internal structure is produced when stirring.

It is important to know the physical behaviour of binders because it determines important conservation factors like aging and future changes.

**Bricks and mortars from the “Patio de Santo Tomás”,  
Alcalá University (Madrid, Spain):  
a combined study of fabric characterization and  
building morphology**

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A combined study of fabric characterization with building geometry and morphology has been undertaken at the “Patio de Santo Tomás, Colegio Mayor de San Ildefonso” from the Alcalá University (Madrid, Spain). A set of bricks and their associated mortars from different periods and locations have been selected to carry out the fabric characterization, which was accomplished by using conventional chemical-physical techniques such as thin section petrographic observations, X-ray diffraction (XRD), X-ray fluorescence spectrometry (XRF), and scanning electron microscopy equipped with energy dispersive X-ray spectrometry (SEM-EDS). This contribution presents the results derived from this combined study.

The original building materials were identified from the morphological analysis dated at the early sixteenth century. Based on the fabric characterization, it has been determined that a first group of bricks is related to some transformations in the building from the sixteenth to the seventeenth century; a second group which belongs to the building of the cloister is dated at the mid-seventeenth century and a third one, which is probably related to the new building additions, is dated at the mid-nineteenth century.

Each of the three groups of bricks showed technological, textural and compositional differences, which can be correlated with their chronology and location in the building. A fine textured clay, the presence of grog or “chamotte” and a relatively low firing temperature characterized the first group of bricks, while the second and the third ones exhibited coarse textured clays, probably mixed with sands, absence of “chamotte” and a higher firing temperature. In addition, bricks from the nineteenth century displayed vitrification evidences. Resulting data from bricks in conjunction with differences were determined in their associated mortars.

This combined study was carried out when wall sections were exposed during rehabilitation of the building. It has provided outstanding data on bricks and mortars, which could be useful in future conservation and/or restoration strategies.

## **Study of alterations on Roman masonry in the Tower of Hercules**

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The Tower of Hercules is the only Roman lighthouse still in use today. It is located on a headland in the city of A Coruña in Galicia (north-western Spain) and it was declared a World Heritage site in 2009.

The round chamber where the luminaire was located, the access spiral ramp and the outer wall of the Roman construction were lost. However, the square-shaped inner core, divided in four chambers and three levels that reach 37.58 metres in height, still exists, although modified.

The most important restoration works on the lighthouse took place in the last quarter of the 18<sup>th</sup> century, under the direction of the engineer Eustaquio Giannini and the advice of José Cornide Saavedra. The present outer appearance of the Tower of Hercules is the result of this respectful and exemplary intervention.

The present state of conservation of the tower is very good, especially if its age, the continued use and the vicissitudes suffered throughout the years are taken into account. However, the Roman masonry suffers from alterations, originated mostly in the past, as a consequence of secondary uses and transformations, and by the inappropriate conservation treatments applied in the early 20th century.

The study of alterations on Roman masonry aims to assess the actual state of conservation in order to establish the appropriate protocol for its preservation.

The document is structured in four chapters, the fourth being the most relevant, since it is the one focused on the study of pathologies affecting the masonry of the different chambers that form the Tower. Such pathologies are reproduced in maps of damage and of humidity and salt.

*Keywords:* Roman engineering, construction pathologies, preventive conservation, World Heritage.

**The application of non evasive geophysical techniques for  
the diagnosis of stone cultural heritage:  
the case of a Portuguese 15<sup>th</sup> century tomb**

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A Geophysical and geochemical survey was carried out in a Portuguese artistic tomb of the fifteenth century made of a porous limestone. This tomb is located inside a church, in the downtown of a historic city where the groundwater level is close to the surface. It has about 2,90m width and 1,50m height and presents nowadays severe decay phenomena, like powdering, saline efflorescences and multiple exfoliation which threaten the historical and artistic significance of this monument.

Today experts agree that a precise damage diagnosis is required for comprehensive characterization, interpretation, rating and prediction of stone damage and thus is vital for its conservation and mainly for sustainable monument preservation. Knowledge improvement of the stones used and the factors, processes and characteristics of stone decay is the basis for sustainable cultural heritage preservation.

Therefore, this study focuses on the assessment of the origin and distribution of moisture in this carved piece of stone and intends to evaluate its relationship with the stone deterioration patterns and to measure the extent and severity of stone decay processes in progress.

Several geophysical (Self-potential (SP) and seismic reflection and refraction) and geochemical techniques (Fourier Transform Infrared spectroscopy and ion chromatography) and also IR thermography were used to appraise the mechanisms involved in the stone decay observed in this tomb. The decay products associated with the decay patterns observed are mainly related with the presence of salts, namely nitrates and secondarily of chlorides.

The SP and the thermography survey performed in the tomb allowed us to verify that different moisture degrees are observed in different side walls of the tomb and that movement of water through the stone is in the origin of spontaneous potentials measured.

The application of seismic methods (refraction and 3-D reflection) showed there is no clear interface between undamaged and damaged stone material. The low values of P wave velocities show: the limestone is soft, the strength is slightly lower in the most humid zones and the stone is slightly better preserved on the cover.

**Preservative substitution of historic books' bindings through facsimile reproduction: the *Registro notarial de Torres* (1382-1400) in the Archive of Real Chancillería de Granada, Spain**

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Reusing manuscript or codex parts for book binding has historically been a common resort. Once studied, these fragments may acquire autonomous historic or aesthetic relevance. Such is the case of the currently unpublished “Registro Notarial de Torres” (1382-1400), which is preserved in the Archive of Real Chancillería de Granada and whose parchment cover is a bifolio that belonged to a Visigothic codex from the 12<sup>th</sup> century.

The paleographic and descriptive study of this document has revealed a unique historic importance that transcends its function as cover. Once considered archival, preservative and organoleptic technical aspects, the results of this research have conclusively determined the decision to preserve the cover as an independent documentary element of the registry of notaries.

The substitution of the cover by a facsimile reproduction followed strict criteria of intervention and methodology in order to test the technical efficiency of the materials to be used in the fashioning of the new cover.

This article presents the results of tests performed on the suitability of selected support materials and ink in a climatic and aging test chamber, particularly attending to chromatic variations (tone, value and saturation), pH, dimension and risk of transfer on a contact paper. The aging conditions and periods were fixed according to ISO norms for the stability of paper, cardboard, paints and varnishes.

These studies have verified the selection of the most stable and innocuous materials for the facsimile reproduction of the cover, guarantying that its substitution maintains a protective function while it keeps the physical appearance through which it was bequeathed.

*Keywords:* Preservation, restoration, book binding facsimile, aging, test.

## Electrokinetic removal of salts on granite: first *in situ* experience

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Desalation of porous materials using electrokinetic methods are well developed in concrete and cement [1-3]. Recently and for the first time, this method of desalation has been approached in granites [4]; the success of this application in laboratory, in terms of efficiency in the removal of  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  and of absence of adverse effects on the rock, encourages trying the method *in situ*. In the present work, an *in situ* desalation experience using electrokinetic method on granite is presented. The granite structure selected is a column from a country house declared as a cultural interest, strongly affected by soluble salts (mainly chloride).

Prior to the salt removal, soluble salt content and color of the rock were determined. After the saturation of the column with electrolyte (0.2M sodium citrate solution and 0.2M citric acid buffer at pH6), a 20V DC current was applied by means of four graphite electrodes: two cathodes and two anodes oppositely placed. To maintain a constant level of electrolyte in the rock, an absorbent sponge (constantly renewed in the electrolyte) was placed between the rock and the electrodes. To eliminate the possible damage caused by acid (anode) and basic (cathode) pH, poultices of different nature with buffer capacity were set between the rock surfaces and the electrodes, periodically controlling the pH during the process. The desalation lasted 4 months; during this time the rate of desalation was monitored by controlling the  $\text{Cl}^-$  amount on the renewed electrolyte. After desalation, samples of rock were taken to compare the soluble salt content with initial values and color was again measured to detect changes.

The soluble salts after the desalation were significantly reduced, indicating that the method was effective in remove soluble salts. The pH was maintained near neutrality, demonstrating the efficacy of the selected poultices as pH buffers. Color changes after the test were minimal and seemed not to be related to the principle of the method. As proposals for improvement, it is necessary to test different currents in order to accelerate the desalination process and also to improve the method of initial saturation of the rock in electrolyte.

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## **Hybrid sol-gel based protective coatings for historical window glasses**

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The glass manufacturing during the Middle Ages, in the Center and Northern Europe, was aimed mainly at the production of windows for churches or cathedrals and civil buildings. The medieval glass is characterized by the use of  $K_2O$  as flux (PLS or potash-lime-silica glass), is particularly sensitive to the weathering phenomena and is generally attacked by atmospheric pollutants conveyed by water in liquid or vapor form (rain, atmospheric humidity, fog), which acts like a trigger for the corrosion process. Since the conservation strategies are currently addressed to maintain the window glasses on their original architectural contexts, it is necessary to protect them from additional degradation phenomena. Most of the protective treatments applied until now are based on organic polymers (epoxy resins, poly-vinyl-acetates, acrylates). The sol-gel technology offers significant advantages in the preparation of protective films for glasses as the Si-alkoxides precursors are chemically similar to the substrate and the final product shows chemical resistance, low viscosity and good adhesion to the glass. Moreover, it can be easily applied (by brush or spray) without damaging the original substrate and with a minimum visual impact.

We show here the results of water-repellent hybrid sol-gel coatings obtained by TEOS (Tetraethyl-orto-silicate) associated to different amounts of Si-alkoxides functionalized with alkyl groups, as Octyl-triethoxy-silane (OTES- $CH_3(CH_2)_7Si(OC_2H_5)_3$ ), Hexadecyl-trimethoxy-silane (EDTMS- $H_3C(CH_2)_{15}Si(OCH_3)_3$ ), 3-(trimethoxy-silyl)-propyl-methacrylate (MTMS- $H^2C=C(CH_3)CO_2(CH_2)_3Si(OCH_3)_3$ ), Trimethyl-ethoxy-silane (TMES- $(CH_3)_3Si(OC_2H_5)_3$ ) and Methyl-triethoxy-silane (MTES- $CH_3Si(OC_2H_5)_3$ ). Isopropanol was used as solvent and HCl as catalyst. The coatings were applied by speed-controlled dip-coating technique on laboratory slabs, thermally treated at 50°C for 1h and characterized by UV-VIS, FT-IR and Raman spectroscopy. Static and dynamic contact angle measurements were performed to check the water-repellency of the surfaces. On the basis of the transparency of the films, the contact angles values and the amount of the organic component, maintained as low as possible to achieve the highest compatibility with the substrate, three compositions based on OTES and EDTMS were selected and applied on medieval-like glass samples. The treated glass was then colorimetrically characterized by means of a spectrophotometric scanner.

The studied silica-based protective materials do not lead to reaction by-products, are found to be water-repellent, compatible with the glassy substrate and are colorless and transparent, hence satisfying the main requirements of the conservation of Cultural Heritage.



## **Colloidal synthesis of portlandite nanocrystals: carbonation and interaction with dolostone or limestone**

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Calcium hydroxide (portlandite), one of the oldest construction materials, is used primarily as a binder in mortars and mural paintings. It is also widely used in conservation to bind loosened grains, primarily in lime- and dolostone, whose porosity is modified by the product of portlandite carbonation,  $\text{CaCO}_3$ .

In recent years, nanotechnology has been deployed to preserve stone materials. Today,  $\text{Ca}(\text{OH})_2$ -based consolidants are the commercial products of choice for limestone and dolostone consolidation, due to the ease with which  $\text{CaCO}_3$  can be obtained from carbonation of these colloids [1].

One of the priorities is the assessment of the stability of this type of consolidants in response to factors such as relative humidity and exposure time. Colloidal synthesis-based  $\text{Ca}(\text{OH})_2$  nanoproducts should therefore be investigated and their interaction with the substrate monitored after application to assess the effectiveness of stone consolidation.

Trials monitoring both relative humidity and exposure time in consolidants applied to Cretaceous dolostone from Redueña (northern part of the province of Madrid) have revealed differences in product carbonation and its relationship to mineralogical phase transformations. Variations have been observed even among  $\text{Ca}(\text{OH})_2$  nanoproducts of the same colloidal pathway.

Differences in nanoparticle carbonation are associated with a number of factors, in particular the combined presence of  $\text{CO}_2$  and liquid water or water vapour in the environment, which expedites the process and induces fluctuations in  $\text{CaCO}_3$  polymorph nucleation and growth. This behaviour affects mineral reactivity and modifies crystal size. Crystallographic and textural factors may modify the hydric capacity of the material and therefore affect its porosity and roughness. The resulting changes in porosity are mirrored in the petrophysical properties of the consolidated stone. Thus, any modification in the petrophysical properties contributes to increase or repair the deterioration of lime or dolostone substrates.

### *Reference:*

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**Characterization by means of  
the application of new resources of documentation on  
covers decorations in the *Arabic Manuscripts Collection* of  
the School of Arabic Studies,  
High Council of Scientific Researches of Granada, Spain**

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While the decoration of book covers historically depends on technical and artistic advances, it is nonetheless closely connected to the book's function and to its owner's social status. The systematic registration of these decorations offers a complementary base for the discussion on codicologic studies results, but it does not always provide useful information for the definition of the decoration's formal structure and its process of execution. This communication presents the study results of a 14 binding collection that belongs to the *Arabic Manuscript Collection* of the EEA-CSIC of Granada, [XII-XIX]. The base pattern of these motifs is enriched with fillet tracings in simple, double or triple straight lines or in different shapes like rosettes, stars, floral figures, circles and other geometric elements, all of them with a fine and complex finish. The techniques of documentation and register used for the extraction of designs in cover decorations include up-to-date technological resources that needed to be adapted to different kinds of decoration and to their state of conservation. The techniques applied to the study of the registers obtained have thus been subjected to a comparative test describing the advantages and disadvantages of each of them. This registration, in connection with other intrinsic parameters of conservation, takes part in a broader research plan on the material characterization and codicologic analysis of the bindings included in this collection.

*Keywords:* Arabic Manuscripts, decorations, covers, documentation, photograph, codicology

## Low-cost airborne ultrasounds scan for Cultural Heritage

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Non-destructive methods are of great interest for the analysis of Cultural Heritage. This work presents a low cost ultrasound sensor without direct contact with the test specimen, studying variation of the phase shifts between the emitter and the ultrasound detector (Figure). This acoustical method meets the requirements to perform *in situ* non-invasive studies of bricks position supporting mural paintings and simple plasters, and could be extended to other antique artifacts such as mosaics, etc. Its simplicity and the low data acquisition time could be put together to obtain real time measurements, which in addition to a position tracking system would enable a fast and versatile non-destructive system. Using this prototype system, an early moisture detection system has been installed in a dome that supports a fresco. We used this prototype for the detection of brick joints under a 15<sup>th</sup> century Renaissance fresco of the Metropolitan Cathedral of the city of Valencia (Spain), with full success in detecting these joints. Both laboratory and *in situ* results are in agreement. Although this is a preliminary study and more tests and theoretical simulations must be performed, the result is encouraging and opens interesting prospects for future research in this field.

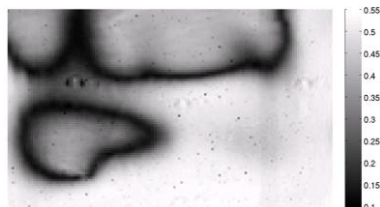


Figure. Two-dimensional acoustical image of the test specimen, colors gradients represents the phase values of ultrasound emitter and receiver.

## **Study of historic grisailles from stained glass windows of Spanish Cathedrals**

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The distribution of the international Gothic stained glass windows in Spain resulted from the contribution of new master glassmakers who imported their rich catalogue of forms, giving a new orientation to the Spanish stained glass windows of the 15<sup>th</sup> and 16<sup>th</sup> centuries. This is the case of Arnao de Flandes, Juan de Valdivieso, Diego de Santillana, Pierres de Holanda and Pierres de Chiberri, who carried out important work in Burgos, Avila, Palencia and Segovia Cathedrals.

In this work, stained glass fragments from the 15<sup>th</sup> to 20<sup>th</sup> centuries, belonging to different Spanish cathedrals were characterised. The work aimed at finding the composition of the glasses and glass paintings and relating these with the corresponding production periods and authors.

Historical documents and recipes provide an insight into the fabrication of grisailles in the past, how they were used and applied. This study includes the recipe books of Juan Denis and Francisco de Herranz.

The chemical analysis of grisailles paint layers on historical glass fragments provides insight in the composition and microstructure of the final product. These results would be compared with the original recipes.

Reproduction of historical glass paint powders will be applied on modern glass panels and subsequently fired. The powder and the resulting paint layers will be characterized.

The elemental compositions of the glass fragments were obtained by means of a non-destructive portable EDXRF spectrophotometer and Raman spectroscopy. These were complemented by SEM-EDX and micro X-Ray diffraction, performed on polished thin cross sections of the glasses.

The compositions and structures, in particular of glass paintings allowed establishing a definite relation between the compositions found and the periods of production. Recipes and chemical compositions indicate that glassmakers of the 15-16<sup>th</sup> century had a full control over the colour of the grisailles they made.

## **Molecular approach for the characterization of ancient/degraded *Cyperus* sp. specimens**

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The aim of this work has been to apply and improve the efficiency of molecular tools for the genetic characterization and identification of *Cyperus* sp. from different sources (museum, herbarium collections, deteriorated specimens, etc).

In this study, samples from different provenance were analyzed and, in particular, dried specimens from *Herbarium mediterraneum*, burned specimens, museum collections. Samples were investigated through DNA extraction NucleoSpin Plant II kit (*Macherey-Nagel*) from 20-30 mg samples and *in vitro* amplification of specific target sequences of the *rcbL* plastid gene (ribulose-1,5-bisphosphate carboxylase/oxygenase large subunit) by specific amplification protocols using a novel set primers (CYP-1f/r, CYP-2f/r; CYP- 3f/r), setting specific annealing temperatures and reaction mixtures (*Invitrogen*). The PCR products, single DNA fragments, were resolved by electrophoresis on 2% agarose gel, and sequenced by MWG operon sequencing service.

The sequences compared by BLAST software allowed us to obtain genetic information in order to carry out phylogenic and taxonomic analyses, also in relationships with fresh samples form Palermo Botanic Gardens.

**Roman glasses from Augusta Emérita:  
study of the degradation pathologies using libs**

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Despite Roman glasses have been widely studied, little attention has been paid to their degradation pathologies occurred during burial or during exposition to other environmental agents. In this contribution, a set of Roman glasses from the ancient town of Augusta Emerita (Iberian Peninsula) has been analyzed to provide some insights into their degradation processes. The glass set consisted of seven whole beads and six fragments from other objects and are dated from the first to the sixth century AD.

The selected glass samples were analyzed by the following techniques: laser-induced breakdown spectroscopy (LIBS), using a Nd:YAG laser emitting at 266nm; scanning electron microscopy (SEM) with energy dispersive X-ray spectrometry (EDS); and X-ray fluorescence (XRF). LIBS has been particularly used to undertake stratigraphic analyses on glasses. This kind of analysis is accomplished by applying successive laser pulses on the same spot to get information on both corrosion layers and in-depth composition of glasses.

The results obtained through the techniques employed indicated that samples were soda lime silicate glasses. Common pathologies mainly consisted on degraded surface layers and dark deposits. As far as degraded surface layers concern, they presented a low content of alkaline oxides which can be connected with a dealkalinization process. On the other hand, dark deposits were manganese-rich and appeared over or, in between, such dealkalinization layers. Additionally, surface decorations displayed a high content of antimony, which could be related to the use of lead antimonite employed by the Romans as an opacifier.

Resulting data demonstrate that LIBS, when used in combination with other conventional techniques, is able to provide useful information on degradation pathologies occurred in ancient glasses.

## Towards the characterization of Galician wall paintings´ materials: construction of a material reference library

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**Project & aim.** Galician wall paintings are relatively unknown cultural heritage, as the few surviving murals have remained forgotten under the plasters of the churches since the 17<sup>th</sup> century. In order to sort out this situation, a project to study and preserve the wall paintings is currently ongoing. One of the aims is to characterize the materials of the paintings, shedding light on issues that are critical for art historians and restorers: *palette* of pigments used, pictorial technique, state of conservation and degradation processes. Thus, the first steps in this research have been the construction of a reference library of materials traditionally used as pigments and binders and the establishment of a protocol for the analysis of these materials in real samples.

**Experimental.** Firstly, historical treatises on painting materials and techniques, such as Cennini and Theophilus, were consulted to orientate the selection of materials that will constitute the library. Next, following the recipes found in the above said treatises, model paint samples were prepared on microscope slides plastered with a thin layer of lime mortar, using a variety of pigments, with both *a fresco* and *a secco* techniques. The *a secco* samples were then subjected to accelerated aging under UV light, to simulate a state of deterioration of the binders closer to that of the real murals. Afterward, pure pigments, extensions of pure binders and the paint mock-ups were characterized by means of a series of techniques: pigments by visible reflectance spectroscopy, micro Raman spectroscopy, FTIR spectroscopy and micro-XRD. Distinguishing among carbon-based black pigments was problematic, so some extra techniques were applied: morphology of the pigment particles was observed under high resolution SEM and the minority elemental composition studied by EDS. Finally, organic binders were analysed by FTIR, FID-GC and MALDI-ToF.

**Results and conclusions.** The reference library was built organising all the results obtained by the group of techniques above mentioned. The library has proved to serve as a useful reference for the characterization of the wall paintings from *A Ribeira Sacra*, a region in Galicia rich in churches and monasteries decorated with 16<sup>th</sup> century murals. Some conclusions have been reached:

- Paintings are complex, heterogeneous systems, so having reliable reference materials is a critical issue for a good characterization;
- Need of accelerated ageing of the models to reproduce changes in time undergone by real paintings, which are old and often deteriorated;
- Importance of combining different analytical techniques to reach an accurate identification of the materials;
- Working with microsamples is a challenge for the analyst: need of optimization, rational planning of the protocol of analysis, “recycling” samples, microdestructive techniques;
- The ideal trend would be to move towards portable, non invasive techniques (Vis RS, XRF, etc.).

**Characterization of stones and  
mortars as a tool in archaeological studies:  
the case of Castle of Naraío, northwest Spain**

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The Castle of Naraío (San Sadurniño, A Coruña, northwest Spain) is a medieval castle linked to Andrade's house dating from the fifteenth century and considered, since 1994, as a Cultural Property in the catalogue of monuments of Spanish Historical Heritage. Currently in ruins and abandoned, its restoration (which includes a viewing platform and interpretative center) will be finished in the coming years.

In the summer-autumn 2010, stones and mortars from this Medieval Castle were characterized by means of petrographical and chemical analyses in order to achieve technical and historical evidence of material production. Mortar samples were studied by optical microscopy (OM), and analyzed by X-ray fluorescence (XRF) and scanning electron microscopy - energy dispersive spectroscopy (SEM-EDS). The XRF and SEM-EDS data were useful to identify the four main construction phases involved. In addition, mineralogical and petrographic characterization of the stone samples allowed locating outcrops geologically compatible with the granite used in the Castle construction, which can be used in the restoration work.



**Evaluation of the reinforcing action of  
consolidating treatments applied on cement mortars using the  
micro-sandblasting technique**

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In the Cultural Heritage conservation field, one of the most challenging problems is the on site assessment of the state of conservation of natural and artificial stone materials and the evaluation of the performances of consolidating treatments. At present few portable methods have been developed to investigate the strengthening of consolidating products. Among these the Drilling Resistance Measurement System (DRMS) has showed the best results but, as other devices, the system exhibits instrumental and methodological restrictions.

This work is a feasibility study on the application of the micro-sandblasting technique for the evaluation of strengthening action of consolidating treatments applied to natural and artificial stone materials. This method has been widely used to determine the wear/abrasion resistance on metals, ceramics, roads and building materials (especially on cement mortar). The micro-sandblasting system is composed of a micro-sandblasting device and a micro-photogrammetry apparatus. The former creates a shallow crater on the surface operating at constant conditions (pressure of the jet, distance nozzle-surface), while the latter lets us quantify the volume of the crater through a 3D digital reconstruction. The micro-sandblasting method was applied to evaluate the strengthening effect, on cement mortar, treated with nano-silica and nano-lime compounds.

The results obtained were compared with three other methods, namely paper abrasimeter, peeling test and DRMS tests. The agreement between these methods and the micro-sandblasting were considered and the advantages and disadvantages were evaluated for the feasibility of this method in the field of conservation of Cultural Heritage. The work is a preliminary laboratory evaluation and a portable blast cabinet useful to apply the micro-sandblaster system on site is under development.

## **Technical aspects and materials of paintings on coffered ceilings using scientific test and analysis**

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Paintings on coffered ceilings spread from North to South of Portugal since the first quarter of the 17<sup>th</sup> century until as late as the beginning of the 19<sup>th</sup> century. This investigation concerns the use of paintings on coffered ceilings since its classical origins, considering particular interest in creativity and originality of techniques and materials achieved in Portugal. In this sense, it concerns not only the different techniques and materials used, but also formats and supporting elements on the ceilings.

The use of test and chemical analysis was crucial as they brought new information to techniques and materials employed in this artistic style. In the observation of samples through light microscopy for morphological stratigraphy, microchemical and histochemical tests were also performed, recognizing pigments and binders. Fluorescence energy dispersive X-Ray's (EDXRF) and photography techniques through ultraviolet light and infrared were done to some paintings to characterize pigments, varnish types and subjacent designs.

The specific case of Mannerist paintings on the ceiling of the former Salvador Convent's nave, in Braga, was examined, determining it to be one of the first ones to be made in Portugal. Among other case studies, we can highlight the Baroque paintings on the ceiling of the former Salvador Church of Ramalde's nave, in Porto, which revealed the authorship of an artistic company.

This investigation provides a better understanding of paintings on coffered ceilings, mainly in the North, and points out aspects which ought to be taken into account for their preservation and maintenance, as well as for better distinction of authorship and artistic groups in the future.



Figure. Paintings on coffered ceiling of the former Salvador Convent's nave.

**Cachão da Rapa prehistoric rock art paintings revisited:  
digital image analysis approach for the assessment of  
Santos Júnior's tracings**

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Cachão da Rapa (Trás-Os-Montes, Portugal) was the first rock art site described in the Iberian Peninsula (1706) and one of the pioneers in Europe. It is considered to be among the most original paintings in Iberian schematic rock art. Since the publication of its first tracings by Jerónimo Contador de Argote (1738), the site was referred to although not studied until 1933, when the Portuguese scholar Santos Júnior newly published a hand-made drawing of the pictorial remains. That monograph constitutes nowadays the most complete study of the site. Both Contador de Argote and Santos Júnior described a dichromatic rock art panel, designed in red and dark blue colours. This blue colour is unique in the Iberian rock art tradition. Although the importance of these paintings is well recognized by both the Iberian and international archaeological community, no further research nor documentation was undertaken.

This work presents a new approach to the recording of the rock paintings, based on the use of digital image analysis techniques, to assess the accuracy of the tracings currently utilised by the researchers (basically, Santos Júnior's work) and also exemplifies the possibilities offered by these techniques in order to perform low cost, low time-consuming and non-invasive tracings. Preliminary data obtained by digital image analysis emphasizing digital decorrelation of pixel values allowed us to reach good results for the delimitation of the red colours. The delimitation of the blue ones resulted more problematic as the spectral behaviour of both: blue motifs and supporting rock, was similarly pointing to the presence of the same elements over both the rock and the paintings. Further work will enlighten this issue.

## Benefits of applying spectroscopic techniques and chemometric methods to identify interaction between historic painting materials

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One of the main goals in Heritage Science is to characterize painting components and their interactions under diverse conditions to promote their conservation. This work is based on an overview of the analytical procedures to deal with problems that concern the field of art paintings. The approaches are based on the combination of spectroscopic techniques with multivariate statistical tools, particularly, principal component analysis (PCA). Chemometric evaluation of spectral data is well accepted as a powerful tool for different purposes, including sample identification and recognition. In particular, PCA is a powerful data-mining technique that reduces data dimensionality, obtaining more interpretable representation of the system under investigation. In the context of these studies, we present research performed applying PCA to Diffuse Reflectance Infrared Fourier Transform Spectroscopy (DRIFTS), Transmittance-Fourier Transform Infrared Spectroscopy (T-FTIR), Raman Microscopy (RM) and Matrix-Assisted Laser Desorption/Ionization-Time of Flight Mass Spectroscopy (MALDI-TOF MS) data from painting model samples (i.e. inorganic pigments, proteinaceous binders and tempera model samples). These studies were devoted to studying the ageing process of the proteinaceous binders when mixed with inorganic pigments and also to discriminate among samples according to different composition and possible interactions. Results showed an excellent ability of PCA on DRIFTS and first derivative Raman spectra to discriminate replica samples according to pigment chemical class and the presence of proteinaceous binder. In addition, PCA on first derivative Raman spectra allowed identification of slight changes in the characteristic C–H stretching region related to interactions between metal-rich pigments interacting with egg yolk binder. Regarding ageing processes, PCA performed on MALDI-TOF MS and T-FTIR data separately discriminated samples based on different UV-ageing states of proteinaceous binder, corroborating the photostabilization of the glue against UV irradiation and the additional photostabilization of the tempera when azurite is present (Figure).

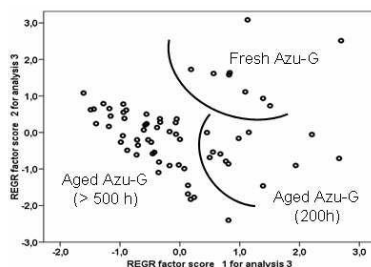


Figure. Scores plots for PC1 and PC2 of the UV-ageing of the azurite tempera model samples in the mass interval between 1760 and 2500 m/z.

## Study of degree of alteration of enamels using micro-ATR FTIR and SEM-EDS

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This work describes a non-destructive approach to the study of the state of conservation of colored glasses. Bronze horse harness pendants with red enamel decorations (14-15<sup>th</sup> century) were analyzed by Micro-Attenuated Total Reflectance (ATR) FTIR Spectroscopy and Scanning Electron Microscopy (SEM-EDS). The goal is to discriminate the role of specific compounds on the structure of the glass network and its relationship with the degree of degradation of glasses. Furthermore, the ultimate aim is to draw archeological conclusions to help clarifying the use of these horse harness pendants according to the raw materials and/or the quality of their manufacture.

In most cases, glasses are elaborated from different compounds (i.e. frit, opacifiers, pigments and/or additives) using specific melting and cooling methods to obtain specific properties. Both analytical techniques (i.e. ATR-FTIR and SEM-EDS) allow a deep and non-destructive analysis and also a compositional and structural knowledge of glasses. In particular, the IR profile between 700 and 1200cm<sup>-1</sup> varies depending on the different degree of polymerization of the silicate network. Thus, the study of slight shifts of Si-O stretching mode allowed the assignment to different glass networks for these objects.

In addition, a detailed observation of ternary phase diagrams showed that some pendants were lead-rich, cobalt/calcium-poor while others were mainly manganese/calcium/potassium/sodium-rich and arsenic/lead-poor (Figure). According to the literature, a high PbO content increases the degree of the depolymerization of the silicate network; it could increase the sensitivity to alteration processes in glasses, corroborating the degradation of the red enamels with higher PbO content. Consequently, surface weathering could be produced and hence, ionic exchanges might explain the low alkali and alkaline earth metal contents of some pendants. These facts could suggest a low production cost and consequently, poor quality glasses. A manufacture without controlling the atmosphere was also recognized thanks to the presence of copper as oxide.

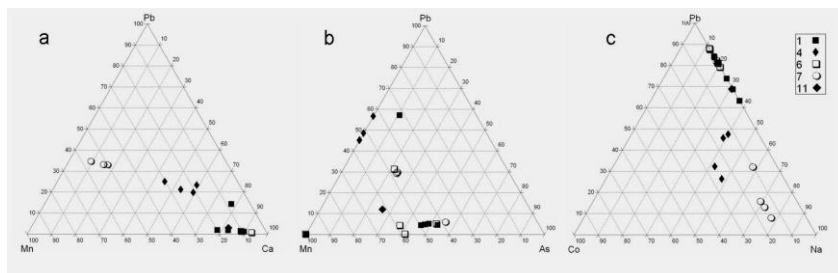


Figure. Ternary phase diagrams of red enamel of horse harness pendants

## Color studies in cultural heritage: colorimetric techniques applied to early detection of biological colonization

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Cleaning is an important aspect of the maintenance and rehabilitation of stone buildings and structures. Colonizing microorganisms contribute substantially to the fouling of buildings, which causes aesthetic as well as physical and chemical damages to the building materials. As biological colonization of outdoor-exposed surfaces is inevitable, it is important to detect the moment at which the colonization begins, so that it can be dealt with as early as possible to avoid irreparable damages. In the case of maintenance work, in which the elimination of biological colonization is almost always necessary, a suitable methodology for monitoring the efficiency of cleaning is required. To date, this has been done either visually, which may produce misleading results or by use of traditional methods of microbiological analysis, which involve sampling (often impossible to perform because of the historical and artistic value of the object) and arduous and costly laboratory work. Therefore, this research proposes a color measurement-based method for quantifying the colonization of stone structures by phototrophic microorganisms such as algae, cyanobacteria and lichens (all colored microorganisms that commonly colonize buildings); the method is rapid, cost-effective, non-destructive and can be applied directly to buildings and structures.

To achieve this main objective, specific research objectives related to the measurement, representation and discussion of the color data were established in relation to the two elements involved in the study - granite rocks and phototrophic microorganisms (cyanobacteria) - and the interactions between these. The best conditions for measuring color in this context were determined during the development of a methodology for color measurement and characterization of the granitic rocks [1] and cyanobacteria [2], and fine-tuning of the method of extracting chlorophyll-a, a biomarker for quantifying phototrophic biomass, from rocky substrates [3]. The methods have been successfully applied to real cases of biological colonization (epilithic phototrophic biofilms) on granite buildings [4].

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## **Consolidation treatments for conservation of concrete sculptures**

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Since the mid-20<sup>th</sup> century many artists use cement as a material in their projects. Currently, some of these works show evidence of decohesion which requires an adapted response to each case. Proposal and validation of consolidants for cement mortar or concrete, adapted to the international recommendations on conservation and restoration of heritage, have been little discussed in scientific literature.

The aims of this paper are to study the consolidant-cement paste interaction and to test the effectiveness of some consolidants for Portland cement mortar or concrete adapted to the international recommendations for intervention in cultural property.

For the development of this study several cement paste and mortar specimens were prepared. Mortar was elaborated with a cement/sand ratio of 1:5. The standard sand was sieved in order to obtain a fine-free sand ( $\Phi \geq 1\text{mm}$ ) which helped to increase the mortar porosity. The consolidants used were the tetra-ethyl-ortho-silicate alone and blended with  $\text{Ca}(\text{OH})_2$  nanoparticles in 4:1 ratio. They were both applied by impregnation.

The structural evolution of the consolidants along the time and at different relative humidities was followed by Infrared Spectroscopy (ATR). The structural modification of cement paste by consolidants was also followed by ATR. The modification of the properties of the mortar after the application of the products, such as water vapor conductivity, water absorption under low pressure, porosity, compressive and flexo-tensile strength, and changes in color and brightness were also studied.

The results show that these consolidants reduce hydric properties of the material significantly and increase its mechanical strength. Color variations produced by the consolidation action are below the limits of perception.

Both consolidants are adjusted to the principles for the intervention of artistic heritage. However, some particularities in their effects could tackle specific requirements of the cultural heritage.

## Thaumasite formation in hydraulic mortars: thermodynamic studies

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Thaumasite is formed as a result of the reaction between sulfates and carbonates, and the calcium silicate hydrates present in old and new hydraulic mortars. It is well known that thaumasite formation is more prevalent in mortars exposed to low temperatures, high humidity and environments with high sulfate contents, as well as mortars made with limestone aggregate. To date, science has not addressed the question of aggressive solution composition (i.e. pH, portlandite and cation) that might explain damage observed from thaumasite formation.

The present study aimed at ascertaining whether pH, type of aggressive solution and mortar composition may further thaumasite formation. Thermodynamic modelling results (PHREEQC program) have been faced to evaluate the potential risk of type of solution in thaumasite formation in cement mortar. On order to avoid sulphate attack, ligands with less aluminates (CEM I SR) as well as 10% addition of pozzolanic materials (Silica Fume) have been used in mortars preparation, plane OPC (CEM I) being used as reference. Samples were immersed for 1 year in the following aggressive solutions:  $\text{CaSO}_4$ ,  $\text{MgSO}_4$  and  $\text{Na}_2\text{SO}_4$  with 1500 ppm of sulphates.

Thermodynamic results indicated that all solutions will be in equilibrium with thaumasite. Additionally samples immersed in  $\text{MgSO}_4$  solution will be also in equilibrium with magnesium silicate and magnesium silico-aluminate and different magnesium carbonates (i.e.  $\text{MgCO}_3 \cdot \text{Mg}(\text{OH})_2 \cdot 3\text{H}_2\text{O}$ ;  $\text{MgCO}_3$ ;  $\text{CaMg}_3(\text{CO}_4)_3$ ). However thaumasite was only formed over the surface of the sample CEM I SR exposed 1 year to  $\text{MgSO}_4$  solution as can be observed in the Figure.

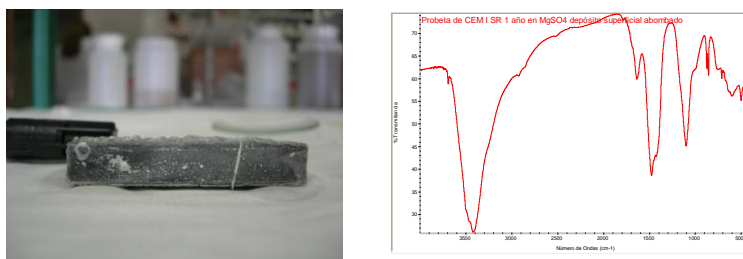


Figure. Sample CEM I SR 1 immersed 1 year in  $\text{MgSO}_4$  (1500 ppm) solution.  
FTIR analysis of the formed salt.



## **Permanent antigraffiti for artificial construction materials: lime mortar and brick**

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Lime mortar, a traditional pointing and rendering material that fell into disuse when Portland cement started to be produced, is nowadays regaining attention thanks to the restoration of historic masonries, such as brick walls. Both lime mortar and brick, artificial construction materials, are susceptible to a new weathering phenomenon, graffiti, which has led to the development of new protective treatments, the so-called antigraffiti treatments. These coatings prevent paint from penetrating the pore systems of the “attacked” materials or from adhering to the surfaces, since the removal of graffiti with traditional (chemical or mechanical) methods is not always successful and/or inevitably entails altering surface characteristics of the materials.

This study aimed at assessing the effectiveness of two of these antigraffiti protective barriers: a fluorinated commercial product and an organically modified silicate (Ormosil), both known as permanent treatments in lime mortar and brick. The research was based on the determinations of the physical properties, cleaning efficiency and durability of the treated construction materials.

The results showed that both treatments induced minimal chromatic variations (slight darkening and weak “yellowing”) in the surface of the construction materials tested, however Ormosil was a better long-term water repellent for its greater capacity to fill the pores in the materials, significantly reducing the saturation coefficient and the amount of pressurized water absorbed. This enhanced resistance to freeze-thaw cycles while lowering water vapour permeability.

The degree of cleaning attained after spraying the specimens with three synthetic enamel paints and cleaning them subsequently four times was satisfactory (no visible traces of paint) for the brick, particularly with the fluorinated antigraffiti (Protectosil). On the other hand, lime mortar resisted only one cleaning episode, which removed not only the paint, but part of the material surface.

**Nanostructured products for the preventive conservation of  
the wooden supports:  
evaluation of their effectiveness and durability**

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For a long time, wood has been widely used in the Cultural Heritage field, such as painting supports, frames, stretchers and exhibition shelvings. Wood susceptibility to degradation, mainly due to its hygroscopy, has imposed a constant research on suitable methods and techniques for its protection. In that sense, nanotechnologies offer new research perspectives by minimizing the risks of historical collections' deterioration, preventing damages produced by environmental factors. The present study focused on testing some commercial nanostructured products borrowed from other industrial sectors (nautical, architectural, etc.) and measured the effects on different wooden samples -selecting the most common species at national level in the cultural heritage field- in order to evaluate their properties, their effectiveness and permanency after ageing. Specifically, products that offer UV-protection and water repellent properties to the wooden surfaces have been studied. For the research, non-invasive and non-destructive analytical techniques have been utilized, such as nuclear magnetic resonance (NMR) and spectrophotometry, suggesting a methodological approach for the control and monitoring of the nanocomposite coatings properties. The treated samples have been artificially aged in an accelerated weathering chamber in order to analyze the treatments behavior. The obtained data intend to offer a first contribution to the evaluation of the potential use of nanostructured materials in the conservation field. Raman measurements and SEM observations will be finalized for the characterization of the involved absorption regions.

## **Characterization and conservation treatment behaviour in brick masonry of the “Santo Cristo de la Salud” church (Málaga, Spain)**

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The façade, of the walls of the Church of “Santo Cristo de la Salud” in Malaga, Spain, as well as the drum of the dome itself, are made of brick. Within the integrated project for the conservation of the church, the restoration of brick masonry was planned. Many samples, characterized and treated with TEOS strengtheners and water repellents were studied in order to evaluate efficacy and alterability and thus select the most appropriate treatments.

The analytical techniques used in the study were: X-ray diffraction, X-ray fluorescence, petrographic microscopy, scanning electron microscopy (SEM), Hg injection porosimetry, hydric properties tests (immersion and capillarity absorption, water desorption), colorimetry, surface hardness and salt crystallization test.

Nine groups of conservation treatments were studied, three with strengtheners, three with hydrophobes and three which were first applied with a strengthener and then, a hydrophobe repellent from the same producer.

|                                 |                          |
|---------------------------------|--------------------------|
| Strengtheners                   | Wacker OH                |
|                                 | Tegovakon V100           |
|                                 | Estel 1000               |
| Water repellents                | Wacker 290L              |
|                                 | Tego XP 337              |
|                                 | Silo 111                 |
| Strengtheners + Water repellent | Wacker OH + 290L         |
|                                 | Tegovakon V100 + Tego XP |
|                                 | Estel 1000 + Silo 111    |

In general, the brick samples are all very similar, with a high content of metamorphic rock (phyllites, slates, etc.) and low content of calcite, including the bricks with the lowest firing temperature, which suggests a raw clay material poor in carbonates and with great amounts of gypsum in its composition.

Regarding the treatments, those that give the best results in the laboratory tests are Tegovakon V100 and Tego XP 337, both when applied alone and when combined.

**Design of gypsum-lime based mortars applied on  
the restoration of Mudejar heritage from Aragon (Spain)**

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The region of Aragon is one of the most important centres of Mudejar architecture in Spain, and has been a recognised part of World Heritage since 2001. It is characterised by the use of brick masonry with mortar-filled joints as the main building materials. With regards to the mortars, calcium sulphate based mortars with the addition of low proportions of lime were widely used not only for joints in exterior walls but also for the rendering and plaster decoration of historical buildings. Nowadays, these building materials are continuously exposed to different causes of deterioration making it necessary to establish a restoration program. The main goal of this paper is to design new gypsum-lime repair mortars compatible with traditional building materials in order to conserve the cultural heritage of this region.

Compatibility requirements for new repair mortar for restoration purposes were defined based on the reproducibility of the original mortar characteristics. As a consequence, different mortars were prepared by varying the binder proportions (gypsum/lime), the type of aggregates (quartzitic sand and alabaster gypsum) and the binder/aggregate ratios (nine different mixtures). A total of 162 new mortars were characterized in order to check their reliability. Since they were prepared following a systematic procedure and observing standards, the results indicated their suitability to be used in building restoration plans. They were compatible and improved some of the properties of the ancient mortars.

Knowledge obtained provides practical information to establish a fitting mortar mixture for restoration repairs on Mudejar monuments and modern architecture where gypsum-lime based mortars is used.

## Old materials, new solutions

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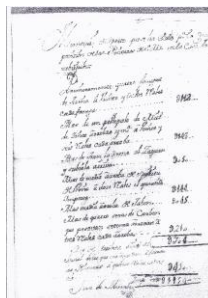
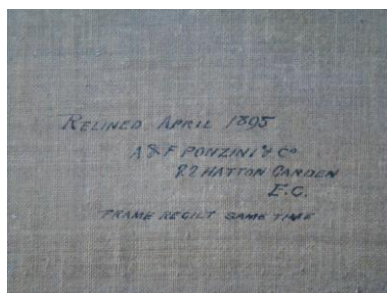
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The Project I+D+i “*Materials and Methods of Pasta Linings for the Reinforcement of Canvas Paintings: documentation, function and conservation*”, is funded by the MICINN and begun in 2012. It aims at conducting a comprehensive and scientific study of traditional “pasta linings”, linking theoretical and methodological aspects of a procedure that has evolved for over 300 years in Europe, to determine their effectiveness and suitability, advantages and limitations, even to suggest improvements and guidelines to preventive conservation.

To accomplish these objectives, a multidisciplinary team of international experts (from academic institutions, researchers and museums) representing the countries where pasta linings have been usually carried out, has been formed, such as the Mediterranean countries (Spain, Portugal, France and Italy), northern Europe (Denmark, Netherlands and United Kingdom) and the Smithsonian Institution (USA), that will participate in the structural tests. The different trends developed over centuries are compared and evaluated in terms of material variables, technical characteristics of paintings and environmental conditions of each country.

In this conference we present the first results obtained through the documental part of the study. In the first step, a desk study has been carried out, collecting recipes old and new, from the consultation of archives, treaties, bill of materials and reports of restoration, and data provided by restorers through questionnaires developed for research. A series of paintings treated by this procedure were examined in order to check their state of conservation. Also, a database has been designed, which has turned into documentary information. It allows searches and relational queries, and comparisons between the various recipes and procedures in order to obtain recipe models on which to perform aging tests and structural behavior in the second phase of the project, to determine the validity of these formulations.



## **Application of the double layer system as preventive method in the moulding process of sculptures and ornaments**

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The physicochemical properties of artworks of the Historic-Artistic and Cultural Heritage are modified by degradative environmental agents and biodeterioration. In many cases, the most effective action/intervention is the replacement of the work of art by a copy, moving the original into a museum or another more protected place. In general, the preventive conservation solution considers, among other practices, the moulding of the original and its reproduction by restoration mortars.

In this regard the study focuses, among other things, on the analysis and optimization of various substances used in the double layer system during the moulding process on various types of stones with different chemical and physical properties. This system is based on the use of harmless alkane hydrocarbon cyclododecane and involves the development of a novel method in the moulding of artworks. The study is controlled by physical-mechanical tests, natural and accelerated ageing tests (thermo-hygrometric and UV). The results are evaluated using specific advanced analytical techniques and control, and monitoring instrumentation adapted to works of art.

In short, this study extends aspects of the field of conservation and restoration of stone materials and, in the broader sense, sustainable in their application to other support materials.

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## Effectiveness of a new nanostructured consolidant on the biocalcarene from the Valley of the Temples, Agrigento

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A study of the effectiveness of a crack-free consolidant nanomaterial developed in the University of Cadiz was carried out for a biocalcareous stone from Agrigento (Italy). A nanostructured consolidant with hydrophobic properties was also tested.

The stone under study is a calcarenaceous shellstone mainly made by fossils, shells and fragment of micritic limestones cemented by calcium carbonate, with some clastic grains of subrounded quartz. This stone was generated in lower Pleistocene age [1]. This biocalcarene is the building stone of the Valley of the Temples in Agrigento, an archeological site of Greek age, dated between the 5<sup>th</sup> century B.C and the 6<sup>th</sup> century A.C..

The new nanomaterials evaluated were obtained by mixing a silica oligomer and a surfactant (*n*-octylamine) acting as pore-structure directing agent. In the hydrophobic product, an organosiloxane (polydimethylsiloxane) was also added to the starting sol. Details of the synthesis are described in our previous paper [2,3]. The consolidation was performed by spraying on 4cm<sup>2</sup> samples until saturation. Next, the specimens were transferred to open vials until constant weight. For comparison, other stone specimens were consolidated, under the same conditions, with three popular commercial consolidants: Tegovakon V100 (Degussa), Compatt (Vilo) and Nanoestel (CTS).

The effectiveness as consolidant of the products was evaluated by comparing changes in drilling resistance (DRMS) of the stones treated. Effectiveness of the nanomaterial by making the stone surface hydrophobic was evaluated by measuring dynamic and static contact angles, and water absorption by capillarity. In addition, negative effects of the products on the stone, such as reduction in water vapour permeability and changes in the colour, were also evaluated.

From the results obtained, we observed that the new materials developed in the University of Cadiz acted effectively as consolidant and hydrophobic products on the biocalcareous stone evaluated. By comparing with the commercial products evaluated, we observed a higher effectiveness for UCA materials than those corresponding to the commercial products.

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## **Technical studies for the restoration of the Immaculate Conception monument, Seville**

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The monument to the Immaculate Conception was opened in 1918, being constituted by an architectural pedestal made of yellow calcarenite, crowned by a figure of the Immaculate in Carrara marble and with four grey calcarenite sculptures at the base. In 2009 its restoration was carried out, mainly motivated by the state of conservation of the base sculptures, presenting fissures and fragmentation, loss of various fragments and decohesion of the stone.

The restoration has included a phase of previous studies, both documentary and laboratory, to determine the origin and characteristics of the two calcarenites used as it was necessary to replace some parts of the sculptures of the base, and to evaluate the effect of consolidants and water repellent treatments to be applied to the monument.

The four stone samples studied, two from the monument (IG, sculptures, and IA, pedestal) and two from quarries of Alicante (BA, grey, and BLL, yellow), were characterized by thin-section and XRD analysis. As regards the physical properties, porosity, porometry, surface hardness and color, the similarities are very marked, although the samples of the monument show a higher porosity due to deterioration that occurs and, therefore, a lower surface hardness.

The proposed intervention included the application of a consolidant (Ethyl silicate) in the affected areas and a water repellent (silicone) for the protection against the entrance of rainwater. To evaluate their effect, the treatments were applied to samples obtained from the monument and the quarry (only water repellent in this case). The color change, surface hardness and porosity, and pore size distribution were determined.

The result of the treatments is quite good: the color does not change significantly, as the porosity and pore size distribution, while the surface hardness increases. Finally all these results were used during the restoration of the monument.



## **Coastal heritage vulnerability in NW Iberia: implementing diagnosis and building solutions**

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Unlike other European regions, dedicated approaches to coastal archaeology and coastal heritage in Galicia (NW Spain) are not fully consolidated. The analysis of the human occupation of the coastal and marine environments has traditionally been done from a strongly terrestrial perspective, failing to address a series of relevant issues inherently connected to them. Among those, the question of coastline evolution and the implications it has for the preservation and management of coastal heritage was never perceived as a priority. Since June 2009 a research line on this subject has been launched at the Institute of Heritage Sciences (Incipit-CSIC) in Santiago de Compostela. A series of projects have already been initiated in cooperation with French colleagues from the Universities of Rennes1 and Rennes2.

As a result:

- Specific surveys of the coastline and the intertidal zone have been performed in Galicia's Atlantic Islands National Park (province of Pontevedra).
- A methodology for the vulnerability assessment of archaeological sites, based on the ALERT Project in Western France, has been applied to several areas of the Galician coast. Vulnerability scores have so far been obtained for 19 sites.
- Subsequent analysis of the survey results has led to specific action at certain sites. Near-object photogrammetry has been tested as low-cost monitoring solution on two archaeological sites. The excavation of one site at high risk is planned for summer 2012.

This research opens new perspectives in the way coastal archaeology and coastal heritage can be managed and understood in the region. We now need to extend the scope of the project to effectively involve local managers, associations and the wider public. This will be the only way of guaranteeing both sustainable research and management strategies for this coastal heritage.

**Documentation of modern architecture within Pernambuco,  
1930-1980: a railway station Caruaru**

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The article is a thematic focus of a larger study in the state of Pernambuco, in the capital and rural cities, from the research project entitled "Documentation of Modern Architecture in Northeast Brazil, 1930-1980." The project was accomplished through inter-institutional cooperation with the support of CNPq. Among other buildings, the study identified the existence of the railway station Caruaru both, as representative of the modernization of the architecture and development of Caruaru, that industrialization brought to the cities of the interior of Pernambuco. In this study, we analyzed the architectural and urban aspects, such as deploying the lot, building technologies, façade details, among others, and signaled their historical and cultural importance.

*Keywords:* Modern Architecture (EP), Industrial Architecture.

## Contributions of GIS and spatial analysis functions in the characterization of painting surface damages

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### Introduction

Geographic Information Systems (GIS) are computer applications designed to "capture, store, analyze and visualize spatial information". Their use in the study of canvas's surface through their photograph records produces analytical graphic documentation, providing qualitative and quantitative data about all the represented elements. This makes possible to precisely define the extent of the damages registered in the painting.

### Methodology

To obtain quantitative data about the deterioration present on a pictorial surface, GIS technology uses a simple vector drawn damage map. However, unlike the graphics and image editing software used up to now for graphic documentation, this allows us to project the real dimensions of the painting and its material alterations by Cartesian coordinates. Because of this, we can easily calculate the areas of the display elements, and operating with such information, also the percentual reach of any recorded pathology.

### Results

Exemplifying the results offered by this method of study, the analysis held on the missing areas of an oil on canvas will be detailed: The Holy Family of the Palau Ducal dels Borja. In this work, its loss percentage could be set at 9.82%, being the 4.63% due to losses in the canvas support and the remaining 5.19% due to missing paint and gesso areas.



Fig.1: Projecting *Holy Family* real size above its photograph.

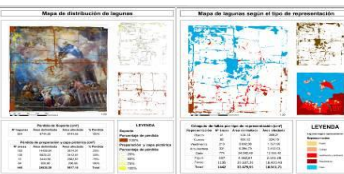


Fig.2: Distribution of the *Holy Family* missing areas according to the affected layer (left) and the type of iconographic representation (right)

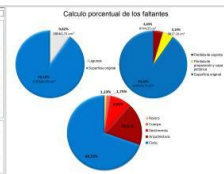


Fig.3: Percentage description of the tears reach

### Conclusions

GIS technology allowed us to deepen in the characterization of Holy Family damage, quantifying it numerically and calculating its expanse in percentage terms. This information, so far out of reach of a restorer, is crucial to limit the subjective component of pathologic diagnoses enhancing their accuracy, and, therefore, to optimize the management planning of any restoration process.

**Predictive Model for the useful lifetime of  
a set of buildings of the Archdiocese of Seville**

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Current predictive models related to the determination of the life of heritage buildings, including the recent norms, ISO TC59/SC14 "Design Life", and ISO 15686 "Standards on Service Life Planning", fail to resolve the uncertainty associated with the various statistical methods involved.

In order to progress on this issue, in the proposed paper, the Fuzzy Building Service Life (FBSL) model is presented. This new model, implemented under XFUZZY 3.0 software, predicts the useful lifetime of a set of heritage buildings with homogeneous usage characteristics and applies the theory of fuzzy logic to a hierarchy of factors provided by an interdisciplinary team.

This FBSL model has been applied to a sample of fifty buildings of the Archdiocese of Seville (Spain) to test its validity. The correlation demonstrated between the planning for the life time estimated of these buildings as developed from this application, and that generated from the direct assessment carried out by different experts, leads us to conclude that the presented model constitutes an evidently useful decision-making tool for competent authorities, inasmuch as its application to a wide range of buildings enables the evolution of their deterioration over time to be determined.

**Risk analysis in historical cities:  
the cases of Carmona and Estepa (Seville, Spain)**

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The degradation of monuments is mainly due to the deterioration effects caused by structural damages, weathering affection, pollution agents and anthropogenic factors. Intensity of degradation may be worsened by the vulnerability of each monument. RIVUPH is a project of the Andalusian government based on the analysis of environmental risk in Historical cities in order to develop conservation strategies and policies. With this purpose Risk and Hazard maps of different towns are being building with GIS software. The aim of this work is the application of this methodology to the cases of Carmona and Estepa (Seville, Spain).

Each hazard has a given frequency and intensity in the Historical cities according to their environmental conditions. The frequencies and intensities of hazards have been determined utilizing a scale of five levels in both historical cities. These hazards have been weighted by values obtained using a Delphi methodology. Three different maps have been carried out for the analysis of structural, environmental and anthropogenic damages. The vulnerability analysis was developed according to the monuments conservation degree. The final risk map was obtained as a combination of the three hazards maps and the vulnerability analysis.

The conservation degree of monuments and the static-structural hazards, related to ground stability problems, set the main risks of the monuments in the Historical Cities of Carmona and Estepa.

Analyzing the risks maps is a very useful tool to identify, evaluate and prioritize the restoration of Cultural Heritage and the budgets of both cities and to forecast the preventive conservation policies. Other Historical Cities as Cadiz, Seville and Ronda are now under Study in the RIVUPH project.

*Acknowledgement:* This Project has been carried out thanks to the funds of the Junta of Andalusia Project RIVUPH (HUM 6775).

## Application of the characteristic parameters of colorimetric measurements as control elements of the conservation status of the Wood

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### Introduction / Aim of the work:

This paper is a methodological proposal for the study of altarpieces on wooden supports; the process was implemented to study the altarpiece of the San Antonio de Padua in Garachico, Tenerife. For this, we conducted a review of key aspects appropriate to the discipline of wood identification carried out by means of macroscopic and colorimetric analysis. For the evaluation of the state of conservation of wood the samples were subjected for the first time to colorimetric measurement. Parallel and complementary, we have created an *online* database to provide information for conservation professionals about the geographical location of the cultural property studied.

### Essential results:

1. The parameter "L\*" or clarity was set as the most important criterion, especially when carrying out control over future photodegradation.
2. Spectral reflectance curves indicate the features present at the time of measurement in terms of brightness and hue of the wood. Based on these, future changes in the depth and shape of the reflectance spectrum could be interpreted as changes in the brightness and hue of the wood respectively.


|  |   |
|--|---|
| Objeto de estudio:   | RETABLO DE SAN ANTONIO DE PADUA, HACIENDA PARTICULAR EL LAMERO, GARACHICO, TENERIFE.  |
| Ubicación actual:  | Facultad de BBAA de la ULL  |
| Ubicación habitual:  | HACIENDA PARTICULAR EL LAMERO, GARACHICO, TENERIFE.   |
|  |   |
| Muestra nº:  | 1   |
| Lugar de extracción:   | Espiga de la Columna central. Lado del Evangelio. 1º cuerpo.  |
| Motivo de extracción:  | la basa ya se encontraba separada de la columna y la espiga fragmentada, por lo que obligaba a restituirla para una óptima sujeción.  |
| Nombre científico:   | Quercus spp.  |
| Familia Botánica:  | Fagaceae  |
| Nombre vulgar:   | Roble   |
| Distribución geográfica:   | Existen limitaciones en la identificación macroscópica de los robles (Quercus sp.) donde muy raramente se llega a la especie con la descripción anatómica solamente, por lo que toda información sobre procedencia, nombre común, país o región geográfica es importante para la determinación. CARRERAS, R. Identificación de las principales maderas usadas en muebles de estilo. |
| Uso y características:   | Madera pesada, compacta y dura. Responde con elevadas deformaciones a los cambios de humedad. Degradación propia del secado, con tendencia a la aparición de fendas. Se encola con facilidad.   |

Figure. Example of the georeferenced database

### Conclusion:

1. The new control points can serve as a standard for monitoring the successive processes of restoration with a georeferenced database (=geolocated) in geographical space and chronologically.

The database contributes to apply global trends of ICT in the new information society and knowledge, which helps social, cultural and economic support for sustainable development.

## **The significance and social value of cultural heritage: an ethiopian perspective**

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The cultural heritage of Ethiopia is closely associated to the discovery of valuable artefacts ensuing today, not only in a lively religious tradition, but also in intense scientific research on the evolution of mankind as well. Concomitant to this is the fact that eight of its nine heritages in UNESCO's world heritage list are cultural. Like many African countries, where development schemes are beginning to give due emphasis to heritage, questions relating the significance and values of cultural heritage have become essential components of the utmost priorities of the general discourse over the subject. In recent times, the heritage industry has developed noteworthy economic potential though several scholars have begun to question the impact of the commodification of heritage on the integrity of custodians and their cultural traditions. In this paper, the author makes an appraisal of the significance and value of cultural heritage in Ethiopia and attempts to assess emerging orientations relating to the subject by illustrating the invention or re-conceptualization of cultural heritages and traditions in the country.

*Keywords:* Ethiopia, Heritage, Cultural heritage, Heritage industry

**Andalusian culture preservation and  
spreading through Flamenco:  
intervention through documents and posters**

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In 2010, Flamenco was recognized as Intangible Cultural Heritage by the UNESCO, a fact that revives the value this artistic manifestation has and that, since it could not be otherwise, reinforces Andalusian identity and culture. Therefore, we defend that Flamenco heritage should be studied, preserved, investigated, promoted and spread as a singular element within Andalusian Cultural Heritage and, since the date above mentioned, World Heritage.

The first flamenco folk club recognized in Spain, “La Platería”, founded in 1949 in Granada and which gave way to the great folk club movement in Andalusia, the rest of Spain and some other areas abroad possesses a very interesting collection of posters, photographs and original pictures dated from 1922. These documents contain some important technical, social, economic, political and aesthetical information, but it is mainly due to its documentary and historic value that it should be preserved. The collection presents some problems in its conservation due to the nature of their materials, the manipulation and the changes in location they have suffered. In addition to the restoring intervention, we consider quite important the design of the exhibition and storing systems adapted not only to those documents but also to the available places for their proper display, as in this case the folk club itself has become a cultural and exhibition centre, where the sense of recovering posters is contextualized with the experience of live Flamenco.

The intervention of this collection will give back those formal characteristics to those documents whose preservation implies an evident damage for their immortality. With this research we will also try to highlight the value of this collection as a source of learning about Andalusian Heritage as well as about Flamenco history through the exhibition and spreading of those restored works helping its preservation so that our future generations could enjoy them.



## **Significance and social value of thermal Roman Heritage in Hispania Baetica**

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**Aim of the work.** In this paper we want to present a study about the real state of roman baths in the current region of Andalusia (Spain). In this area, mainly corresponding to the region Baetica (Hispania), there are no general works about this building typology, despite the proliferation of studies on thermal Roman Heritage in many areas of the Roman Empire.

**Essential results.** The study of archaeological reports and the administrative restoration reports of the Junta de Andalucía have revealed the existence of a large number of roman baths, more than 75 examples (many of them belonging to Roman villas).

**Conclusions.** This ignorance about this not well-known heritage is increased as a result of the low level of conservation interventions that have been made in such buildings by the competent local government; ignorance of the singularities and the importance of these baths being precisely one of the many reasons for the limited interventions. In this paper, we propose that the construction studies of Roman baths and the application of their local peculiarities in enhancement processes should be the argument to support restoration and conservation actions in order to increase the social value of thermal Roman Heritage.

Because of the international dimension of this Congress, we consider it is a key opportunity to exchange views and experiences with specialists from other geographical areas with experience in the subject, in order to improve the constructive Interpretation for the dissemination and enhancement of thermal heritage sites in restoration processes, a researching project proposal we pretend to develop at the Academy of Spain in Rome during 2012-2013.

## The Tarragona Wall, from repair to Director Plan (1986-2012)

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*Working teams that participated in the wall:*

**1986:** Ramon Aloguin, architect, Generalitat de Catalunya

**1989:** Andre Bruno, Universidad de Padua

**1990-1991:** Taller Escuela de la Muralla (Wall Workshop-school), Alejandro Bermudez (archaeologist), Pau Arroyo (restorer), Joan Menchon (archaeologist), A. Álvarez (geologist), J.L. Prada (geologist), Eustaqui Vallès (restorer)

**1991-1994:** Taller Escuela de la Muralla (Wall Workshop-school), Jaume Costa (architect), Pau Arroyo (restorer), Joan Menchon (archaeologist), A. Álvarez (geologist), J.L. Prada (geologist)

**2002:** Restoration of the *Paseo de ronda* Baixada del Roser, R. Mar (architect) and A. Abelló (Heritage technician, Ajuntament de Tarragona)

**2002-2003:** Restoration of the paseo de San Antonio and Matadero. Jaume Costa (architect, Generalitat de Catalunya), Pau Arroyo (restorer), Joan Menchon (archaeologist), J.L. Prada (geologist), UPC (photogrammetry)

**2005-2006:** Restoration of the roman stretch *paseo* Sant Antonio, X. Romaní and M. Olivé (architects), J. Menchon (archaeologist), Némesis (excavation works)

**2007:** Wall Director Plan, Joan Figuerola, Joan Gavaldà, Jordi Romera (architects), Joan Menchon (archaeologist), J.L. Prada (geologist), P. Arroyo (restorer)

**2009-2010:** Restoration of the *del Socors* Gate. Joan Figuerola, Joan Gavaldà, Jordi Romera (architects), J.A. Adell (work direction)

**2009:** Intervention on the *del Rosari* Gate (I. Teixell, archaeologist).

**2010-2011:** Restoration of the stretch Bajada del Rosario (stage 1), Joan Figuerola, Joan Gavaldà, Jordi Romera (architects), J. Menchon (archaeologist), Némesis (excavation works).

**2010-2011:** Restoration of the stretch Huerto del Arzobispo (stage 1), Joan Figuerola, Joan Gavaldà, Jordi Romera (architects), J. Menchon (archaeologist), Némesis (excavation works).

A critical and diachronic vision of the interventions in the Tarragona Wall is given. The main problems are: exceptional age (200 BC), complexity of building stages, degradation of construction materials, removal of the original filling (adobe) and later refilling with earth; colonization of the interior, leaks that led to up to 5 collapses between the 19<sup>th</sup> and the 20<sup>th</sup> century, and the location in a living historical centre with town-planning problems, traffic, wiring, public adornment, etc.

In the 19<sup>th</sup> century “restorations” and repairs were undertaken and in the 1930s Jeroni Martorell presented the Wall global recovery, with two basic items: the Paseo Arqueológico urban development and the internal reinforcement with concrete arcades. The 1960s and 1970s actions by A. Ferrant were the ashlar substitution in the sea area. In the 1980s a controversial test of brick masonry restitution was presented. Between 1991 and 1994, the Taller Escola de Restauració de la Muralla - TERM (Wall Workshop-School) already acted in an interdisciplinary manner (archaeologists, architects, geologists, biologists, etc.) that established the methodological development guideline and that crystallised in 2007 with the Director Plan.

Even then, questions like the Wall stability or the emptying or not of the interior bring a debate to be solved at a technical and conceptual level, without forgetting the consideration of the wall dermis solutions (brick? stone scale? masonry? etc.).

**Review of conservation/restoration interventions:  
effects on the Roman archaeological site of Mérida (Spain)**

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Nowadays all experts involved in conservation of cultural heritage have to deal with the issue of past and even relatively recent restorations, where application of criteria and methodology still lack a deep scientific research. Restoration, as everything else, has changed according to fashions related to the release of new products and technologies. Concatenation of different treatments on the archaeological remains surface and the lack of monitoring procedures, besides the fact that the remains are usually exposed to weathering conditions, lead to an unpredictable number of damages that contribute to the general degradation of the materials and even the whole site. Some efforts have been made to solve this problem in the architectural field, where functional needs and technical requirements force evaluation measurements. However, archaeological sites, unlike historic buildings, have certain features that preclude the extrapolation of results. Research in stone conservation has also a long tradition in identification of pathologies, mechanisms of degradation and development of treatments. Nevertheless, the effects of some of those treatments in the mid- and long-term are still poorly known.

Taking into account the above mentioned considerations, specific goals on the first stage of the project are:

- Review of conservation/restoration interventions and treatments applied to the archaeological heritage throughout the twentieth century and during the early years of this century.
- Development of methodology (products and techniques) within different archaeological sites of Merida.
- State of the art related to evaluation of treatments, and decay arising from application of those treatments, focused mainly on porous inorganic materials. Most studies are focused on architectural heritage, few of them on *in situ* archaeological heritage.

On the basis of this previous research we will be able to state a second phase of research in order to determine the effects of the interaction of restoration products on the original substrate, and evaluation of their effectiveness and durability, and on the other hand a deeper study of compatibility between old and new treatments -the problem of re-treatability still lack from deep research-.

The R&D groups in which this project falls are:

- Analysis and Intervention in Architectural Heritage (AIPA, UPM);
- Applied Petrology for Heritage Conservation Research Group, Geosciences Institute (CSIC-UCM).

Excavations in the Roman city of Mérida began in 1911 and first restorations were performed in the early 30's, with the anastylosis' project on the Theater. In this case study we can count with an evolution of criteria, techniques and products, thus a wide range of analysis' cases, many of them on building structures (stone and mortars) as decorative elements (mosaics and wall paintings mainly), key subjects for laboratory tests. The multidisciplinary work of archaeologists, restorers, architects and geologists in this project will ensure competent outcomes.

## **New experiences in the Historic Preservation University Education**

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The current tendency in construction is oriented towards the recovery of existing buildings in the historic centres of European cities, particularly in Spain. In addition, the recent interest in linking the construction industry with a sustainable architecture, making the most of the existing building and at the same time controlling excessive growth of its cities, converts the field of building rehabilitation into a professional field and a growing force.

In this context, five years ago, the Alfonso X University of Madrid, created a postgraduate course to complete the training programmes of related studies: Architecture and Technical Architecture, which treated the subject as a tangential option of little depth, resulting in two different realities: the first, a high-level theoretical training with little practice in the uniqueness of this type of work and the second, a course dealing closely with simple professional hard work, lacking in theoretical and historical base to support the reasons for requiring unique treatment. The Master's Degree in "Rehabilitation, Maintenance and Restoration of Buildings" proposed by the UAX, sought to remedy both deficiencies, trying to train professionals to meet both demands and needs.

After five years of the programme, we had the participation of a total of 70 teachers, among which, the barrier of academic training and work experience dissolved. They trained a total of 130 students, including architects, building technicians and engineers, from all over the country. Those who have experienced the new methodology proposed by the Masters based the direct application of knowledge to their professional reality, bringing them closer to both the academic and professional.

This paper collects the work of this group of professionals who have experienced a different way of approaching training in this field, and through it have offered attractive rehabilitation projects of many different issues and approaches from different professionals often cooperating with each other, as well as a universe of research on specific topics somewhat forgotten. They gather much of the current landscape of this activity in our country, and have the methodology and the common seal of the programme, a truly remarkable profession facing such important as the Rehabilitation of Architecture with a look toward the future.



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# C U R S O S   E   C O N G R E S O S

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Because European Cultural Heritage is an invaluable legacy, the Ministry for Science and Innovation funded the Spanish Network on Science and Technology for the Conservation of Cultural Heritage (TechnoHeritage), which began its activities in March 2011. Currently seventy five groups participate in the Network, including Spanish National Research Council (CSIC) and Spanish universities teams, cultural institutions, foundations and museums, and private companies. One of the activities of the Network is the organization of annual meetings. This International Congress—organised on behalf of TechnoHeritage by the Universidade de Santiago de Compostela— has a goal of creating an interdisciplinary forum for discussion on all aspects of cultural heritage conservation while providing an up-to-date and comprehensive picture of the state-of-the-art investigations in this field.

