5th International Conference
YOCCOCU 2016
Youth in Conservation of Cultural Heritage
5th International Conference

YOCOCU 2016

Youth in Conservation of Cultural Heritage
This publication presents some of the papers from the YOCOCU V International Conference (YOuth in CONservation of CUltural Heritage), held in Madrid, in September 2016 under the auspices of the Museo Nacional Centro de Arte Reina Sofía Department of Conservation–Restoration, the Instituto de Geociencias (CSIC–UCM), and the YOCOCU association.

The purpose of the conference is to promote intergenerational exchange and support the participation of young researchers in the conservation and study of cultural heritage. The main themes of the conference were subsequently compiled for publication as a way to make the discussion available to all who might be interested.

The 89 selected articles, representing more than 241 authors from more than 114 institutions and 19 countries, offer a glimpse into the enormous diversity of conference attendees. International participants came from Africa, the Americas, Asia, and Europe and from institutions as varied as the Istituto Italiano di Tecnologia, the University of Isfahan (Iran), Univerzitet u Novom Sadu (Serbia), and Universidad Autónoma Metropolitana (Mexico).

The selected papers reflect a broad range of cultural heritage conservation, from landscapes to time-based media art, including traditional and contemporary manifestations of material culture and intangible values managed by public and private institutions. The scope is addressed by the multidisciplinary approach often found in conservation–restoration practice, covering cases of nondestructive material analysis; technological innovation applied to intervention, diagnosis, and documentation; networks of shared scientific knowledge; outreach; education; and heritage at risk.

A forum for the exchange of experiences, the conference proved to be an exceptional opportunity for engaging new generations of conservator-restorers in sharing and enhancing recently produced knowledge. The goal of this initiative was the dissemination and debate of conservation practice as a strategy to preserve heritage for the future.

Last but not least, we acknowledge the generosity and continued support of the conference participants in preparing their results for publication, and to the organization board who made this project possible.

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CONTEMPORARY ART & ARCHITECTURE
Nowadays Matter Does Not Matter!

INTRODUCTION

Throughout the history of restoration, there has always been an intense debate between form and matter; that is, a dialectical discussion about the primacy of the image over the historic authenticity of the physical, material structure. According to Benedetto Croce’s (1866–1952) idealist theories, which were later followed by Cesare Brandi (1906–1988), the work of art used to be identified with the finished physical object. Brandi’s Teoría del Restauro has been one of the most influential works on heritage conservation theory since it describes how, for a work to be acknowledged as such, it must satisfy the material requirement, the physical state of the work.

THEORETICAL REFLECTION

The authenticity of an artwork used to be based on the matter, the physical material, used to create it and that transported the viewer to a previous period. The theories that sustained the fundamental value of matter arose mainly in Italy, where cities are the scenery of the past, and the value of art is identified with history and with inherited cultural identity.

Traditionally, matter has been fetishized, considered almost sacred, something that could not be altered because inside it resided the authenticity of the artwork, and the matter was considered original for its uniqueness and exclusiveness.

Nowadays, this makes no sense because art has become immaterial. Performance art, installation art, conceptual art, digital art, and process art are art forms in which matter no longer matters. Then comes the rub: the need to rethink the theoretical foundations of the profession of restoration.

We can no longer perceive the value of history in an object that has not been made by the hand of the artist. On the contrary, the work might have been created based on a design generated by software, with precise measures and exact colors, then later reproduced by a machine or mass produced. The elements used in creating a piece of art today are often bought at a market or industrially manufactured, losing in this way their “aura,” (as explained by Walter Benjamin in 1936).

The “creative” gesture of the artist no longer intervenes in the process of making the artwork. Therefore, what can stop it from being reproduced, remade, or reprinted again and again?

In those works of art that are no longer “autographs,” authenticity does not reside in some original matter but in an idea, in the intention with which it was created.

Art today is a different kind of communication. No longer a formal representation of reality, it goes further: it transmits, communicates, provokes, and, above all, creates experiences. For this reason, if the material out of which the piece of art was created ages, breaks, or gets dirty, the art stops “working.”

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Hiltrud Schinzel talks about recuperating Kunstwollen (artistic willpower), an idea previously explored by Alois Riegl (1858–1905). In the same way, the phenomenology of Edmund Husserl (1859–1938) brings us closer to the experience, emotion, and sensations that art has to offer, aiming to recover the intention of art, and rescuing the sentiment, the thought, and the willpower, and differentiating between authenticity and originality.

We should be conscious of the immateriality of art today, as well as the superiority of ideas and the artistic intention as fundamental values. This requires a new methodological approach to the conservation of art. For this reason, conservationists must work in an interdisciplinary way to identify not only the matter but the symbolic meaning of the material, the artist’s intentions, and the conceptual aspect of the work.

The material fetishism should be dispensed with, as stated by the Italian philosopher Massimo Carboni, who maintained that the most important issue in contemporary art is not the material but the conceptual and symbolic message.

On the other hand, for Theodor W. Adorno, art (including music) is more than matter and form. Adorno also noted the social character of contemporary art.

In Cesare Brandi’s Teoria del Restauro, in order to be an artwork, the image needs to have a specific matter. However, in contemporary art the image is a purpose itself, independent of the matter. For this reason the relationship between the meaning of the matter and the images in this new art, an issue overlooked by idealist theory, must be researched.

The symbolic value of the matter acquires greater significance in Arte Povera and readymade art.

But, if the matter loses importance in relation to the image, this raises the question of the difference between an original work and a copy.

We have become used to copies and even to perceive them as authentic. In some case, original works have been replaced by copies without people’s knowledge.

We belong to a visual society that uses images to communicate, images that are symbols of ourselves, an aesthetic of the seduction of images. Perhaps that is why we should think about how contemporary art parallels society. Design, colors, forms, images—these are what we see as a real.

In the case of manufactured works, the value of the artist’s intentions is very important, as well as the value of the original object as a carrier of its originality.

On the issue of the importance of the patina (the traces of time over matter), Carboni states that works of art in ancient times were conceived as an unchanging object that needed to be preserved and restored. Today, however, other artistic concepts are also important, such as transitoriness and the ephemeral.

Concerning Adorno’s aesthetic theory, Carboni questions how “the idea of duration of the work is modelled on his category of possession.” Carboni shows how contemporary art gradually loses its status as an object and tends to be a gesture of creativity, action, or process.

In this respect, we should talk about the resemblance of this type of immaterial art with dance or performance; that is, art without a physical, object-like support, which leads to the second question of whether we can preserve an action.

Beyond the importance of matter for contemporary art, the second question relates to the image of the art over the time, and how to preserve the original aspect of the artwork.

On the aesthetic quality of art, many philosophers have explored the relationship between the social role of art and the understanding of its meaning. This is one difference with the traditional theories. Nowadays there is a new way of thinking about the conservation of art, one that is more respectful of the creation process and the intention with which the art was created. But this change of attitude is possible only if society makes a mental effort to understand the intention and memory of art.

In relation to the conservation of contemporary art, maybe we must admit that the process of change is what we must conserve, like a methodology defined by dynamism.

At the Nara conference (Japan, 1994), a document was created that established a new attitude to authenticity. This document addresses the need for a broader understanding of cultural diversity and cultural heritage in relation to conservation in order to evaluate the value and authenticity of cultural property more objectively.

The thinking nowadays has shifted toward dynamic restoration instead of conservation with the intent to “freeze” the object: “Conserving the change is maybe the biggest challenge, for Contemporary Art restorers.”
CONCLUSIONS

Perhaps we should ask ourselves whether we want to preserve the archaeological relic of contemporary art, conserving its matter, or whether we want to “keep it alive.”

If restoration consists of preserving the authenticity of art, our mission is to recover the original intention for which it was created; that is, the desire to produce experiences, emotions, and, ultimately, the desire to make people feel more alive!

CURRICULUM VITAE

Carlota Santabárbara Morera has a degree in art history from the Universidad de Zaragoza, a degree in the conservation and restoration of cultural heritage from the Escola Superior de Conservació i Restauració de Béns Culturals de Catalunya, and a PhD in art history from the Universidad de Zaragoza.

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3 Schinzel, H., Touching Vision, Brussels, VUB Brussels University Press, 2004
INTRODUCTION

Rick Prelinger, founder of the Prelinger Archive,¹ said home movies are everything: enigmatic, undisciplined, evidence, surprise, unpredictable, endless, definitely astonishing. These films contain valuable information for many research areas. Home movies hold enormous potential as data sources and historical references for historians, anthropologists, sociologists, psychologists, archaeologists, and more (Fig. 01).

“A home movie is a film shot by a family member; its images relate in some way to the family history and are generally intended for the members of that same family. . . . All that matters is that the person holding the camera has chosen to preserve this object, this person, or this moment as part of the family’s collective memories.”²

The United Nations Educational, Scientific and Cultural Organization defines audiovisual heritage to include home movies among the audiovisual materials that should be preserved by film archives. The website of the Spanish Film Archive, however, demonstrates that this important part of our audiovisual history, one often captured in obsolete formats, has not been appropriately covered.

Fortunately, across Spain many proposals have been made to achieve (via a variety of means) a common goal of not letting home movies die.

METHODS & METHODOLOGY

The methodology used to create the Home Movie Network was not preset when the Memorias Celuloides team started to contact people involved with home movies in 2013.

The first step was to determine the situation of participating projects, their mission statements, expectation of the network proposal, and what commitment each was willing to make.
Next, we analyzed existing projects with similarities to the kind of network we wanted to establish: dFoto, Archivo Nazionale del Film di Famiglia, Center for Home Movies, archive.org, and Europeana.

Meetings were held so participants could present and discuss their home movie projects, with time allocated for each participant to show their achievements and make new proposals.

Between meetings, research work and relevant information was shared online via Google Drive and a private Facebook group.

Database development and website design were assigned to people with knowledge in those fields.

Finally, all measurable data from all partners was collected, allowing the success of each experience to be evaluated quantitatively.

RESULTS & DISCUSSION

The data-collecting phase is nearly complete. Based on preliminary assessments, the following can be stated:

Three meetings have been held. At each meeting, new initiatives were incorporated into the project. The network now has eleven active members.

At least two new initiatives were born after each meeting. In July 2014, the database work team launched a beta version (http://www.memoriasceluloides.com/) that will host all the information and home movies from each project in the network. In May 2015, the Home Movie Network was officially launched: http://www.redecinedomestico.com/. Many home movie collections have been recovered thanks to the efforts and information sharing of the network.

CONCLUSIONS

Despite economic, geographic, education, and technical differences, the project of creating a network to help people recover home movies has been a success. More work is needed to develop and polish the public interfaces, but the internal work, project spreading, and overall experience has been successful (Fig. 02).

The longer-term goal is for a platform that meets our needs better than other platforms, will gather any home movie recovery project, and will serve as a basic reference tool for anyone interested in the field.

Professionals from disciplinary areas with very different perspectives agreed to work together, which shows how valuable this heritage is for them and for humanity.

ACKNOWLEDGMENTS

The authors thank Pep Benlloch and Archivio Nazionale del Film di Famiglia for sharing their projects and experiences and give special thanks to Bill Brand for sharing his work and his energy and love for film preservation, which encourage promoters of this network to make it happen.

CURRICULUM VITAE

Clara Sánchez-Dehesa is a conservator of archival material. Since graduating from the L. Jeffrey Selznick School of Film Preservation, she has been working as a freelancer in Spain. A volunteer with various film archive projects in the United States, she started Home Movie Day Vitoria and is now developing the Rollos de Familia recovery project.

Salvador Vivancos is an art historian and visual artist who has been working on image and memory from various perspectives
since 2004. He is the founder of Memorias Celuloides, a project for the preservation of home movies.

BIBLIOGRAPHY


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1 Prelinger Archives was founded in 1983 by Rick Prelinger in New York City. In 2002, a collection of more than 60,000 “ephemeral” (advertising, educational, industrial, and amateur) films, was acquired by the Motion Picture, Broadcasting and Recorded Sound Division of the Library of Congress. The collection can be browsed on https://archive.org/details/prelinger&tab=about.

INTRODUCTION

This article reviews documentation models for born-digital art conservation but concludes that no universally applicable models exist (Fig. 01).

The need to update documentation models is clear since not all models consider aspects such as software and hardware obsolescence or provide options for unifying documentation and conservation efforts.

Art, far from retreating in response to the present “digital era” has embraced and been deeply influenced by it. This has led to new typologies in the contemporary art field:

- Digitized art (analog works that have later been digitized)
- Born-digital art (works that have a digital existence from the beginning)
- Analog art (mixed works)

The new, born-digital art presents new challenges for art conservation.

The apparently infinite possibilities of “digital” are often advanced as solutions to all “problems,” particularly those involving the archive. However, art conservation by digitalization and conservation of
digital art (which is digitally codified from its conception to its final born-digital form) are different things.

A key element in the conservation of these works of art, and the core of any conservation and preservation strategy for technology-based art, is documentation.

METHODS & METHODOLOGY

The bibliographic recompilation is supported by publications, doctoral thesis and on the diffusion of results from research projects published in conference proceedings, Internet sites, and research projects.

Critical analysis of extant conservation models—including Documentation and Conservation of the Media Arts Heritage (DOCAM), Variable Media Network (VMN), Variable Media Questionnaire (QMV), Media Art Notation System (MANS), Capturing Unstable Media Conceptual Model (CMCM), and Inside Installations and Matter in Media Arts—confirmed that the lack-of-applicability problem remains unsolved. With each model, conservationists must adjust their methodology for every use case.

Specific models explain how to seek the necessary information, how to describe it precisely, how to actively maintain works, and how to develop guidelines for care.

The main problem for preservationists is that the models must be adjusted for each case, since achieving a general rule entails great difficulty.

Conservationists must document numerous aspects of an artwork, including the artist’s intention and purpose (interviews), diagrams and technical details for the work’s assembly, instructions for the movement and installation of the work (including its ideal spatial conditions), and descriptions of how the piece behaves and is interacted with. Such details must then be combined with information gathered from reference texts and exhibition catalogues, taking into account migration options, media actualization, and reinterpretations.

In reviewing the documentation models, I assessed whether they considered such important issues as

- technological obsolescence (components susceptible to deterioration, such as USB and compact discs);
- technological progress (software actualization and new versions); and
- copyrights and licenses.

Conservation finds its targets not only in digitalization but, because of digitalization, is immersed in an endless war with its own media.

As a counterpoint to traditional conservation (which is oriented toward maintaining the work or documenting it in its original state), born-digital artworks must continually be modified and transformed to ensure they remain accessible and comprehensible. Documentation plays a major role here. Digital interventions affect the document and its description, and the continual intervention requires permanent funding, but an appropriate intervention policy can ensure permanence.

RESULTS & DISCUSSION

The four most commonly used strategies for born-digital art conservation are

1. Conservation of hardware (storing spare parts);
2. Migration (transferring data from one format to another);
3. Emulation (“simulating” original software behavior); and
4. Reinterpretation (transferring data from one storage medium to another).

Supplementary strategies may also be necessary. For example, conservators may need to preserve models, copies, and spare parts to ensure the artworks can successfully be emulated, transferred (migrated), and so on. Artworks might need to be “replicated”; that is, digital copies stored online, in standard formats.

The “analogization”: which implies betting for time sustainable items, like paper, microforms, and so on, and the digital archaeology: which forces us to wait until the future casual selection.

Each of these strategies has its own problems and limits.

Migration, emulation, and reinterpretation consider two basic actions in digital preservation, usually together. These are medium actualization and format migration. In both cases, precise documentation of the work is essential.

One final consideration is the storage of the information obtained from the documentation models, since that information will be transferred to other formats and other software and thus predisposed to suffer the same problems as born-digital art.

Projects have produced reference models for digital documentation; we present a relation of the ones,
under which guidelines or influences the current documentation models have been configured (Fig. 02).

One of the first initiatives to produce models for digital documentation of video art was organized by the nonprofit Electronic Arts Intermix (EAI), founded in 1971 and still active. Other ambitious projects have emerged since then.

Some of these documentation models present specific tools for technological art, others have holistic approaches (properties that must be analyzed as a whole) that are related to field conservation efforts, collecting, or cataloging.

The most relevant documentation models (and thus the objects of this research) are the tools and models of DOCAM, VMN, and QMV, the documentation system MANS (which was influenced by the earlier models and by CMCM), and the models of Inside Installations and Matters in Media Art. Figure 2 shows how the models are related to one another.

Critical analysis of the inspected models confirmed that the lack-of-applicability problem remains unsolved. The conservationist will have to adjust his or her chosen methodology to fit each use case.

Digital Art Conservation and the database ArtBase are two newer projects working to find new models and solutions. In developing the first of these projects (2010–2012), led by Bernhard Serexhe, questions of digital art conservation were analyzed from two perspectives: one theoretical and one practical. The theoretical perspective was used to develop a foundation for documenting born-digital art, and a separate documentation model was developed in response to the analysis of particular cases.

Using open-source XMind software, Serexhe’s team created an interactive, interdisciplinary, and updatable archive.

The Rhizome ArtBase database project, led Ben Fino Radin, is a pioneer in born-digital art data storage for preservationist purposes. The project suggests its archive be actively maintained to ensure universal access and to promote dissemination and mitigate obsolescence of born-digital artworks while respecting the artist’s intentions. The project is an expansion of the main mission of ArtBase, which is to use emerging technologies to support and promote art.

ArtBase has identified three important risks that preservation must address: dispersal (databases and works may exist in several places and on several platforms), data obsolescence (works or parts of works may depend on content from sources that are changed or updated), and physical deterioration (i.e., deterioration of components containing digital information).

Conservation of source code (i.e., the instructions a computer must follow to execute a software program) is a special case that requires continual re-creation.

ArtBase’s preservation methodology incorporates the use of automated scripts (to detect connections—such as hyperlinks—that no longer work) and crowdsourcing to detect errors.
CONCLUSIONS

None of the conservation models suggest alternatives for when the items (hard drives, DVDs, USB) that until now have been used to store the data obtained under their guidelines become obsolete, nor do they point out what type of operating system (software) would be the most recommendable in that sense.

We share the opinion that a software obsolescence solution could include the creation of a legal model supported by computer tools to simplify the distribution and use of public domain content.

The “dispersal” that ArtBase identified as one of the three main threats to born-digital art preservation may also be related to the warning that copies are practically indistinguishable from originals. That is, in migrating born-digital artworks (transferring data from one format to another) copies must be made, which means fully or partially modifying the originals.

Under current law, such preservation measures cannot be accomplished without committing a criminal offense. Reaching agreements with the artists of such works is therefore essential.

ACKNOWLEDGEMENTS

I thank my doctoral supervisor, Pilar Bustinduy, for assistance with this project.

CURRICULUM VITAE

Amelia Boogen Ybarra has a degree in fine arts, specialized in conservation and restoration of cultural heritage. She also holds a master’s degree in conservation and exhibition of contemporary art and is currently a predoctoral fellow at the University of the Basque Country.

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2 The DOCAM documentation model provides a frame that facilitates the organization of global information about a work, by concentration, categorization, and accessibility. DOCAM, http://www.docam.ca/ [26-08-2016].


4 The Variable Media Questionnaire, http://variablemediaquestionnaire.net/ [06-07-2016], can help register opinions and experiences (particularly for interactive works) about how to preserve works when their medium becomes outdated.

5 Media Art Notation System, http://www.bampfa.berkeley.edu/about/ formalnotation.pdf [26-08-2016]. This is a model with directions for the distribution of information about a work.


10 Established in 1999, ArtBase includes a wide range of projects by artists from all over the world who use materials such as software, websites, motion images, games, and browsers for aesthetic and critical purposes. ArtBase, http://rhizome.org/artbase/ [18-07-2016].

11 A questionnaire answered by museums, confirmed that they have used compact discs, DVDs, hard drives, and USB thumb drives as media storage, although not all are used to store masters.
Case Study on New Media Art Conservation, Evolution, and Degradation: From the Artwork to the Demonstration Artwork

Diego Mellado Martínez,a Lino García Moralesb

INTRODUCTION

This article presents a case study of the conservation and restoration of Cannula, a multimedia artwork by Daniel Canogar,a and the consequences of the decisions made during its production.

Cannula is a digital artwork based on the execution of a custom code (developed in the C++ coding language) on a computer. The output is represented on an LCD screen whose appearance—frame, resolution, and so on—is also a fundamental aspect of the artwork.

The need for future conservation was a key factor for the artist. Therefore, conservation was considered from the beginning of the artwork’s production and was based on the paradigm of “evolving conservation.”

Unfortunately, the artwork relies on an online service—YouTube—whose long-term continuity is not assured. Making a full copy of the service is not viable, and loss of the service could jeopardize the integrity of the artwork. To avoid this, a novel kind of documentation of the artwork was introduced: the demonstration artwork, or artwork as documentation of itself.

METHODS & METHODOLOGY

Based on a previous work by the same artist developed with the same tools—openFrameworks,a C++ library—Cannula would implement an interactive component. The brief for its production can be summarized as “using low-demand YouTube videos as a new palette to make a continuously changing abstract painting.”

The work’s reliance on computer code raised a variety of conservation issues: hardware life span, operating system, coding language, and so on. To address these problems, the “evolving conservation” paradigm was applied. The idea behind this paradigm is to allow the artwork to evolve, to change over time so as to be properly conserved with no significant loss.

For this to happen, the artist must define which aspects of the artwork cannot be changed under any circumstance, both symbol-object elements, which constitute the image of the artwork—whether physical or virtual—and system-object elements, which support the artwork as structure elements. These definitions will allow the artwork to be reconstructed (if necessary).

The screen on which the artwork is shown, which can be easily described by size, resolution, and so on, is part of both the symbol-object and the system-object, for example.

In this case, the system-object is the combination of software and hardware needed to run that software. For the software to be able to “evolve,” it must be defined in an abstract way that can be easily implemented in any coding language. This definition must include all elements needed to accomplish the artist’s will. Figure 01 is an example of how the software can be described. The hardware definition might be summarized as “that which can run the software at a minimum of 30 frames per second at the defined...
resolution with the desired interaction.” The following is an example of how conditions can be presented:

- Apple Mac OS X 10.11.3 operating system using XCode 7 IDE.
- C++ language and openFrameworks 0.9.2 framework.
- Artwork value does not rely on OS, IDE, or programming language used.
- The artwork is based on obtaining content from YouTube.com.
- This custom software uses Youtube-dl, FFMPEG, and HAP as third-party tools.

One aspect of Cannula that presented serious conservation problems was the artwork’s reliance on videos taken from a specific online server: YouTube. What would happen if that service were not available? In that case, the artwork, as defined, would cease to exist.

To avoid a blank screen, copies of the most recently requested videos are downloaded and stored in the hard drive of the artwork’s computer. Then, if the service is not available, the software can use the copied videos to generate the image.

Whether the work when presented using previously downloaded videos is still the artwork as originally defined is an open question.
RESULTS & DISCUSSION

To implement the “evolving conservation” paradigm, some decisions were made. As shown in Figures 01–03, which describe the program workflow, several processes run in parallel. In addition, those processes use third-party applications.

One of the ideas behind “evolving conservation” is the possibility that the parts that make up the system-object may be substituted. For this to be possible, each process must be implemented in a separate piece of software. Communication among the pieces of software must be defined as well. That approach is closest to Garcia’s model of a3.nexus and a3.cubes.6

During the production of Cannula, the lack of resources suggested a more straightforward approach: combining all processes in a single piece of software. Since all processes were correctly defined by the flow diagrams, this was not a problem.

Flow diagrams, together with all the information that defines the artwork, are presented as part of a manual that accompanies the artwork, thus allowing all parts that make up the artwork to be redone with no loss of meaning.

Still, a basic element, the video server, could fail. To avoid that, a demonstration mode is used. This, however, raises a question: Is this mode the actual artwork? The answer must be no, since the artwork is defined as an interactive installation where users can request videos from YouTube in real time.

The demonstration mode is a degradation of the original artwork. It uses videos requested in the past and thus presents a past representation of the artwork, thus linking the demonstration mode to the concept of “art documentation.” The degraded version of the artwork can work as documentation of itself.

The use of documentation as a preservation tool has been widely discussed,7 especially performance
Authors want to present a novel approach to this concept, using the artwork as its own documentation. This creates opportunities to experience the artwork completely with the same interface as the actual artwork.

CONCLUSIONS

The “evolving conservation” paradigm was implemented during the production of a specific artwork, Cannula, allowing for its future preservation and conservation.

In addition, a demonstration mode was implemented to avoid the complete loss of the artwork in case the service on which it relies shuts down. This introduces a novel turn: the demonstration mode as a degradation of the artwork and its use as self-documentation.

CURRICULUM VITAE

Diego Mellado earned a degree in telecommunications engineering from Universidad Carlos III de Madrid. He designs and produces new media artworks.

Lino García received a PhD from Universidad Politécnica de Madrid and a Ph.D. from Universidad Europea de Madrid.

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**Mínimos, a Series by Mikel Díez Alaba: Reinterpretation of the Landscape to Preserve Natural Heritage**

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INTRODUCTION

In 2014, the Museo de Bellas Artes de Bilbao held an exhibition called *Transitando un tiempo* (After an age) by the Basque contemporary artist Mikel Díez Alaba.\(^1\) The exhibition presented 144 small pieces in acrylic paint applied to printed images and called *Mínimos*. Throughout his career, the artist has been closely connected to his surroundings, a connection that must be taken into account when conserving these artworks.

When studying contemporary art, every aspect of the work must be valued, and current tendencies in the conservation of world heritage must be considered. This article reflects on the major changes that the concept of the term heritage has undergone and the new guidelines for determining the value of an artwork’s authenticity.

Conservation Concerns

Díez Alaba’s Mínimos were considered holistically; that is, both the tangible (the paintings themselves) and the intangible aspects were considered. The latter includes society’s collective memory, since the works evoke constructed ideas about the main characteristics of the island.

To accomplish this comprehensive strategy of conservation, we considered three distinct levels of the artist’s working method, each with its own value and complexity:

Specific landscape. This is the natural scenery, which changes with the passage of time and human activity. To maintain the island’s quality of life and environmental characteristics, modifications to the landscape are regulated by standards developed by the United Nations Educational, Scientific and Cultural Organization.

Photography of a specific landscape. This is the natural scenery captured in a specific moment. Conservation of these images is necessary to preserve both the changes to the evolving landscape and Díez Alaba’s artistic view.

Artist’s view of the landscape. The artwork represents a specific landscape as remembered by the artist. The artwork should be preserved both for its materiality and for its immaterial values, which represent the island.
METHODS & METHODOLOGY

Theoretical Review

Díez Alaba’s career was studied from the beginning to achieve an overview of his work and to understand the development of his method. The research then focused on the artist’s most recent period, which includes the artworks he created while living on Minorca.

Díez Alaba was born in Bilbao in 1947, and his career was marked by evolution. He was one of the main figures in the Basque scene of the 1970s. His disagreement with the sociopolitical context and his interest in experimenting with new procedures led to the creation of expressionist works with an abstract tendency and a critical sense.

In 1979 he quit painting for a year because of tension and stress. Taking advantage of the pause in his artistic activity, he moved to the countryside and took time to rethink his career.

Inspired by his new surroundings, Díez Alaba refocused his work on the landscape. At the beginning of this new stage, he painted based on the old masters while trying to understand the origins of painting techniques.

In 1981 he moved to Minorca. He was interested in the landscape’s power of evocation and suggestion and sought to learn how to convey in his art a strong impression of the light and color of the Mediterranean.
Thereafter, he followed a more sensitive and harmonious tendency in which the artistic process itself was the most important part of the artwork. Since then, Díez Alaba was focused both on the material aspects of the artwork and on how they related to the surroundings that inspired the creative process. With his landscapes, he recreated calm and peaceful spatial environments with the luminous tones inherent to the natural heritage of the island.

Study of the Methodology Used in the Mínimos Series

Díez Alaba’s working method changed over the years as he was influenced by his surroundings. From realism and expressionism (because of the sociopolitical situation at the beginning of his career), he shifted to abstraction (works from the 1980s onward), and from large formats he shifted to small ones to better show the closeness between the artworks and his feelings.6 In the Mínimos series he painted abstract interpretations of the Minorcan landscape as seen through the artist’s eyes. Some of these works show the quietness of the Mediterranean; others show its wildness.

Because of their small size, approximately 6 x 9 cm, the works in this series look like fast sketches made during his trips around the island. In reality, he produced each work only after reflecting on his feelings about the moment it depicts.

He carefully prepared the substrates before painting. First, he used Photoshop to manipulate the images he took during his outings (Fig. 01), removing almost all color and introducing other distortions. Then he printed the images on office paper and applied several layers of polyvinyl acetate to protect the pigment inks. When the adhesive dried, he painted over the underlying image with acrylic impastos.7 He used a limited color palette, typically comprising blue, white, green, red, and yellow—colors that are directly related to nature (sky/water, clouds, vegetation, sun) and its reflection on various surfaces (Fig. 02).

CONCLUSIONS

Much as the Minorcan landscape and environment are protected by the regulations of the Balearic Islands, Díez Alaba’s Mínimos also deserve special attention. Not only are these works valuable as artistic productions; they form part of the social identity that is the island’s heritage. Moreover, the correlation of the works’ materiality with their conceptualization of landscape characterizes the artworks as authentic in the sense described by the Nara Document on Authenticity.

All the aforementioned should form the basis of every research endeavor regarding contemporary art, where the study of ideas (through personal interviews with the artist, deep study of the work’s production, multidisciplinary approaches to heritage, etc.) is vital for conserving the materiality of the artifacts. This article is itself the beginning of research into the Mínimos series, a starting point for further articles that will ensure the conservation of the artworks.

ACKNOWLEDGEMENTS

We thank Mikel Díez Alaba for his availability and help during this research. Our interviews and talks with him gave us insight not only into his working methods but his thoughts.

CURRICULUM VITAE

Iraia Anthonisen-Añabeitia has a bachelor’s degree in art conservation and a master’s degree in conservation and exhibition of contemporary art from the Euskal Herriko Unibertsitatea /
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A Walk along the Path: The Restoration of a Spanish Icon at the Museo Nacional Centro de Arte Reina Sofía

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INTRODUCTION

During the latter part of 2015 and the beginning of 2016, the Conservation and Restoration Department at the Museo Nacional Centro de Arte Reina Sofía developed the complete restoration of a replica of the sculpture El pueblo español tiene un camino que conduce a una estrella (Spanish people have a path that leads to a star).

The original sculpture is by the Spanish artist Alberto Sánchez (1895–1962) and was designed for the Spanish Pavilion at the 1937 International Exhibition in Paris, where it was shown alongside works by other major artists such as Joan Miró, Alexander Calder, and Pablo Picasso.

In 2001, as part of the Alberto Sánchez retrospective at the Reina Sofía, a replica of the original sculpture was built using a plaster cast of a copy of the model in bronze, following photographic documentation. Placed in the front facade of the museum’s Sabatini building, it has since become an icon of the museum.

This paper describes a scientific approach to the methodology of landmark sculpture conservation and...
METHODS & METHODOLOGY

Before an appropriate plan could be developed, the materials and aesthetics of the replica were researched. A video documentary made in 2001 and kept in the museum archives shows how the sculpture was made.

First, a polyester cast was made from the original model, which was constructed with an iron core to give greater stability. A series of horizontally placed rebar added rigidity. The cast was later filled with polyester and artificial stone made with concrete.

In 2015, as the result of inclement weather and several acts of vandalism, the condition of the sculpture had deteriorated to an alarming degree. Structurally, it presented diverse cracks, fissures, and material losses both inside the replica and in the thin mortar layers outside. The lower section of the sculpture was damaged by paint and graffiti.

After building a suitable scaffold, the restoration began with a surface cleaning with an aqueous medium and the removal of graffiti with acetone solvents and abrasive methods. Most of the dirt was confined to the base of the sculpture, which had been used as a seat on many occasions.

The degraded mortar within the structure was then removed and replaced, both in the sculpture and its base. The degradation of the mortar was caused by rainwater filtering through the vast cracks of the sculpture, weakening the whole structure over time (Fig. 01).

Once the loose mortars had been removed, the metallic elements of the inner structure were protected from oxidation before new mortar was applied.

Next, the generalized oxidation of the iron structure was neutralized. FERTAN® dissolved in alcohol was applied to inhibit iron corrosion, followed by INCRAL® (benzotriazole in alcohol). This process was also performed on the small metal area beneath the red star on the top.

Once the metal support structure of the sculpture was consolidated, the lost material was reintegrated. To replace the previous mortar, we tested different possibilities, which included marble dust, lime, and concrete mixed in several percentages. In the end, a manufactured industrial mortar was chosen as the most stable and resilient for outdoor purposes: SikaRep®-817. The mortar contains concrete, lime, and selected aggregates for regularization and decorative coating. It also mixes well with water, so it is easier to use. A small percentage of water and ACRIL® was also added to the mortar to increase its adhesive strength and ensure its adherence.

This mixture turned out to be extremely resilient in addition to providing more granulometry than the original surface. We thus applied the last mortar layer with a much thinner grain size and used an industrial hydraulic lime (PLM©) with greater hardness (Fig. 02).

During the consolidation, small cracks were filled with water and ACRIL© to merge the noncohesive parts and thus seal the surface against aqueous filtering. Furthermore, larger areas lacking mortar were reconstituted with an industrial mortar, SIKA®, and finally with irregular stone pebbles (about 3–5 cm wide) to fill the gaps without adding significant weight.
The mortar application was carried out on successive working days. Each 1–1.5 cm layer took about 24 hours to harden, so that the process of application was gradual. Finally, the original textured surface was imitated by referring to the traces made in 2001. The texturing process consisted in using metal rasps to make exact incisions throughout the sculpture.

The last stage of the restoration involved replicating the sculpture’s original color. Recovering the color palette of the original sculpture was complicated by the lack of color photographs from the 1937 International Exhibition in Paris. However, the tonal contrast between low relief lines and the markings of the vertical path became evident after studying the available (black-and-white) images.

Once paint was applied, the star recovered its deep red color. An acrylic paint was used since it is both impermeable and weatherproof. The rest of the sculpture was painted with ochres and white tones in varying degrees of shade. Pliolite paint was used, dissolved in Disopol synthetic solvent.

The paint was applied first in lighter tones, mixing vanilla and white colors in proportion 2:2. After making the first layer, texture lines were marked using a metallic rasp. The vertical path was painted a considerably brighter shade, a 3:2 mixture of both colors.

Finally, darker tones were applied as shading to those areas that appeared darker in the original sculpture. This final tone was accomplished by adding a brown earth pigment to the base color to darken the mixture.

RESULTS & DISCUSSION

The conservation and color recovery methods used to restore the sculpture improved not only its structural but aesthetic integrity, helping it regain the iconographic and symbolic importance it had during the Universal Exhibition of 1937.

To convey the respect and social recognition it deserved, a glass barrier was installed to restrict access to the sculpture. This has effectively prevented further vandalism since the completion of the restoration.

CONCLUSIONS

The restoration concerned not only the material dimension of structural consolidation but the recovery of a symbolic image from a specific historical period. The preservation of this landmark returned its symbolic value to the Reina Sofia. Even more important, it returned a historic icon to all citizens.

ACKNOWLEDGMENTS

We thank the Reina Sofia team who collaborated during the restoration (November 2015–January 2016): Pilar García Serrano (coordinator), Paloma Calopa, Ana Iruretagoyena, Begoña Juarez, and Juan Antonio Sanchez. Restorers hired for the project were Rodrigo Martin and Carlota Santabárbara. We also thank Diana Lobato for photographic documentation and Jorge García Gómez-Tejedor, head of the Conservation and Restoration Department at the museum.

CURRICULUM VITAE

Carlota Santabárbara Morera has degrees in conservation and restoration and art history, as well as a PhD in art history from Universidad de Zaragoza.

Rodrigo Martín Navarro is an art registrar with the Museo Nacional Centro de Arte Reina Sofia. He has degrees in art
history and conservation and restoration from Universidad Complutense Madrid.

Pilar García Serrano is a sculpture restorer in the Conservation and Restoration Department of the Museo Nacional Centro de Arte Reina Sofía. She coordinated the restoration of *El pueblo español tiene un camino que conduce a una estrella*.

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1 Concrete Pregunite Light H and mineral oxides to obtain the rock tone, as stated in the report of the company that made it, AVICO REALIZACIONES SL, which has already disappeared.

2 It can be coated with plasters or paints or silicate minerals and presents good adhesion to most supports of traditional buildings. Different surface finishes can be applied.

3 Acril 33 is a resin used in all restoration sectors. Its characteristic properties include excellent freeze-thaw stability, good pH stability, optimal binding power, and high resistance to yellowing.

4 Pliolite paints are solvent-based, present recognized durability due to their great penetration and adhesion, have waterproofing and microporosity organic coatings, and provide high resistance in exteriors.

5 Composition: mixture of esters, ketones, alcohols, and aromatic hydrocarbons. Composition: mixture of esters, ketones, alcohols, and aromatic hydrocarbons.
INTRODUCTION

The limits of art do not seem to be clearly defined for the contemporary artist, and the first evidence of that is the wide range of meanings the art concept can adopt nowadays. Contemporary artists do not need to be subject to traditional art categories. On the contrary, they can either explore or create new ones. As a part of that, contemporary artists experiment with new materials, techniques, and applications during the creative process. As a result, artworks have been created using heterogeneous materials of unknown composition or materials taken from outside the usual artistic practice. This is one of the main difficulties art restorers face in their conservation work.

An example of contemporary artists who go beyond the old boundaries of art is reflected in Patricia Gomez and Maria Jesus Gonzalez’s research artwork. These two Spanish artists have been working as a collective since 2005. Their research is based on abandoned places or places that are destined to disappear, and their aim is to recover the memories of the people who used to live in those areas. The most representative technical element in their artwork is the adaptation of mural detachment techniques. Although Gomez and Gonzalez use an extraction process for their artwork that is suggestive of the Italian strappo technique used in restoration work, the materials, criteria, and results differ from art restoration orthodoxy.

The research presented in this paper is part of an investigation of the changes suggested by these artists in a recent art project, À tous les clandestins. As a further step in their experimental and open-minded attitudes toward other subjects, they decided to ask for an active collaboration with restoration specialists. As a result of this experiment, the artists became more familiar with the authentic materials, techniques, and processes of the “traditional” strappo, and the restorers increased their knowledge on the artists’ concept of their artwork and the materials they use.

METHODS & METHODOLOGY

In the collaboration on Gomez and Gonzalez’s project À tous les clandestins, the restorer’s methodology evolved along with the artists’ creative process.

Initially, Gomez and Gonzalez made some inquiries to the restoration specialists regarding materials and techniques, which is a common practice for these artists. Later they asked for on-site assistance to prepare the surfaces and consult on technical issues. During these activities, the artists decided to experiment with the original strappo technique, so the restorer’s role gradually increased from that of being just an assistant to becoming a full-time collaborator.

After completing the on-site work—the detachments—the collaboration continued, and the restorers’ work was focused on two research directions: practical experimentation with materials and an independent study of the properties and characteristics of those materials.

The goal of experimenting with materials was to achieve an ideal combination of adhesive, support, and technique that would offer the greatest similarity in appearance...
to the works done with the artists’ own technique, which was what they were looking for. In addition, the combination sought by the restorers had to possess enough stability to guarantee long-term conservation.

The first stage of the experiment involved selecting materials for testing from both the artists’ requirements and the restorers’ suggestions. Five types of fabric and three adhesives were chosen. The fabrics were different natures but of similar appearance. Two of the adhesives were vinyl resins used by the artists; the third was an acrylic resin recommended by the restorer and similar to those used by the artists but better suited for conservation. The stage was completed by the restorers testing all the possible combinations with the materials chosen on the first step.

Four stages followed the first, always in an ongoing dialogue with the artists. Those stages involved figuring out how to reproduce certain aesthetic aspects and forms from the artworks created by the artists with their own technique—not strappo—producing a link between the new forms and their general artwork.

On the other hand, the theoretical research supported the practical experimentation by evaluating the tested materials from different perspectives. To understand the compatibility of the materials used, how well they supported the artists’ ideas, and what impact they would have on the conservation of the artworks, the restorers followed a methodology based on the principles of risk assessment and risk management initially proposed by Robert Waller of the Canadian Museum of Nature (Ottawa) (1994) to develop a preventive conservation plan. The method has also been used worldwide in the evaluation of risks in other contemporary interventions. For this collaboration, the restorers adapted the plan as needed during the creative process.

RESULTS & DISCUSSION

The first stage of the project—the practical research—did not reveal remarkable differences between the diverse combinations tested. However, the other three stages, which were intended to get specific results, were unsatisfactory for the artists, who finally decided to avoid those modifications and accept the results achieved in the first stage.

The material experimentation enabled the artists to establish which materials revealed differences and similarities compared to their other artworks—those made with their own technique in this and previous projects. The acrylic adhesive recommended by the restorers was found to be the best option both for the artists’ needs and the future conservation of the artwork. Although the synthetic and natural fabrics used in the test showed similar appearance, the former provided better stability and thus was more suitable for future conservation than the latter.

CONCLUSIONS

The research supported our opening claim that “The limits of art do not seem to be clearly defined for the contemporary artist.” However, we would like to highlight the role of the restorer.

In this collaboration, the restorer witnessed the “creative moment” alongside the artists—first, as a mere observer seeking information about their artwork; later, giving advice and offering possible solutions. The restorers completed their own research and carried out an experiment to determine why they considered particular materials positive or negative. This work, in addition to accelerating the artists’ production, increased the restorer’s knowledge of the physical and conceptual aspects of the artworks, thus facilitating possible future collaborations with these artists allowing them to make the most appropriate decisions in the event the authors cannot offer opinions about a restoration or other kind of intervention.
Within the project, art and conservation were consciously blended, a reminder that the preservation of art delves into the same creative processes as the creation of art. Both disciplines have much to contribute to one another, and we invite other researchers in conservation and restoration, as well as other artists, to take advantage of these kinds of collaborations during the creative process. They present great learning opportunities and will lead to better conservation.

CURRICULUM VITAE

Eva M. Fuentes Duran graduated in art history from Universidad de Salamanca. She is a postgraduate student in art conservation and restoration at the Universitat Politècnica de València. She has been collaborating with the artists Patricia Gomez and Maria Jesus Gonzalez since 2014.

Rita L. Amor Garcia is a PhD candidate researching the strappo of aerosol art. She has participated in various projects on the conservation of wall paintings, including collaborations with artists, and is a member of the Urban Art Working team of Grupo Español del International Institute for Conservation.

María Pilar Soriano Sancho has a PhD in fine arts from the Universitat Politècnica de València. She is a professor, master’s degree program director in the Art Conservation and Restoration Department, and member of the University Institute of Heritage Restoration, Universitat Politècnica de València.

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1 For more on the collective, see http://www.patriciagomezmariajesusgonzalez.com/ [22-07-2016].

2 Strappo is a traditional technique used to preserve wall paintings; it consists of using animal glue and cotton fabric with the purpose of separating the paint layer from the wall support.

3 A tous les clandestins is a project exploring immigration routes from Africa to Europe, developed in two immigration detention centers (in Mauritania and Fuerteventura).


INTRODUCTION

Contemporary artistic discourse understands public sculpture as a part of a city’s landscape and as representative of its culture and identity. Public sculpture gives cities an intrinsic social and aesthetic definition in commemorative and sociopolitical terms.

However, many of these artistic works have not received the proper care needed to ensure their conservation and are therefore in a poor state. Lack of care leads to progressive deterioration and negatively affects the city’s image. The urban outdoors, one might then conclude, is not the most appropriate location for the conservation of such works. However, public spaces should be appropriate for museum-like exhibitions, since they are inhabited by human beings and the presence of art turns them into hybrid places for communication. Hence the need to properly conserve public sculptures.

As background for this project, I consulted studies by the Leganés Museum of Sculpture and the Andalusian Contemporary Art Museum (on the public sculpture of Aracena), a study devoted to the works of the Conexiones urbanas exhibition organized by IVAM and a study of the conservation of sculptural projects located in urban and natural settings.

The city of Granada, Spain, has many public sculptures created by renowned sculptors. These works can be found on public streets, in roundabouts and in public gardens, and are in various states of conservation. For this reason, the city council of Granada has enforced a Heritage Conservation Municipal Plan (2013–2015) devoted to the conservation and care of its heritage assets.

Many of the city’s public sculptures were made by Miguel Moreno Romera (b. 1935, Granada). Moreno makes sculptures and jewelry pieces in a figurative and personal style that references the works of Constantin Brancusi and Henry Moore. He has received international artistic recognition and is still active.

The objective of this research was to determine the state of conservation of several public sculptures made by Moreno in the city of Granada. Works were examined to determine whether they required conservation work or, if they had been restored, whether their preventive conservation resulted in the loss of their formal identity and location.

The causes of deterioration were also noted and led to a proposal of measures to improve the works’ conservation.

METHODS & METHODOLOGY

The public sculptures titled Venus de Ilíbiris (Fig. 01), Luna (Fig. 02), and Yehuda Ibn Tibón (Fig. 03) were chosen because they were in need of restoration or because restoration work had already been conducted on them to improve their state of conservation.

The methodology used was both theoretical and practical. Documentary sources were consulted to help in the detection of changes and problems caused by the...
continuous exhibition of the sculptural works outside. Analysis was conducted by visually identifying the works.

RESULTS & DISCUSSION

Venus de Ilíbiris (1977) (Fig. 01) is located on the grounds of the Universidad de Granada’s Auditorium Garden on a surface of cement mortar. Made of cast and patinated bronze, the work is 330 cm wide and is surrounded by vegetation. It has been damaged by the elements, irrigation water, biological attacks (animals and plants), and human vandalism. It shows numerous graffiti, scratches, stains, encrusted dirt, coating changes, biological deterioration, corrosion and salts, and needs a general cleanup and adequate external protection due to its outdoor exposure.

Luna (Fig. 02) is situated on the grounds of a large roundabout in the city center. It consists of blocks of natural stone (Travertine marble) that are joined together. Elemental damage has been exacerbated by irrigation of the surrounding vegetation, environmental pollution generated by traffic, and biological deterioration in addition to human neglect and vandalism. Layers of dirt, salt, and fungi were observed, along with stains, cracks, and the loss of stone material between the joints of the work’s various blocks. The adhesive material used to join the blocks or fill the cavities and natural cracks of the material has oxidized. The work needs a general cleanup and consolidation, and old adhesives need to be replaced.

Yehuda Ibn Tibón (1988) (Fig. 03) sits on a pedestal in Calle de la Colcha (Realejo neighborhood) and is made of cast and patinated bronze. In 2014—prior to which the work had been damaged by painting, scratches, scars, corrosion, decohesion, biological deterioration, and salts and was not properly attached to its base—a general cleanup and proper reinstallation process were carried out.

CONCLUSIONS

The public sculptures of Granada contribute to the creation of the urban landscape of the city and its favorable aesthetics.

The studied public sculptures by Moreno have suffered the ravages of environmental and polluting agents, the effects of irrigation and the routine cleaning required for the maintenance of the city, human attacks and vandalism, and biological deterioration. The works also show various alterations.

The state of conservation of these sculptures suggests a need (1) to promote greater awareness among the citizens of Granada regarding the conservation of public art works, and (2) to continue to apply appropriate municipal plans to ensure the conservation, restoration, and maintenance of cultural assets. Because these works are elements that define the city, the city council
should support their restoration (if required), improve their conservation, and raise greater public awareness about the need for their care and preservation.

The studied sculptures’ state of conservation should allow for their continuous exhibition for a long time to come. Despite alterations, they play an important role in humanizing the city and its open spaces and in fostering cultural dialogue with citizens. Hence, they should continue to be exhibited outdoors, although their longevity will be shorter than if exhibited indoors, where conditions for their continued conservation and exhibition might be better but where their conceptual discourse would change.

ACKNOWLEDGEMENTS

I thank the Universidad de Granada (Research Plan 2015–2016, Integrated Actions), Miguel Moreno Romera, and the city of Granada.

CURRICULUM VITAE

María del Carmen Bellido Márquez has a fine arts degree and master’s degree in museology from the Universidad de Granada, where she also obtained her PhD in the same field. A tenured lecturer with the Universidad de Granada, she received the 2003–2004 National End of Degree Award from the Spanish Ministry of Education and Science and the 2009–2010 Extraordinary PhD Award from the Universidad de Granada.

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Asilah Arts Festival (Morocco): The City as a Stage and the Rediscovery of Everyday Life

INTRODUCTION

Since 1978 the Asilah Arts Festival (AAF) has been held each summer in the small Atlantic coastal town of Asilah, Morocco. Over two weeks, a wide range of cultural activities transforms the city with an explosion of artistic output that attracts artists and scholars from all over the world.

The origins of the festival can be traced to 1978, some years after the journalist and politician Mohamed Benaïssa (b. 1937) and the artist Mohamed Melehi (b. 1936) came back to their hometown and found it poorly preserved. The two friends mobilized the population to seek better life conditions, an initiative that started from small actions such as making garbage collection easier.

As these improvement tasks were being carried out, the two friends dealt with the town council to remodel the village’s external appearance by paving the streets and restoring ancient houses and historic buildings such as the Portuguese Kamra Tower or the Rassouni Palace. The rehabilitation process sought to achieve coherence with the original image of the town and paid homage to tradition by, for example, incorporating elements from ruined buildings (e.g., arches and doorways) into new ones or by including traditional features such as zellij tiles. This respectful architectural project was awarded the Aga Khan Award for Architecture in 1989, and the town was proclaimed a National Monument.

In 1978, after the first initiatives had yielded results, Melehi and Benaïssa organized an event under the slogan “Culture and Art for Development” in which international artists were invited to paint the town’s walls in collaboration with its inhabitants. The first edition of the festival had then been informally launched. The festival has continued over the years thanks to the Al Mouhit Association, now the Forum of Assilah. This article presents AAF, through its history, program, and outcomes, as an interactive platform for international and local cultural interchange and preservation.

METHODS & METHODOLOGY

The research project was conceived as part of the author’s final dissertation for a master’s degree in Islamic art and architecture from the School of Oriental and African Studies (SOAS), University of London. Specialized publications on AAF are rare, and thus academic research was followed by a three-week stay sponsored by the Ralph Pinder Wilson Award. The information included in this article is partially based on this research and the conclusions drawn from it.

To complement the limited bibliographic material available on AAF and to build an extensive photographic archive, fieldwork was undertaken and involved three components. First, interviews were conducted with participating artists (Othman el Bahri, Hakim Ghailan), event organizers and coordinators (Mohamed Anzaoui, Abdallah El-Hariri), Forum of Asilah members (Majdouline Khalladi), local residents, and outside artists, gallerists, and knowledgeable professionals (Mareta Espinosa, Said Messari). Second, on-site visits were made to the festival...
quarters (Bibliothèque Prince Bandar, Centre Hassan II, Raissouni Palace, and medina), Asilah art galleries (Aplanos, Monassilah), local artists’ ateliers located in traditional restored houses (Hadik Haddari), and key architectural sites (Kamra Tower, Kirikiya, Lakma). Finally, in the summer of 2015, programmed festival events were attended, as well as nonfestival events with local residents (e.g., a Sufi recital at Fishers’ Café).

DISCUSSION & RESULTS

The AAF program annually includes a variety of activities: engraving, painting, and writing workshops (in past editions, Ikram Abdi, Sandro Brancchita, and Amadeu Dieng were among the participants), storytelling, theater and musical performances (e.g., Saloua Chouair, Oud Caravan Trio), indoor and outdoor exhibitions of international and local artists (e.g., Bahri masters, Asilah youth), interdisciplinary conferences and colloquia (e.g., Arab Media Today, Poetry in Crisis, The Arabs: To Be or Not to Be), awards for artistic creation (e.g., Bouland al Haidari de la Jeune Poèse Arabe), fashion shows, and medina wall paintings (e.g., Mizue Sawano, Malika Agueznay).

On-site research revealed the festival’s ongoing commitment to the preservation of Asilah’s urban and architectural sites. The festival, using funds partially generated from the event itself, paid for periodic restorations and an annual prefestival inspection, in addition to using the town’s renovated historical buildings as festival headquarters, administrative offices, theater stages, urban canvasses, and artistic residences and ateliers (Fig. 01). In addition, the festival attracted numerous visitors whose spending boosted the town’s tourism industry.

Second, the study showed that the festival’s preservationist, bidirectional (local-international) attitude had spread toward traditional and contemporary cultural expressions, evidenced in the interwoven celebration of, for example, gnawa or fado music performances alongside the latest artistic manifestations (e.g., exhibitions at the Centre Hassan II, in the medina, or at the Palais de Culture). Asilah’s cultural panorama (from Hakim Haddari to local art galleries) and everyday life also received special attention during the festival as the city gained international visibility and evolved into a stage for lively intercultural exchange.

Third, the inclusion of activities such as artistic workshops for children (Fig. 02) or conferences on topics ranging from identity and migration to cinema and climate change disclosed a social educational character that reflected the local inhabitants’ active involvement. Most activities were free and sought to bring a taste of the international cultural panorama to the town while encouraging a festive and entertaining approach to its own heritage.

Beyond the opportunities for practical cultural learning, the children’s art workshops occasionally focused on the medina’s architectural features, and the residents participated in the creation of wall paintings (Fig. 03) or in the urban rehabilitation and maintenance campaigns undertaken since the first edition of the festival. This active involvement has encouraged residents to interact in a new, bodily, hands-on way with inhabited...
space, leading to rediscovery and better knowledge of their hometown, while simultaneously raising awareness of its preservation needs and procedures.

In recent years AAF has become more sophisticated and crowded, receiving minor criticisms about its reiterative character, poor information distribution, and limited spaces for activities. Its main challenges today are to avoid repetition, conformism, and elitism; evolving into a tourist trap; abandoning its original laudable principles; and neglecting its crucial inclusive, preservationist, and educative roles.

CONCLUSION

Since its foundation, AAF has been conceived as an inclusive celebration organized for and by the inhabitants of Asilah. Its preservationist and disseminative goals have soaked into the local population thanks to its “learning by doing” nature, which on the one hand has raised awareness of the central role people play in preserving their own heritage and, on the other hand, has succeeded in fostering a progressive assumption of culture and, in this case, the festival itself, as effective tools for conservation, social education, self-expression, and intercultural dialogue.

ACKNOWLEDGMENTS

Thanks to SOAS, Simon O’Meara, Majdouline Khalladi, the fabulous Asilah and Tetouan teams, and all who were part of the project.

CURRICULUM VITAE

María Gómez is an art historian specializing in contemporary Middle Eastern and North African art at the School of Oriental and African Studies, University of London. Currently starting her PhD studies, she has published in Ibraaz, Afribuku, and Reorient and collaborated with Santander Bank Foundation, Sabrina Amrani, Selma Feriani, and Casa Árabe. She received the 9th Mutua Madrileña Postgraduate Scholarship and the Ralph Pinder-Wilson Award in 2015.

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Fig. 03. Hiba Khamlici wall painting. AAF 2015. Photograph by María Gómez López.


(Endnotes)

8 Examples from AAF 2015.
10 The use of moussem as an AAF designation seems to be a statement of intent. This Arabic word, which refers to a traditional Moroccan seasonal celebration during which cultural activities are organized, contains an ontological hint pointing to agricultural cycles and religion. The celebration of Asilah Moussem is, in the fullest sense, a perpetuation of this ancestral practice and a metaphorical expression of the survival of Moroccan cultural heritage. Benáïssa, M., et al., Asilah, premier moussem culturel juillet—aôut 1978, Casablanca, Al Mouhit Association, Shoof, 1979, p. 34; and Reysoo, F., Des Moussems du Maroc: Une approche anthropologique de fêtes patronales, Enschede, The Netherlands, Sneldruk, 1988.
INTRODUCTION

Since its construction in 1957, the roundhouse for steam locomotives in the city of Burgos has undergone sporadic but significant transformation. This type of building, which is also known as a “cocherón” or “hangar,” is an icon of railway industrial heritage, easily recognized by its fan architecture, which is both aesthetically beautiful and functional.¹

The influence exerted by the Burgos roundhouse and its surroundings have changed along with the changing history of economic and social issues in the district. From their creation, the industrial areas were associated with a working-class neighborhood. When the industrial areas were abandoned, the area around the roundhouse became unsafe, with vandalism, drugs, and graffiti. Finally, with its recovery, the area has been converted to a new green area where children and old people can play and rest peacefully.

METHODS & METHODOLOGY

Information about this part of Burgos’s industrial heritage was compiled from the writings of Félix Escribano, author of the Special Plan for the Station in 2004 and of the rehabilitation project of the hangar in 2009; Luis Santos y Ganges, a geographer with several books and papers related to the transformation of the railway in Burgos; the Municipal Archive of Burgos, which provided several historical images and information plans; and the Burgos City Hall’s archives, which contain project files, drawings, and other relevant documents.
All the information was evaluated and ordered. In 2014 three reports were written as part of the author’s master’s degree in the restoration and conservation of architectural heritage: “Intervenciones sobre el antiguo cocherón El Hangar, Burgos,” “Evolución del entorno del antiguo cocherón El Hangar, Burgos,” and “La arquitectura en abanico de los depósitos y reservas de locomotoras de tracción vapor.”

RESULTS & DISCUSSION

The first roundhouse in Spain was built in Valladolid in 1860. By the middle of 20th century, as many as 50 had been built in Spain. The original use of the roundhouse was not as a garage, a place to park locomotives, but as space for technical functions. After 1975, as steam locomotives were replaced by their diesel and electric cousins, roundhouses had to be renovated for other uses, although many were abandoned or even demolished. When the latter occurred, the result was a degradation of urban space, often of space in the middle of cities. In several cases, roundhouses divided districts and the city, and their abandonment created economic and social differences.

In Burgos, the relocation of the commercial station in 1997 meant the roundhouse would be abandoned, becoming, like other garages and railways, a residual element in the urban planning of the city (Fig. 01). In 2004, however, the roundhouse received protection under the Special Plan for the Station, and in 2009 it was restored by the city as a new public facility for the youth of Burgos. With this restoration, the broader district entered a period of regeneration that led to such venues as a concert hall, craft market, theater, workshops, and conference space. Because of the rehabilitation, the surrounding area was modified following the criteria established in the Special Plan for the Station. In 2004, the city developed a masterplan to promote the reconstruction of Burgos as a city for the 21st century. The masterplan, developed by Herzog & De Meuron, calls for the transformation of the railway areas by removing barriers between the city’s northern and southern districts and creating new communications and functional buildings and areas. The passenger railway station was accordingly moved in 2009 to the outskirts of the city. This decentralization is still notorious. However, with the construction of new residential buildings and green areas, people are returning to the area. However, replacement of the old station with a boulevard for cars, taxis, buses, bikes, and pedestrians that is surrounded by green areas has increased the landscape quality and the social conditions of the neighbors by joining two districts of the city that had previously been separated by the railway (Fig. 02).

The masterplan improved access to the area that surrounds the roundhouse. To prepare the area for children, the elderly, and people with disabilities, the intervention included the installation of new pavement textures, traffic lights that emit noise, and trees and play areas.

The buildings with the greatest historical, architectural, and social value were the station and the roundhouse. Rehabilitation of the latter has been completed, and rehabilitation of the station is currently under way. This will give another public use to an industrial building that was in disuse, bringing more quality and opportunities to the district and to the city itself.
By recuperating these buildings, the memory of their former use can linger even as the actual industrial use disappears from the city (Fig. 03). However, documenting and publicizing the area's industrial heritage is a vital part of ensuring that the past is not forgotten.

CONCLUSIONS

The recent, growing interest in the industrial heritage of the 20th century is beneficial for conservation. However, more support and awareness are needed from the companies or institutions that own this heritage. Society must continue to recover and disseminate culture. As with the Burgos roundhouse, one good way to do so is to reinvigorate buildings with new uses. Writing about industrial architecture is one way to demonstrate its worth. City residents must understand why and how these buildings were built if they are to understand and value their heritage.

Evaluations of the intervention in Burgos have been positive. The architectural, functional, and aesthetic elements of the roundhouse have been respectfully conserved and renovated. Moreover, the intervention was sensitive to the needs of all elements of the population, including children, the elderly, and people with disabilities.

The rehabilitation of even a single building can transform the surrounding area, as shown by the revival of the Burgos roundhouse. Regenerating such areas can help prevent population loss, increase the value of the area for inhabitants, and result in overall improvements to the economic and social life of the city.

ACKNOWLEDGMENTS

The author thanks Félix Escribano and Santiago Escrribano from AU Arquitectos for sharing project information and images; Luis Santos y Ganges for his books on this topic; and the Universidad Politécnica de Madrid’s master’s degree program in conservation and restoration of architectural heritage for the knowledge needed to carry out this research.

CURRICULUM VITAE

David Ramos Ramos received his bachelor’s degree in architecture from the Universidad de Valladolid, his master’s degree in conservation and restoration of architectural heritage from the Universidad Politécnica de Madrid, and an advanced master’s degree in structural analysis of monuments and historical constructions from the Universidade do Minho and the České Vysoké Učení Technické v Praze (Prague).

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INTRODUCTION

This study aims to examine how the revival of industrial heritage drove experience consumption in the case of the techno club Drugstore, which is located in a former industrial zone dating to the late-19th century on the right bank of the Danube River in the Belgrade municipality of Palilula. Initially called the Culture Center Drugstore and situated in the former BEKO building in the downtown Belgrade neighborhood of Lower Dorcol, Drugstore opened in 2012 and later became a techno music club offering two venues—one indoor and one outdoor. BEKO, once a successful state-owned factory, had had a significant impact on the textile industry in the former Yugoslavia. The low-budget club managed to resuscitate one building of a derelict brownfield site and proved to be a success among the city’s outgoing youth. However, the owners had to relocate for legal reasons, so the new Drugstore club was established in 2014 in a space that had once been a slaughterhouse. In the period after World War II, it belonged to BIM Slavija, an enterprise serving the food industry.1 The young entrepreneurs opted for derelict industrial buildings as locations for the club because these areas seem to “speak” to the visitors who frequent the place on the weekends.2 Why are industrial sites suitable locations for techno clubs? How and why do consumers revel in experiencing such settings?

METHODS & METHODOLOGY

The research was conducted in 2016 utilizing research methods such as participant observation, focus groups, and semi-structured interviews. Participant observation was conducted over a period of 10 years by a researcher immersed in the “rave” subculture. The focus group consisted of eight people, mostly acquaintances the researcher met during the period of immersion. Respondents were 25–35 years old and shared several interests, including attendance at parties in the Drugstore club. Other respondents included one of the owners of Drugstore and a resident DJ. Semi-structured interviews were conducted face to face with them because they are a significant source of information about the experience of consumers who are their target group.

RESULTS & DISCUSSION

When Drugstore had to move from the premises of the BEKO building, the owners sought another isolated building, one where noise from the club would not bother locals, therefore allowing the club to operate until the crack of dawn. The owners selected a former slaughterhouse located in an abandoned industrial complex along the Danube River in the Palilula borough beneath the Pancevo Bridge. The first rave parties were illegal, organized in the warehouses of Detroit, Chicago, and New York, soon followed by London and Berlin in the 1980s. The techno or so-called rave culture was thus established on the concept of squatting. The new movement gathered a mixture of people who felt marginalized, celebrated freedom, and opposed mainstream culture. Raves are intended to be open to everybody regardless of class, gender, race, or age, suggesting they are (up to a point) an extension of the hippy movement. However, they showcase a new kind of music made by machines.3
In the beginning, rave was a subculture featuring several types of underground electronic music, but in later years it entered the sphere of club culture, gaining more aficionados and becoming less subversive. Correspondents agreed that former industrial buildings are suitable locations for techno clubs because they are an integral part of the “techno folklore” and resembled prominent techno clubs in Berlin, which boosted their appeal in consumers’ minds. Additionally, abandoned industrial buildings often offer broad spaces for dancing, mingling, and moving, including several music stages and appropriate acoustic. Such spaces are usually darker, minimalistic, and raw (i.e., “authentic”), with few details. Most important, their aesthetic appearance matches the repetitive, raw sounds of techno music.

Location is an important factor for both club owners and club goers. The advantage of former industrial buildings is their location. Whether situated in the outskirts or in downtown, seclusion from residential buildings was an important consideration. Seclusion removed concerns about noise pollution and allowed consumers to thoroughly consume the experience at any hour and to feel good in their “safe” place. Respondents visited the Drugstore from one to four times per month, usually arriving after 1 a.m. on weekend nights.

Consumers went mostly to socialize, listen to music, dance, vent surplus energy, escape reality, relieve the tedium of everyday life and problems, relax, and enter an altered state of mind, which some respondents described as “meditative” and was variously achieved by the music, the location, alcohol, and often drugs. Among club goers, Drugstore is often referred to as a “techno temple” or “techno cathedral” because of the spiritual feeling it creates among consumers and because of the cathedral-like appearance of the club’s main space.

CONCLUSIONS

Space is a socially constructed notion, and specific spaces such as dance clubs acquire social meanings through the discourses that surround them and the ways in which they are accessed and developed. As individuals, we tend to have expectations about how specific places will make us feel, even places that are geographically, socially, or psychologically distant from those of our everyday lives. Scholars who research music festivals have pointed out that certain social spaces become liminal spaces. Respondents agreed that they feel like they are entering an “outer” dimension when crossing Drugstore’s threshold. Thresholds have long been used to distinguish and define the transition from “the known to the unknown.” The liminal experience thus tends to represent metaphorical crossings as spatial or temporal thresholds.

The organization of space itself is also important. Visitors can dance, listen to music, hang out with friends, keep to themselves in corridors, or even make out in dark corners or backstage. The reuse of industrial heritage for this type of content began in the 1980s and became “trendy” before long.

Significant investment is generally not needed with such spaces because they are already suitable for transformation and their somewhat historical background seems to be compelling for visitors. Keeping the spirit of former industrial buildings alive and transforming them from derelict brownfield to social space—and thus reshaping the processes of urbanization according to the right to the city—can often be more useful for citizens than remaking the city’s industrial fabric to suit more corporatist purposes.

CURRICULUM VITAE

Dragana Kostica, a Belgrade-based researcher, is founder and editor in chief of the online magazine Still in Belgrade.

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3 See, for instance, the documentaries Pump Up the Volume: The History of House Music and Detroit Techno—The Creation of Techno Music from 2001 by Carl Hindmarch.


Converting Industrial Heritage into Museums: Aragon (Spain) Case Study

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INTRODUCTION

The recovery of industrial heritage for exhibition purposes has been in the spotlight for the last few decades. Improvements in production processes since the beginning of the industrial era have led to the abandonment of many factories, posing the problem of what to do with these typically large buildings that were designed to meet highly specific manufacturing needs. Musealization has become one of the more frequent choices for the recovery of industrial heritage. Examples include the Bankside (London) and Mediodía (Madrid) power stations, which now house the Tate Modern and the CaixaForum respectively. As Jesús Pedro Lorente claims, “the provocative aesthetics of industrial lofts with their extensive spaces and their brick walls . . . is getting increasingly fashionable.”¹ In Aragón, interest in recovering a lost industrial heritage can be seen in

Fig. 01. Museo Minero de Escucha, Spain.
The creation of the Catalog of Industrial Heritage and Public Works in Aragón, an exhaustive collection of documentation presented as an online database.2

The present study comes from the investigational work that was part of the author's doctoral thesis, “Museums’ Architecture in Aragón (1978–2013),” which focuses on the typology and characteristics of the region’s museums from the beginning of the Spanish democratic era. This article presents the results of a critical analysis and review of 20 initiatives for recovering industrial heritage in Aragón. The goal was to determine which trends had predominated and were most successful.

METHODS & METHODOLOGY

The study involved the reading of bibliographies, checking regional periodicals, searching for information in public and private archives,3 interviewing architects who had carried out remodeling projects, and conducting detailed on-site analyses of buildings. The analysis of the interventions was based on a critical review of different rehabilitation processes to determine whether they had been aggressive in their treatment of the original building or whether respect for the historical architecture was given priority.

Exhibition spaces were chosen as the key element for organizing the study. The main criteria was the relationship between the content of exhibition spaces and the buildings in which the spaces are located. Three categories were identified:

- integral musealization of the industrial heritage, with on-site preservation of original equipment and machinery;
- musealization of the industrial heritage where content is related to the original buildings; and
- musealization where content is totally unconnected to the industrial ensemble (i.e., the industrial space is a mere container for content of a nonindustrial nature).

RESULTS & DISCUSSION

The most noteworthy cases of integral musealization of industrial buildings are framed by public investment policies for the restructuring of former mining areas, thanks to nonrecoverable grants intended to create alternative economic activities to coal mining and thus encourage the development of affected areas. The Museo Minero de Escucha (Teruel) is one example. The museum is placed inside an authentic mine (Fig. 01). The container (frame) thus becomes the content, since the main focus of visits is the mine itself. The museum’s galleries are accessed via a mine cart.

Other integral musealization initiatives in Aragón involve the food industry; specifically, the manufacturing of flour and beer. Although musealization commonly occurs only after an industrial site has ceased productive activities, in one case the museum coexists with production. At the brewing company La Zaragozana, museum visitors

Fig. 02. Museo de la Ciencia y la Arqueología Minera, Utrillas, Spain.
can visit some of the original places in a business that is still fully functioning after more than 100 years.

Some of the most well-known cases of musealization in which the new museum’s content is related to the space’s original function involve the mining industry as well. For example, the Museo de la Ciencia y la Arqueología Minera in Utrillas is located in the village’s mining hospital (Fig. 02). Although the interior of the hospital was fully remodeled, some of its original elements were preserved.

Another initiative, the exhibition Pozo Corral Negro took place in the old supermarket of the mining district in Arinó, showcasing the strong social identity that still exists today in these locations surrounding the mining industry. The exhibition was not set up by a public institution, as is usually the case, but by a cultural association created by several retired miners with the intention of recovering the mining heritage in the village.

When industrial architecture is musealized so that the new contents are completely unrelated to the original function of the building, the industrial heritage frequently loses its identity with the reduction of the space to a multifunctional architectural container. One of the most significant examples is the Instituto Aragonés de Arte y Cultura Contemporáneos Pablo Serrano (Zaragoza), which might be the most radical proposal from the point of view of industrial heritage preservation (Fig. 03). This museum of contemporary art, which opened in 1995 in an old workshop, recently underwent a huge expansion involving several floors that caused the original building to be forcibly embedded in the new construction. The dimensions of the original factory are now difficult to assess. The expansion project fits what Ascensión Hernández calls “practices that are alien to what could be understood as restoration from a heritage-friendly perspective.”

CONCLUSIONS

In Aragón, integral musealization is limited to five cases (most are related to the mining industry) in which the original machinery has been retained and the architectural complex remains whole. These examples show, with different outcomes, several ways of creating an exhibition discourse based on machinery that has been abandoned or no longer serves its original purpose. The success of these museums depends on the capacity to avoid transforming the industrial equipment into uncommunicative museum pieces. Dynamic discourse seems to be the key.

Slightly more examples can be found of musealization with related contents. The six initiatives that fall in this category prove that industrial heritage constitutes an appealing ensemble for exhibitionary purposes due to its privileged architectural features (enormous size and wide spaces), especially in old mining areas in need of new cultural facilities.

With nine identified examples, the most common approach in Aragón is musealization with unrelated content. In many cases, functional needs (together with a lack of awareness on the part of some cultural promoters) have led to the emptying of the building and the elimination of its layout. This disrespectful approach to industrial heritage is unfortunately common not only in Aragón (as in the Instituto Aragonés de Arte y Cultura Contemporáneos Pablo Serrano) but in examples elsewhere in Spain, such as the ancient power station of Mediodía in Madrid, entirely transformed to house the CaixaForum in an intervention that completely disregarded the building’s uniqueness.

Nevertheless, in 11 of 20 museums studied, a (more or less) obvious link connects the container and the content, which shows how much the industrial typology is a conditioning factor in the election of the expositive discourse in place.
Acknowledgments

This research was supported by the Spanish Ministry of Education, Culture and Sports through an FPU grant (Beca para la Formación del Profesorado Universitario), 2009–2013.

Curriculum Vitae

Elena Marcén Guillén has a PhD in art history from Universidad de Zaragoza. A researcher in museology, museums architecture, and recovering heritage, she has worked at the Museo Nacional Centro de Arte Reina Sofia, Madrid.

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INTRODUCTION

Today our cities are to deal with a dense built fabric and at the same time with a constellation of empty inside forgotten or underutilized. Make them usable again, restoring them and giving him a sense within the society, is an action to focus attention on the question of the future of these spaces, wondering about what opportunities they can offer. Often it decides to revive the urban fabric from a particular building, whether it be of historical importance or simply representative of an industrial past of the city. Resilience is the basic concept: the historical artifact is projected into reality. Attempts to produce exchange places and relationships in the contemporary city have led to the creation of non-places, ie spaces without identity, relationship, history.

THE FRAGMENTS OF THE CITY

In urban areas the gap is diversified, open, collective, it produces movement and variation. In the contemporary urbanization process the void assumes new value going to be background to be a definite figure. “Les oubliés”, the fragments of the city, become active materials of the urban project and the indefinite distances evolve into possible design tools. With the uncontrolled expansion of the city, with the wild zoning that isolates some buildings of the post-industrial city, the distance becomes only a free space, undeveloped, which generally separates elements, parts, fragments scattered in urban areas, among which becomes necessary to establish a new principle of rationality. The latter could be restored precisely through the spaces forgotten the service sector, too often associated only with non-active environments, asociality. When we are talking about “restoring” the thought is aimed directly at the monument intended as magnificence of a particular era but the same concept should be used in a broader sense, to recover fragments of urban land has always been linked to the normal course of city activities. Using the aphorism of Luigi Snozzi about the life of the aqueducts that continue to be an integral part of the landscape even after their disposal, it can be said that a structure even if it loses its work, continues to live because man needs it although it has lost its initial task, then you can find out the true quality of architecture only through non-function of it.

THE INDUSTRIAL SPACES AS OPPORTUNITY

In the design of cities, public parks have always been seen as the green spaces, born of an empty area, useless for the town. It is different for the new one: in the contemporary contest, new dimensions of urban spaces show up, in which the relevance of the the landscape and green areas as a result of the shrinking process get really important. Art is the nearest neighbor of uneducated, wild, spaces: this phrase exemplifies how the uncertainty of the “terrain vague” feature can be associated artfully. Wild means not a virgin territory and intact, but it refers to the processes that take place beyond being human. The various parts of the industrial complexes are assembled in new ways to create environments and atmospheres suitable for recreational activities and sports. The ecology and eco-sustainability play an important role in this type of redevelopment. The result is a symbiosis between elements of different nature with the aim of giving new life to a place otherwise left to itself: the city accepts its industrial
heritage that has dramatically altered its natural conditions. The general idea of this new approach to landscape design, as with the Landschaftspark Duisburg North (Fig. 01), is to preserve the identity of the place, witness of a strong story for the company, looking at the project as a temporal and special process. In the North Duisburg landscape park was founded in the populated district of Ruhr, along the Emscher River, on the site occupied by the former steel industrial area of the Thyssen: it has been transformed into a multi-functional park that is a combination of industrial and cultural heritage. It’s offered a landscape by opposing and contrasting aspects. The idea of Peter Latz was to preserve the identity of this witness place important for society: the goal is to preserve the most of the site and to interpret the various components of the place to give them life with features and different meanings. In this post-industrial park, where the industrial ruins mingle with nature, living very different structures: a museum of steel, the boulevards to stroll, suitable places to play and sports activities, other destined to parties and cultural events. Most of these stolen pieces to industry present themselves as places to discover, to experience and conquer through an approach which involves all the senses. Another element of analysis could be the post-industrial city of Brussels, whose study is part of my doctoral dissertation project. Brussels is, until the late ’70s, the main industrial city of the country as regards manufacturing. Already in 1860, it was one of the largest cities on the continent, when Belgium was the fourth-largest economy. The Charleroi Canal, the only channel that currently crosses the city, was the port of the city. The spaces that follow one another along it offer an opportunity to create equipment that are missing to the districts bordering the channel: green areas, sports halls, multi-purpose centers. Since the canal was one of the engines of the city center, you will find the small and medium business, the old industrial structures, which still give a gray vision of this stretch while going more on the outskirts meet place of great scenic interest. The restoration of some buildings, turned into flagship projects, creates new urban poles and start to improve the neighborhoods that are currently only negative symbols of urban life. The regenerate some small industries can start a process of regeneration of entire neighborhoods. And ‘what we tried to do with the “Brasserie Belle Vue” (Fig. 02), situated along the canal at one of the old doors of the city, the Porte de Ninove. Already the image of the building is very strong, almost inaccessible, like a fortress, and the project aims to alleviate all through visual links to the heart of the block. The Old Malthouse will be renewed following the environmentally friendly standards and will house the Hotel School function, while a new passive structure containing a Hotel will be joined to it. For the City, which owns the site, it was faced with a project that would combine urban renewal, upgrading of historical and industrial heritage,
sustainability and inclusion of tourism-related facilities and vocational training. The project changes the location of the site with respect to the neighborhood: while at the beginning it was mostly open to the Brussels city canal, now caters to the molenbeek district, the protagonist not so happy events in the last year. Work began in August 2012 and ended in August 2015 with a cost of 10,800 million euro. Creatures That Make up a healthy ecosystem. Nature tries to regain what Has Been taken away by providing the reuse of areas marked by industrial activities.

CONCLUSIONS

Working with this places could give value to the absence. The perception of emptiness is therefore not a value in and of itself, but relational characteristic. What do this spaces have relational features? First it gives centrality to the concrete man, to his perception, to his needs. In architecture we have to give importance to the user since it is the one that fits and makes concrete space. The industrial vacuum could be the measuring element of the new dimension of the city, capable of feeding new figures and images, for example that of the porous city, in which is precisely the void between an object and the other to allow the movements. There is a merger between the two to make the city livable and ensure that it is provided with public spaces that stimulate human relationships. At the heart of urban design will be the person and the best unit of measurement for the city it will always be the human scale.

CURRICULUM VITAE

The Architect De Felice R., graduated with an international thesis in architecture “Bruxelles_The Other Side of the Ring” in 2014, is doing her Ph.D at the Second University of Naples. She carries out her research at the “Università Cattolique de Louvaine”.Brussels, and at the “Archives d’Architecture Moderne”. Civa, studying the urban movements influencing the current structure of the city.

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The Importance of Industrial Heritage: The Case of Ceramica Ligure Vaccari

INTRODUCTION

The term cultural heritage typically suggests certain kinds of cultural assets, such as environmental heritage, paintings, and other artworks. Often forgotten in such discussions is the fundamental role industrial heritage plays in the artistic environment. A new field, industrial archaeology, deals with the history, protection, and preservation of industrial heritage. Why is it so important? Because the past is closely connected with the history of manufacturing and economic growth.

While preparing my master’s thesis, I studied an exemplary case of industrial heritage: the Ceramica Ligure Vaccari in Santo Stefano di Magra (La Spezia, Italy), which represents a rare case of preservation of early 20th-century warehouses and a workers’ village (Fig. 01).

METHODS & METHODOLOGY

The first stage of my research focused on reconstructing the history of the factory. To do so, I researched in the factory archive and spoke with people who had worked there.
The Ceramica Ligure Vaccari in Ponzano Magra was one of the largest factories in the ceramic industry during the 20th century. Its importance was linked to its production of glazed ceramics, which were exported around the world and used for both flooring and ceramic mosaics.

The plant was established at the end of the 19th century as a brick factory. Thanks to the intuition of the factory’s Genoese owner, Carlo Vaccari (who was well aware of the clay’s potential), production shifted to ceramics. The fortunes of the factory rose in the 1930s as it became the first to produce ceramics in Italy. After a shutdown due to the war in 1944–1945, factory sales increased in the 1950s and 1960s, at the height of the postwar economic boom.

In the 1970s, weakened by battles in defense of employment rights, a lack of liquidity, and the short-sightedness of the business class, the factory entered a period of deep crisis that led to its failure in 1972. Ceramica Ligure Vaccari then underwent several changes of ownership, but the new owners were unable to restore the factory to its former glory.

Two years after the Austrian group Lasselsberger acquired the factory in 2004, it closed for good.

Facing the loss not just of a simple factory but of a symbol of the community of Ponzano, the municipality of Santo Stefano Magra (in particular, Mayor Juri Mazzanti) decided to preserve materials from the factory that otherwise would have been quickly dispersed. Thus, in 2007 all documentation relating to the factory was taken to a warehouse owned by the city.

The archived materials comprise not only documents (e.g., tracing paper, seals, floor plans) but artistic mosaics and old machinery. For this reason, the archive was divided into three thematic areas:

- technical office;
- direction; and
- laboratory.

The collection allows for a wider knowledge of the factory and its dynamics, including its extensive use of skilled workers and the various stages of production of the so-called grès rosso ponzano. This unique type of sandstone, which became popular all over the world, is named for the color of the clay extracted in Ponzano.

The typical sandstone tile produced by the factory had a 2 x 2 cm shape. This format was made popular thanks to futurist artists such as Fillia and Enrico Prampolini, who used it for their mosaics, including the mosaics in the Palazzo delle Poste in La Spezia.

The Ceramica Ligure Vaccari is one of the few instances of an Italian factory with its own company town. Carlo Vaccari understood the importance of giving a home to those workers who came from other regions, so he created a cutting-edge village made up of houses for the workers and a master’s house. Later, the engineer Giulio Mazzocchini built a company store, in which there were a dining hall for office workers, showers, and bicycle storage. Finally, Luigi Ferrari designed the Church of St. Carlo Borromeo in memory of the company’s founder. Together these elements created an independent community that grew along with the factory (Fig. 02).

RESULTS & DISCUSSIONS

The closure of the Vaccari factory had a deep impact on the community, which, having enjoyed the benefits of the factory for more than a century, had to find a new identity.
For this reason and thanks to the willingness of the city of Santo Stefano di Magra to prevent the factory from slipping into oblivion, the site was turned into a new attraction, no longer industrial but cultural. Nuovo Opificio Vaccari per le Arti (NOVA) was created to save the complex and its memory by returning the area to its central role in the development of the region and its communities.

Thanks to an innovative public-private partnership, the city took a portion of the area in free loan for eight years, turning it into a cultural district. Some buildings were assigned to private cultural operators, such as a contemporary art gallery and an enterprise product design company that reuses industrial waste.

Collateral to these activities and with the aid of regional funding, the municipality purchased the former calibration stable, one of the oldest and most valuable buildings in the factory complex, to preserve the ceramic mosaics on its facade. This building now houses the Vaccari Archive, which preserves what is left of the documentation of the various offices, along with examples of the machinery used in the factory.

CONCLUSIONS

My research draws on the resources contained in the archive, supplemented by memories of former factory workers.

NOVA marks a new stage for the factory, which is no longer connected to industry but to cultural production and in this way is creating a new future for the community of Santo Stefano di Magra.

In my opinion, this is the best way to reuse a factory, as it both preserves the past and looks to the future.

CURRICULUM VITAE

Alice Cutullè is an art historian. She has a bachelor’s degree from the Università di Pisa, a master’s degree in art history from the Università di Genova, and a second master’s degree in beni storico artistici from the Scuola di Specializzazione of the Università degli Studi di Padova. She deals with art in general, architecture history, and industrial heritage.

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2 Carlo Vaccari (1865–1919) was the founder of the factory in Santo Stefano di Magra. He was a Genoese industrialist. Five of his sons worked in the factory.
3 Titled Le comunicazioni terresti e marittime and Le comunicazioni telegrafiche, telefoniche ed aeree.
4 Cutullè, A., Ceramica Ligure Vaccari: Storia, archivio, produzione, Genoa, Sagep, 2013.
Niels Bohr’s Guesthouse: Tradition and Modernity in Denmark

INTRODUCTION

Despite the shift in meaning of the aesthetic expression and the creation of a new architectural image, what Sigfried Giedion (1888–1968) called the “third generation of architecture,” developed in Denmark, shares values with the traditions of buildings of the past. Its roots can be found in Danish tradition: in handicrafts, the skilled use of materials, and the knowledge of vernacular construction. It combines all artistic disciplines and traditional crafts related to building design and construction in order to advance and regenerate itself through the absorption of international influences, thus achieving seamless interaction. It is forged in the emergence of a common ideal of enormous personality that today has come to be valued as an authentic contribution to the world of architecture from a culture that was formerly seen as peripheral. Its objective is to achieve authenticity by maintaining a common cultural identity while renewing itself upon the foundations of the familiar.
The aim of this investigation was to unveil some of the keys to Danish modernity, using Vilhelm Wohlert’s first work, in order to recognize, discover, and revive its legacy, whose lesson is seen as entirely of the present.

METHODS & METHODOLOGY

Backgrounds, figures, and buildings relevant to the Danish tradition were analyzed, along with examples of Japanese traditional architecture and American architecture. Connections and shared interests were identified.

RESULTS & DISCUSSION

The Dane Jensen Klint (1853–1930), a fundamental figure in Denmark’s journey toward modernity, defended a distinct respect for context, craftsmanship, materials, and the importance of details. He was inspired by mathematics and nature’s rules of growth. His son, Kaare Klint, introduced the elder Klint’s teachings at the Royal Academy of Fine Arts in Copenhagen, the so-called School of Klint, where Danish architect Vilhelm Wohlert (1920–2007) and others studied. Thus did they share a feeling for the landscape, topography, materials, and climate, and an architecture begotten in part by nature, toward which Jensen Klint had blazed the trail.

Niels Bohr’s guesthouse (1957) was Wohlert’s first building. Built in a period of blooming modernity, rooted in the Danish tradition and the principles of the Skønvirke, it represents a reconciliation of both vernacular lessons and the international impulses of American architecture and Japanese tradition (see Fig. 01, Fig. 02, Fig. 03).

Wohlert’s work encompassed a variety of commissions. Despite their disparate scales and functions, they show his commitment to human comfort, his dedication to precise construction, and a respect for materials. These features are nowhere more evident than in the modest guesthouse he created for Niels Bohr, winner of the Nobel Prize in Physics (1922), in a remote virgin forest in the north of Zealand.

He created an abstract self-contained object that preserves the open space of the clearing around it. The architect’s task is to understand the vocation of the place, establishing a new site where architecture and nature will live together. The individual is readied for the experience of architecture, perception is slowed to deprive the user of mental assumptions, and in this way a level of intimacy is reached.

The building alludes to the modern concept of the pavilion as a piece that is conceptually its own entity. The enclosure is not merely light but confers that aspect of delicate work that sits mildly. The adopted solution seems deceptively simple: a floating timber-clad box over a flat platform, opened to the southwest and closed to the northeast. The wood box has the responsive character of a living organism that is continually changing according to variations in daylight or temperature. It also has the ability to move itself and to mobilize space through the flexible positioning of its layers. It alludes to the fact that everything in nature is constantly undergoing change and evolution. Thus, there is a connection to the surrounding nature and to the variations that take place with the passing of time or with the seasons. But due to an innate sensitivity that can trace its roots to the Dane’s culture of agriculture, the Danish attitude toward nature is not domination but conciliation.
In that connection with nature, natural light plays the part of protagonist. Daylight, the distribution of which varies so throughout the year in these latitudes, marks the architectural spaces and the mood of their users. The perception and the meaning of the Nordic light, which casts no sharp shadows, play a significant role in the experience of space and form. Its effect enables surfaces to manifest their spatial value through their texture. Wohlert is expert in this.

CONCLUSIONS

Beautiful parallels to traditional Japanese architecture are established in the investigation, a culture where the link between nature and life is constant. The pavilion pays tribute to transformation, associated to the change between seasons.

Folding doors and shutters generate extensions of the rooms. The unexpected lack of closure, the air circulation, and the elements that give flexibility create an evocative air of freedom and fluidity, reminiscent of the idea, first formulated by Heraclitus, that the world is in a state of flow. Flow that, at a basic level, is based on trust. The horizontal plane predominates, offering security and order, in the face of the force of gravity. A close relationship with the land is established, and it gives security to users.

The pavilion could be seen as the Japanese art of flowers, *ikebana*; that is, rigorously constructed, where is produced a circulation of air between its components. *Ikebana* is “the art of space”; it is something alive whose emptiness projects tension and power. It expresses features that are also present in the guest house: the asymmetrical balance; the third dimension; and an interest in the material—its texture and the emotional effect that emanates from it.

Wohlert knows the material, exhibiting his love for it, taking advantage of the power of the finish, respecting its capacity to provoke emotions. What stands out is the use of natural materials that express their age and their wear together with the enriching experience of time. The wood ages and returns to the earth, and in this way the building disappears. Thus, a connection is made with both ecology and death. The concept of the elimination of the superfluous and the exhibition of a material’s natural aspect are common to East Asian cultures.

The beauty of the building is based on its usefulness, on the proportionality of its parts, and on harmony with the environment, where it is assumed that exaggeration is not needed. Scale is valued. The architecture is adjusted to the human scale, within which lies the aesthetic effect. The building’s commitment to human comfort is shown. It is an architecture to be lived from inside. The connection with American architecture is clear; however, the great American masters of the Bay Area and their work have the closest connection.

The modular framework of the vernacular tradition of building with timber, from Danish rural homes, is present. An anonymous architecture, one where constructive form is marked by structural order, component of its enclosure, where a unified system of construction fits to measures, is simple and well proportioned. The “Long Danish houses,” which perform the more stable structure of the Danish tradition, and projects made entirely from the wood that typifies Danish
functionalism, are a source of inspiration for Wohlert. The study suggests that the look to the vernacular could be a response to the loss of identity brought about by globalization. The vernacular may concern a high level of modernity, supplying buildings and settlements that are more sustainable; it can be an answer to the search for both the identity and the essence of architecture.

Design is developed at all scales, from the plan of situation, to the definition of the construction details and assessment of the joints, where the furniture is integrated, forming a comprehensive work. Users play an important part. A psychological character of architecture emerges. Sensation is used as a tool in the creative process, where the sense of touch is valued above the strictly visual experience. Wohlert’s work is a lesson about the thought that nature, the lives of building’s inhabitants, and architecture itself are united; where a world of relationships is gentle to human beings; it represents an architecture that is needed in the time we live in.

Curriculum Vitae

Carmen García Sánchez studied architecture at the Escuela Técnica Superior de Arquitectura, Universidad Politécnica de Madrid, where she obtained her PhD. Her thesis, “1950 en torno al Museo Louisiana 1970,” analyzes several buildings in Denmark. As a licensed architect, she works to develop architectural design projects at her office in Madrid.

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1 “Skønvirke” is a Danish version of Arts and Crafts and Deutscher Werkbund.
ARCHITECTURAL AND ARCHEOLOGICAL HERITAGE
INTRODUCTION

The Four Sewers Fountain of Daganzo is one of the items of cultural heritage included in the Plan of Historic Gardens and Fountains, promoted by the Community of Madrid and containing a list of 583 fountains and 84 gardens. This plan provides information about the site, known historical data, a description of the formal and constructive characteristics, and so on. It concludes with proposals for restoration and enhancement.

The Community of Madrid, through its General Directorate of Cultural Heritage, has signed an agreement with the Universidad Politécnica de Madrid to promote the practical knowledge of students in the Master in Preservation and Restoration of Architectural Heritage program and to train these future specialists on historic heritage. This management model is intended to support the conservation of cultural properties in the Plan of Fountains, as well as those included in the Plan of Historic Bridges and the Plan of Visitable Sites.

OBJECTIVES & METHODOLOGY

Prior to the restoration project, a series of analyses and studies were carried out to deepen our knowledge of the fountain. The most relevant diagnoses are summarized below.

Role of the Fountain in Daganzo

The Four Sewers Fountain is in the Valley of the River Henares, a zone characterized by its richness in groundwater and historically used for human settlement.

At the territorial level, the fountain is part of the livestock watering system that was built along the Vía Pecuaria Galiana. At the urban level, it is a basic element in the establishment and development of human populations.

Its purpose was functional and evolved in phases. Initially, two pylons were built, one for the human population and one for animals. Later, a two-basin laundry facility was added downstream, thus optimizing the water cycle. Lastly, the laundry was sheltered to improve labor conditions.
In addition to the utilitarian function, the Four Sewers Fountain became a landmark in the town, as it created a strong social space symbolizing the value of water to the community (Fig. 01).

**Historical Documentation**

Although its origin is uncertain, the fountain can be dated to sometime between the late-16th century and the early 18th. References to a water supply appear in 1579 and in 1847. In 1985, a paving project for the square included laundry “demolition and relocation.”

**Petrological Analysis**

To assess the causes of water leakage at the fountain and determine what actions to take for restoration and enhancement, a series of analyses and trials were conducted, including visual inspection, ultrasonic survey, in situ water absorption, infrared thermography, petrographic analysis of thin films, and determination of surface hardness by rebound permeability measurements.

**Archaeological Excavation**

An archaeological excavation led to the discovery of important remnants of the old laundry brick and the stone foundation of the covering building, as well as the original cobblestone boulders placed around the pylon and the original stone slab foundation. The team in charge of the restoration works proceeded to study, document, and partly integrate these ancient remains in the restoration project (Fig. 02).

**Objectives and Criteria**

The intervention focused on three targets: recovering the fountain’s original face (Fig. 03), partially buried when the square was paved in 1985; preserving the memory of the demolished laundry; and conditioning the pylon and its surroundings to restore the area as a recreation and meeting space that evoked the neighborliness of the original.

To achieve these goals, the ground level was lowered to its initial level; the original height of the guardrail and the pedestal of the sewers were restored; and the laundry’s footprint was marked on the ground.

According to the general criteria of intervention included in the *Plan of Historic Gardens and Fountains*, the following principles were adhered to:

- Compatibility of old and new through the reinterpretation of what exists.
- Global integration in the whole, but marking new interventions in detail.
- Characterization of newly introduced elements by their modern design and the use of a unitary architectonic language to ensure contributions can be read clearly.
• A cleaning exercise to highlight the value of the historical object, by integrating the facilities on the ground and the perimeter wall.

• Conservation and protection of the remains of the original laundry.

• Proposal for urban improvement, involving a partial pedestrianization of the square.

RESULTS & DISCUSSION

Restoration

Restoration had to account for the historical and architectural significance of the monument. Thus a multidisciplinary team played a fundamental role. Treatments were tested in situ, and team members evaluated the results as a group so as to promote the agreement of all actors on intervention decisions.

Restoration work included the following:

• The stone was cleaned to conserve and preserve cultural property and allow a true picture of its status while preparing it for subsequent treatments.

• Cement was substituted for limestone and/or mortar. Cleaning allowed the status of older Portland cement reconstructions to be determined and for removal methods to be evaluated.

• The use of cement mortar joints had unfortunate consequences for the conservation of the fountain due to the mortar’s lower porosity and elasticity, its hardness, its thermal and mechanical behavior, and its high content of soluble salts, which crystallized the stone material. Therefore, the existing cement was replaced with lime mortars.⁶

Fig. 03. Analysis of conditions in three periods: before 1985, from 1985 to 2015, and present day.
Pylons were waterproofed. One of the main problems that can arise when restoring historical fountains involves waterproofing. In most instances, the goal of waterproofing takes precedence over or simply does not consider the impact on the conservation of stone. This has led to the indiscriminate use of resins directly applied to the stone, which consequently impairs it. We went further and planned for the future reversibility of our treatment by using a layer of intervention, an easily removable layer between the stone and the waterproofing compound.

**Divulgation**

To make citizens aware of the intervention, signage was integrated into the pavement noting historical events and explaining the pylons’ role in the water cycle.

Furthermore, an exhibition entitled *Fuentes de Daganzo, aguas con historia* was organized by the architect V. García, the Daganzo city council, and the municipal archive, in collaboration with the Community of Madrid.

**CONCLUSIONS**

The intervention in Daganzo restored value to the Four Sewers Fountain, which regained its presence and original proportions. Furthermore, the intervention restored to collective memory such historical elements as the old laundry, whose footprint is now marked on the pavement.

Moreover, thanks to the promotion of these efforts by the Comunidad de Madrid, Dirección General de Patrimonio Cultural, this urban space was regenerated. The intervention focused not just on a single object but encompassed the nearby environment, thus improving the entire area’s social uses and ensuring that urban facilities complied with current requirements.

**ACKNOWLEDGMENTS**

Thanks to the Comunidad de Madrid, Dirección General de Patrimonio Cultural, Area of Conservation and Restoration; Instituto de Geociencias (CSIC-UCM), Petrology Group applied to Heritage Conservation; Proiescon, S.L.; Orogreg Building Engineers, S.L.P.; Reno Archeology; and VGARQ.COM.

**Curriculum Vitae**

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José Juste Ballesta has a doctorate in architecture. He is a technician with the Comunidad de Madrid, Dirección General de Patrimonio Cultural, as well as an associate professor with the Escuela Técnica Superior de Arquitectura de Madrid, Universidad Politécnica de Madrid, and a professor in its master’s degree program in preservation and restoration of architectural heritage.

Elsa Soria Hernanz is a professor in the Techniques and Practices Department of the Escuela Superior de Conservación y Restauración de Bienes Culturales in Madrid.

**BIBLIOGRAPHY**


(Endnotes)

Deterioration Assessment of Three Types of Limestones from Pasargadae World Heritage Site in Iran

INTRODUCTION

Pasargadae was the first dynastic capital of the Achaemenid Empire, founded by Cyrus II (“the Great”) (559–530 BCE), in Fars, homeland of the Persians and one of Iran’s United Nations Educational, Scientific and Cultural Organization World Heritage Sites. The capital included the mausoleum of Cyrus the Great, three royal palaces (gatehouse, audience hall, and residential palace), a fortress (Toll-e Takht). The remains are outstanding examples of the first phase of royal Achaemenid art and architecture and exceptional testimonies of Persian civilization (Fig. 01). The monuments of the Pasargadae site are made with three types of colored stone: beige, green-gray, and dark gray. These stones are classified as limestone, but their composition and texture are different. The beige stone is pure limestone, while the green-gray and dark gray stones are limestone with a minor amount of quartz grains.
Different types of deterioration were identified in Pasargadae stones: scaling, peeling, and pitting in the beige type; disaggregation and a powdering pattern in the green-gray type; and exfoliation in dark gray type. Variations in weathering were also observed, despite the fact that all three stone types were limestone and were subjected to the same environmental conditions. This made us eager to find out more about the decay patterns and the factors that caused the different rates of decay.

The first step in the conservation of an archaeological building is to identify the composition and evaluate the degree of deterioration. Hence, the aim of this research was to evaluate the decay process of each stone and identify the main decay factors as a first step in the conservation of the stones used at Pasargadae. To identify the deterioration patterns and the probable decay agents, several samples were taken from the surface of the monuments: four from Cyrus’s tomb that show a variety of decay patterns, two from the winged figure at the site, and two from Toll-e Takht that seem to be covered by a patina layer (Table 01).

### METHODS & METHODOLOGY

High-magnification images and analyses were carried out using a BRUKER Leo-Gemini field emission scanning electron microscope (FE-SEM) coupled with an energy dispersive spectrometer (EDS). Samples were carbon coated prior to the analyses.

X-ray diffraction (XRD) was performed to identify the mineralogy using a Panalytical X’pert Pro MPD diffractometer with automatic loader. Analysis conditions were: radiation CuKa (λ: 1.5405 Å), 3–60° 2θ explored area, 45 kV voltage, and 40 mA. X-Powder® software v.12 was used to interpret the diffractograms.

### RESULTS & DISCUSSION

In the beige stone, some dissolution and recrystallization processes were observed, as well as some pitting of the surface. Some of these holes were blocked with cells similar to lichen cells, and others were not. This phenomenon was probably the result of chemical activities of lichen on the stones, because the pitting is related to the endolithic thalli and the embedded lichen fruiting body inside the stone holes. Dividing bacteria cells of lichen in all samples of beige stone, as well as organic filaments (fungal hyphae), were observed. Also, some recrystallization occurred in holes that also contained organic remains. The recrystallization was likely related to biomineralization, a byproduct of lichen activity on limestone. Lichen respiration generates CO₂, which in combination with water forms carbonic acids. Metal-complexing compounds are also produced by biogenic processes that cause mineral dissolution. Studies have proved that oxalic acid is one of the main compounds produced by lichens. Concentrations of oxalic acid might be sufficiently high to precipitate oxalate salts on the surface of thalli within lichens, including calcium oxalate. Also, several studies have indicated that the formation of oxalate (and the amount formed) depends on the species of lichen, the substrate, and environmental factors. In addition, according to

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Location of collection</th>
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<tbody>
<tr>
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<td>Southwest of Cyrus Mausoleum</td>
<td>Surface of the stones having pitting pattern</td>
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<tr>
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<td>Southeast of Cyrus Mausoleum</td>
<td>Scaling surface</td>
</tr>
<tr>
<td>B.K.3</td>
<td>Northeast of Cyrus Mausoleum</td>
<td>These blocks are half a day in shadow and half in sun</td>
</tr>
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<td>B.K.4</td>
<td>Northwest of Cyrus Mausoleum</td>
<td>These blocks are almost in shadow and probably suffering by freezing</td>
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<td>Gateway Palace Winged Figure</td>
<td>Patina layer</td>
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<tr>
<td>B.KD.2</td>
<td>Gateway Palace</td>
<td>Lichen part</td>
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<td>B.TT.2</td>
<td>Northeast of Toll-e Takht</td>
<td>Patina layer</td>
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<td>B.TT.3</td>
<td>Northwest of Toll-e Takht</td>
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<tr>
<td>B.ZS.1</td>
<td>South of Tomb of Cambyses I</td>
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<tr>
<td>D.G.1</td>
<td>Base of pins in Residential Palace</td>
<td>From exfoliation</td>
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<td>D.G.2</td>
<td>Gate of Audience Palace</td>
<td>Black stones used in the gate</td>
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<tr>
<td>G.G.7</td>
<td>Lower floor of Residential Palace</td>
<td>Disaggregated part</td>
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<tr>
<td>G.G.8</td>
<td>Lower floor of Residential Palace</td>
<td>Intact part</td>
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Table 01. Samples collected for analysis from the surface of the monuments
the studies, micrite is also a possible biological product, but only where a lichen thallus has established. SEM observation confirmed that the studied materials had the different recrystallization shape and size to be micrite.

The patinas on the samples taken from the northeast and northwest surfaces of Toll-e Takht and from the back part of the winged figure were reddish in color. The patina of the winged figure had a different decay pattern in some parts, including intact and lichen-damaged parts and the presence of some pitting on the surface. Under high magnification, the intact patina was completely covered by a thin layer, but the patina parts affected by lichens had been removed in some areas. Cracks, pitting, and erosion were also obvious. EDX analysis of the patinas on the winged figure and the Toll-e Takht samples gave different results despite similarities in appearance. The winged figure’s patina was rich in Ca, Si, and P, while the Toll-e Takht patina contained Ca, Mg, Si, Fe, Al, and K (Fig. 02). XRD analysis of these two samples did not identify any oxalate phases, possibly because of the low concentration of oxalate within the stone.

In the dark-gray stone, clay and quartz (5% by weight), secondary calcite veins, and a compact network of calcite were observed, along with microcracks that had probably been caused by clay shrinkage (Fig. 03). Some weak points of the dark-gray stones were the result of the presence of secondary calcite veins as well as clay minerals. Clay minerals are sensitive to moisture; thus, clay swelling might have been the main factor in the decay process of the dark-gray stones.

The green-gray limestone was composed of calcite, along with quartz grains and clay minerals (the total amount of the latter two components was 17% by weight); it showed disaggregation of grains and partially dissolved calcite crystals. In some parts, organic filaments were observed. The dissolution of calcite crystals may have resulted from lichen activities or acidic rain. By affecting acidic water on calcite and clays (causing calcite dissolution and clay swelling), quartz grains do not change, and powdering is probably the most common deterioration pattern in this type of stone.
To confirm the existence of salt as a decay factor, XRD analyses were carried out on parts of the samples that were deteriorated, as indicated by powdering or scaling (Table 02). XRD results showed no salts in the samples.

### CONCLUSIONS

The investigation showed that the deterioration processes of three types of stones were completely different. The decay patterns in the beige stone were mainly the result of lichens causing both mechanical and chemical deterioration. Patinas in these types of stone comprised a variety of elements even when the patinas appeared similar to the naked eye. The patina of Toll-e Takht was composed of soil elements with oxalate or calcite deposition. In contrast, the patina layer of the winged figure was composed of calcium phosphate formed by lichen activities. Disaggregation phenomena in the green-gray stone were probably caused by heterogeneity related to the presence of clays and quartz grains (17% by weight). Humidity was likely one of the main decay factors at the Pasargadae site. Moreover, the presence of clay minerals in the dark-gray stone could have increased stone deterioration if these phyllosilicates suffered swelling in the humid environment.

### CURRICULUM VITAE

Atefeh Shekofteh is a PhD student in the conservation of historic and cultural artifacts at the Art University of Isfahan, Iran. She is a visiting research scholar in the Department of Mineralogy and Petrology, Universidad de Granada.

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### BIBLIOGRAPHY


<table>
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Table 02. XRD analysis results

(Endnotes)

The Preservation of Namibia’s Vernacular Architecture: Toward a Sustainable Development of Local Communities

Rui Maio, a Elao Martin, b Jon Sojkowski c

a Universidade de Aveiro, Portugal
b Namibia University of Science and Technology, Windhoek, Namibia
c Independent Architect, United States

INTRODUCTION

The built vernacular architectural heritage plays a fundamental role in safeguarding and promoting the cultural characteristics of communities and their relationships with their territory, contributing decisively to the expression of the world’s cultural diversity. Vernacular heritage encompasses not only the built environment but intangible aspects that are intrinsically connected to communities, such as building techniques, lifestyles, territorial connections, and transmission of skills from one generation to the next. Moreover, approximately one-third of the world’s population is thought to live in vernacular structures. Vernacular architecture is thus important not only for its cultural outstanding universal value (OUV) but as a feasible housing solution for the sustainable development of local communities worldwide, which might help strengthen the category of livable architectural heritage. The preservation of ancient building techniques and materials and the enhancement of the living conditions of vernacular structures are thought to revive people’s faith in their own culture. However, several globalization-related phenomena are making vernacular heritage increasingly vulnerable; it faces serious problems of obsolescence, internal equilibrium, and integration. Principles for the care and protection of our built vernacular heritage are needed.

Southern African countries can boast of an extensive natural heritage. The region is internationally acclaimed for the richness and diversity of its flora and fauna.

Even though largely ignored by Western scholars and decision-makers, a few relevant projects and initiatives have been recently carried out. For example, the African Vernacular Architecture project, which aims to collect and store photographs of vernacular architecture in Africa in an open-source database, invites explorers to contribute by sharing their own photographs.

Fig. 01 Sketch of some of the most common typologies of huts and their location in northern Namibia.
The present article aims to provide insights on the main issues that are contributing to the faster degradation and potential extinction of vernacular architecture in rural areas of Namibia by documenting the OUV of a vernacular typology commonly observed within the Owambo tribe in northern Namibia. The goal is to raise awareness of the urgent need to protect not only these structures’ integrity but the respective sustainable building techniques as living traditions.

**OWAMBO TRIBE CASE STUDY, NORTHERN NAMIBIA**

The region discussed in this case study has traditionally been known as Owamboland and is in the far north of Namibia between Etosha National Park and the Angolan border (Fig. 01). After Namibia’s independence on 21 March 1990, Owamboland, which is by far the most densely populated rural area in Namibia, was divided into the regions of Omusati, Oshana, Ohangwena, and Oshikoto.

Among the traditional Owambo, family groups live in round, stockaded homesteads (*ongandjo*) built on the raised ground between *oshanas* (shallow, seasonally inundated depressions), surrounded by a few hectares of cultivated land. With the resulting scattered settlement pattern, the homesteads are able to constitute villages governed by selected headmen who report to local and traditional authorities. The homestead structure is composed of several quarters of huts, enclosed by a wooden palisade or millet-stalk fence to constitute a home that also includes articulated walkways and corridors to control movement patterns within the household. In the past, a wooden palisade (made of tree trunks) fortified the homesteads and protected occupants from wars and cattle raids. The palisades also differentiated Owambo architecture from that of its neighbors. However, extreme deforestation, forest fires, and veld fires have greatly reduced wood supplies in the region, leading local communities to search for innovative building techniques and materials. One outcome has been the appearance of small adobe huts, again differentiating the tribe’s vernacular architecture and building technique from others (see Fig. 02).

The vertical structure of the adobe huts (see Fig. 03a) is mainly formed by load-bearing masonry made of adobe blocks with a poor mortar and erected using manual adobe production. This ancestral earthen construction technique, still in use in several African countries, consists of manually shaping or sculpting units of plastic earth, which are then sun-dried before being used to construct walls. Figure 03b shows the detail of connection between the thatch roof and the vertical structure. Figure 03c reflects the dismal trend of abandoning and replacing vernacular architecture and ancient building techniques with new building technologies and materials, a trend that is unlikely to foster the sustainable development of local communities.

**Fig. 02 Location of the Owamboland region and exact site of the documented homestead.**
SUSTAINABLE DEVELOPMENT OF LOCAL COMMUNITIES

Sustainability can be broadly defined as development that is economically viable and socioculturally acceptable and minimizes environmental degradation. The following principles promote sustainability in construction while preserving vernacular architecture:

• rational use of local materials and resources rather than importing new technologies and materials at a higher cost and with a larger carbon footprint;

• site planning and management to protect vernacular cultural heritage from hazards, avoiding population displacement and local communities’ growth and development;

• rational water management by introducing strategies for rainwater harvesting and water recycling;

• promotion of safe and healthy environments by guaranteeing good performance in indoor air quality (through use of natural light and air and improved solar exposure through building orientation), acoustics, thermal comfort, health conditions, and energy efficiency;

• reduction of waste through recycling.

When addressing sustainable development, which should be centered around social equity, knowledge transfer and the need for community participation in the preservation of cultural identity are crucial considerations. Thus, not only do local Namibian communities need to be sensitized to the cultural value of vernacular architecture, but the urban myth that the living conditions provided by this type of construction are not decent needs to be demystified. The sustainability of vernacular housing is undeniable, even though the construction technique itself can be improved to achieve better structural resistance and better health outcomes for inhabitants. Nonetheless, the particulars of this construction process need to be taught by experts to local communities to guarantee structural quality and occupant safety. Moreover, capacity-building programs need to be put in place to facilitate community involvement and collaboration on the preservation of vernacular architecture. Finally, strategies must be implemented to reduce the vulnerability of homesteads to the most recurrent hazards.

CONCLUSIONS

To safeguard vernacular architecture in Africa, particularly in northern Namibia, more awareness of these structures is needed. Future developments should focus on how vernacular architecture can be adapted to current human needs, including a desire for modernization, in a sustainable way without limiting future generations’ access to past heritage. Moreover, a full architectural characterization of homesteads within the Owambo tribe, as well as the mechanical characterization of building materials, should be conducted. Finally, although not addressed in this article, the impact of the preservation of vernacular cultural heritage on tourism in the Owamboland region should also be considered, as it is potentially a key aspect of local communities’ development and the protection of vernacular heritage.

CURRICULUM VITAE

Rui Maio is a PhD candidate in the doctoral program in analysis and mitigation of risks in infrastructures (infrarisk-) at the Research Centre for Risks and Sustainability in Construction, Civil Engineering Department, Universidade de Aveiro, Portugal. His focus is on earthquake risk mitigation for urban cultural heritage.
Elao Martin is from Namibia and is a master’s degree candidate at the University of Johannesburg’s Graduate School of Architecture in Windhoek, Namibia.

Jon Sojkowski is an independent architect with a passion for African vernacular architecture. He has documented the vernacular architecture in Zambia, Malawi, and Swaziland and is currently in South Africa to document Xhosa vernacular architecture.

BIBLIOGRAPHY


(Endnotes)
Analyze to Assess: Architectural Characteristics of the Traditional Housing of the Casbah of Algiers, Algeria

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INTRODUCTION

This article investigates the architectural characteristics of the traditional houses of the Casbah of Algiers. The historical center was formed by a succession of civilizations. Currently, an Ottoman residential typology of great historic and artistic value is at high risk of disappearing.

The main source for this study was the thesis of Sakina Missoum, an architect trained at Universidad Politécnica de Madrid. Her thesis encompasses the most extensive information about the city, its history, and architecture, providing maps of the Ottoman period and planimetry of many houses in the upper area of the medina. The maps have been the basis for all subsequent studies.

A second source was the rehabilitation plan drafted in 2008 by the Algerian ministry of culture; it shows the current situation in the Kasbah, poverty, and serious deterioration of the buildings. This plan, alongside the manual for rehabilitation, tries to provide the first theoretical guidelines to intervene in this architectural ensemble after it was declared a United Nations Educational, Scientific and Cultural Organization World Heritage Site.

<table>
<thead>
<tr>
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<tr>
<td>I. Type</td>
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</tr>
<tr>
<td>II. Load-bearing walls</td>
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<tr>
<td>IV. Vaults</td>
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<td>X. earthquakes elements</td>
<td>X. Set of houses</td>
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</table>

Table 01. Invariant relationships
METHODS & METHODOLOGY

The work focused mainly on architecture dating from the 17th and 18th centuries. Four representative houses were chosen for presentation in this article. Unlike many, these buildings have not been significantly modified since the end of the French colonial period.

The first step was to establish two different groups of elements: one composed of significant elements at the urban level: mosques, fountains, and shops; the other one made of architectural elements of dwelling, distinguished by having a clear function and not only a decorative presence.

Each architectural element was studied individually using the two main source texts, thus allowing the parts to be located and connected.

The new documentation began by following the plans Missoum had compiled in her thesis, including dimensional details that were described in the rehabilitation manual, in order to redraw and fit in all homes on different levels.

This information made it possible to develop a 3D plan of the four chosen houses.

RESULTS & DISCUSSION

In studying the selected sources, the objective was to compare two different groups of elements: the conditions of the environment; and the architectural elements of the house. We can appreciate the close relationship between architecture and conditions of departure from the place and the problems of adaptation. These two groups have been called “architectural invariant” and “urban invariant” (Table 01).

1. The traditional typology in the Casbah is the patio house, although exceptions can be found. The patio is usually the center of the house, because this allows for four galleries and the distribution of a greater number of rooms in four bays. The patio is sometimes moved to one side to accommodate a retaining wall, thereby allowing only three galleries. This also occurs when houses overlap each other. Thus, the structure of the city changes to integrate them.

2. Load-bearing walls, the main structure in patio houses, comprise a rigid part consisting of masonry brick and a flexible part consisting of wood logs. The walls are designed this way to withstand the horizontal forces caused by earthquakes. They are the result of the builders’ knowledge and experience in an area heavily affected by this type of natural disaster.

3. The rooms have a kind of recess, called a Qbou, inserted though the thickness of the wall and located in front of the entrance to each room and flanked by niches. This element occupies the entire thickness of the wall. This means we can know the chronological relationship between groups of houses, because one of the walls must have been built prior to the other. Otherwise the Qbou would open a hole in the contiguous house.

4. Spaces with larger dimensions, such as mosques, have traditionally been covered by vaults. However, due to a shortage of wood in the region, vaults are also used in residential architecture to make the traditional ceiling. Vaults provided covered spaces, improved stability, and were a good solution to the problem of moisture infiltration.

5. As the population of the Casbah increased, residents dug wells in their homes to provide water for use in household chores. Tahari concludes that although there is no clear rule about where inside the house these wells are located, they do possess continuity among themselves. This indicates that the placement of the wells was communally planned. The wells are commonly found where water falls from the terraces.

6. The residences occupy public space in such a way as to relegate the outside to the background. The patio at the interior of the house is an elemental space used as a distributor, a base of decoration, and an activity center. The new public space is moved to the terraces. The irregular-shaped plot becomes more regular in the main areas of the house.

7. The streets were developed in stages according to their steepness. Commercial spaces and warehouses are the intermediaries between the inclined and horizontal planes of the houses. The entryway, flanked by two doors, is one of the main spaces of the house.

8. Sun protection is regulated by the galleries, and ventilation is provided thanks to patios that play the main role in regulating heat. Convection currents are created by the weight of air, which varies depending on room temperature. A door and windows are to the sides. Over these holes there are usually one to three openings in the walls to facilitate ventilation (Fig. 01).

9. The terraces are where neighborhood life develops. A terrace room called a manzah (meaning “pleasure” or “recreation”) is commonly seen. The manzah is
usually constructed on the west side, extending out from the walls of the house, built above and reinforcing the impression of the space as being like an amphitheater.

10. Several architectural elements work against the horizontal forces caused by earthquakes. These include the flexible/rigid wall, the pointed arches of the galleries and their extensions to the walls for fasteners around the courtyard, as well as capitals with rounds of wood which connect the galleries with the interior walls and the vaulted cellars to provide stability.

In general, the most important structural reinforcement comes from grouping the homes in ways that guarantee greater stability (Fig. 02).

CONCLUSIONS

These are the most relevant characteristics of Ottoman architecture, knowledge of which is needed before interventions are attempted. The Casbah has undergone a process of modernization that has deeply affected the architectural landscape of the medina. If this process continues, its distinctive architecture could become completely lost.

In addition, extreme deterioration and poverty require the government to propose realistic plans that account for both the historic central residential area and tertiary uses (e.g., tourism).
However, any development should require special procedures for the restoration of its architecture. Until now, only certain points of urgency have been identified. In the future, these houses should not be refurbished individually. Instead an organized plan of intervention should be developed for all of the houses, thus ensuring that they continue to function in the ways they were intended (Fig. 03).

Restorations to individual houses, if undertaken without consideration of neighboring houses, may spoil the unique values this architecture possesses and may even damage or destroy neighboring structures.

**Curriculum Vitae**

Sonia Prieto Sanz is pursuing a master’s degree in architecture at the Universidad Politécnica de Madrid.

**BIBLIOGRAPHY**


(Endnotes)


Multihazard Risk Mitigation as a Tool to Aid the Sustainable Development of Local Communities and the Preservation of Namibian Vernacular Cultural Heritage

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INTRODUCTION

Disasters are occurring in Africa with increasing frequency and severity, compounding the challenges to sustainable development and undermining Africa’s prospect of achieving the United Nations Millennium Development Goals. Climatic and hydrological hazards—such as droughts, floods, cyclones, and landslides—dominate the disaster profile of the African region, affecting, on average, around 12.5 million people per year.1 Furthermore, the extremely high social vulnerability in some regions of Africa has the potential to transform minor hazard events into human disasters.

In developing countries, disasters are known to disproportionately affect poor people and have the potential, for instance, to cause food insecurity, human losses, and hardship, constrain progress, and cause damage and destruction to infrastructure and the environment. Hence, the establishment of disaster risk management policies focusing on disaster risk reduction within the broader context of sustainable development are of vital importance. However, reducing disaster risk across Africa requires a radical shift in the current thinking of governments and an even more radical shift from rhetoric and centralized, top-down instructions to decentralization and respect for local knowledge and initiatives.2

OWAMBO TRIBE CASE STUDY, NORTHERN NAMIBIA

The area traditionally known as Owamboland is situated in the extreme north of Namibia between Etosha National Park and the Angolan border (see Fig. 01), and it is by far the most densely populated rural area in Namibia. Many of the villages and farmlands situated on the raised ground between watercourses are flooded after heavy rains, despite the average rainfall in this area varying between 400 and 550 mm (see Fig. 02a). Flooding is probably the most common and most hazardous natural phenomenon in the region, which has experienced severe floods over the last five years,

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Fig. 01. Location of the Owamboland region and exact site of the documented homestead.
causing population displacement, loss of human life and livestock, destruction of vernacular homesteads, crops, and social infrastructure, and severely affecting the livelihoods of the affected communities.

As a result of rapid population growth, scarcity of arable land near permanent water-supply points, changing socioeconomic lifestyles, and township development, many of the Ovambo no longer live in traditional homesteads. During the past two decades, large villages have sprung up in proximity to the main routes. People stay in rectangular houses built with poles, corrugated iron, and other material. The felling of trees for the construction of huts, cattle enclosures, and fences has resulted in extensive deforestation. Other socioeconomic factors affecting deforestation in northern Namibia include population growth, settlement patterns, land use practices, the structure of production, consumption patterns of wood, and valuations related to forests. In Owamboland’s wilderness, settlers not only cut large amounts of forest for poles to construct huts, palisades, kraals, and fences, but they have obliterated most of the tree and bush vegetation on their prospective farm plots. Fire was the settlers’ most powerful tool when clearing land for farms and fields.3

Additionally, forest and veldt fires are responsible for burning 3.5–7 million hectares of forest and veldt every year in Namibia. For example, in 2002, 3.7 million hectares were burned, and in 2001, 5 million hectares were burned.4 Although these figures fluctuate annually, they indicate the seriousness of this hazard in Namibia (see Fig. 02b).

Namibia has also experienced several disease outbreaks (Fig. 02c) that have required state intervention; for example, an August 1970 cholera epidemic struck more than 150,000 people and killed about 20,000.5 Outbreaks of livestock diseases such as foot and mouth disease, as well as outbreaks of anthrax, rabies, and lung diseases, pose a threat to all of Namibia.4

MULTIHAZARD RISK MITIGATION APPROACH

Considering hazards separately has proved to be a good approach for identifying specific health issues linked to each hazard. However, it is also important to identify potential hotspots where the population might be exposed to multiple hazards simultaneously. A literature review by Kappes et al.6 identified not only the main challenges posed by each step of a multihazard risk analysis but discussed current studies and approaches addressing these difficulties. To determine the intensity and regional distribution of the multihazard risk, El Morjani et al.7 assigned weights in a first stage to each of the addressed hazards based on the human and economic impact of each event reported in a variety of databases. Hence, for each hazard, regional averages of indicators were computed, standardized, weighted using the pairwise comparison technique, and aggregated using the weighted linear combination technique.8

Despite the great value of this work, multihazard analysis must account for not only the characteristics of single hazardous events but their mutual interrelations; for example, landslides can be induced by earthquakes and floods can be triggered by extreme rainfall. The fundamental challenge remains how to compare multiple hazards with distinct reference units (nature, intensity, return period, etc.) and complex interrelations.

Fig. 02. Spatial distribution of (a) the average annual rainfall (adapted from the Vision V2030 report); (b) the forest and veldt fire outbreak (adapted from NDRMP 2011); and (c) both human and livestock disease outbreak (adapted from NDRMP 2011). Sources: Republic of Namibia, Vision V2030, Windhoek, Republic of Namibia, 2004; and Republic of Namibia, National Disaster Risk Management Plan, Windhoek, Republic of Namibia, 2011.
The multihazard risk approach presented in this article (see Fig. 03) is based on a multihazard risk index, which results from the multiplication of the hazard by the vulnerability. The exposure model is implicit in the formulation. The scale, magnitude, and probability of single hazards are defined within the hazard module. Moreover, to account for climate change, a range of possible climate scenarios are considered. The exposure module results from the multiplication of a set of indicators related to the elements at potential risk. The analysis of such elements is used to create reference baselines of qualitative and quantitative characteristics of residents and buildings, which can be subsequently applied to identify and define elements that are potentially more exposed. Finally, the individual vulnerability of the elements when exposed to different hazards is also assessed, taking into account their mutual dependencies (cascading effects).

The integration of the results into a Geographic Information System (GIS) tool represents the last and most fundamental step of this multihazard risk approach. The GIS tool allows for spatial analysis of the study area (i.e., consideration of different scenarios) and management of data about the characteristics of the elements exposed. With the GIS-based analysis system, officials can outline optimized predisaster planning, including risk communication campaigns, and postdisaster intervention, such as emergency planning and reconstruction.

CONCLUSIONS

The benefits of disaster risk reduction approaches are widely recognized in Namibia, particularly in governmental decision-making processes. However, when assessing individual hazards, all actors and ministries should use a compatible language. We recommend the multihazard risk approach presented in this article. Additionally, the use of open-source GIS tools in mapping and interpretation of results for decision-making purposes is a fundamental step in moving toward more efficient and proactive strategies.

Furthermore, local communities need to be made aware of risks well ahead of time so they are prepared when disasters strike, and capacity-building programs need to be put in place to facilitate community involvement and participation.

Getting all these sprocket wheels working together will contribute to a more calibrated and optimized tool for disaster risk mitigation of Namibian vernacular cultural heritage.

Curriculum Vitae

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INTRODUCTION

For many centuries, the Roman Catholic Church had a great influence on the landscape of the northern part of Belgium, known as the Flemish region. Religious buildings are monumental witnesses to a strong Catholic footprint in the history of the region. Since the 1960s, secularization has been weakening the bonds between religion and these buildings. Today, many buildings have been abandoned and have lost their original function of gathering people in a Catholic frame. The reuse of religious buildings poses a challenge that needs to be tackled by experts in an attempt to adapt historical buildings to modern society. Numerous initiatives in multiple countries have begun to revive this religious heritage.

This case study concerns the neo-Gothic St Joseph church in Rabot, a former working-class quarter in Ghent, Belgium. The church will be deconsecrated in 2017, and its conversion will be realized in the near future.
We sought to preserve the church for future generations by proposing a refurbishment project. In this context, deconsecration is a challenging opportunity because of the importance of this moment in the building’s existence: an old function was to be replaced by a new one.

METHODS & METHODOLOGY

Getting to know stakeholders, context, and the building itself through regular site visits, workshops, technical surveys, and archival research was necessary for a complete understanding of the cultural, social, and economic assets of the quarter and the church. The first part of the research resulted in a complete urban, architectural, historical, technical, and economic analysis. This synthesis was the basis for three evaluations; namely, a value and authenticity assessment, an assessment of the state of conservation, and a project evaluation. The last of these combined a strengths, weaknesses, opportunities, and threats (SWOT) analysis, a multi-criteria analysis, and a social survey to evaluate each rehabilitation proposal.

By tackling research questions from various domains related to the monument, its environment, and its social context, this methodology allowed us to develop a more complete picture. The information we obtained created a strong base for further analysis of the selected rehabilitation proposal to create a sustainable, long-term, and future-proof reconversion project.

RESULTS & DISCUSSION

1. Value and Authenticity Assessment

The history of Rabot, where St Joseph church is located, is still present in the urban landscape, although it not always distinguishable or comprehensible.

St Joseph church was built from 1874 to 1883. As was typical of the time, the church was placed in the middle of the neighborhood, where it would be visible from every angle (Fig. 03). Architect Auguste Van Assche designed the church for the Kerkfabriek (Church Fabric) of St Joseph Parish in the spirit of the Saint Luke Movement.1 The combination of sober, predictable Scheldt Gothic2 for the exterior (Fig. 01) and a colorful, experimental High Victorian style for the interior (Fig. 02) indicates the church was built in the Reformed Gothic style.3 Since no subsequent interventions were made and the church is still used for a religious purpose, the integrity of the architectural concept and interior are high. The monument and its urban landscape are significant for spiritual, social, historic, and cultural reasons. The authenticity of the church is high. (The authenticity evaluation of the building was based on the Nara Grid scheme and the value assessment.)4

2. State of Conservation

The exterior and interior of the church are in a good state of conservation, although cracks due to settling of the church
annexes and crypto-efflorescence at the height of the mural painting should be analyzed in detail to avoid further damage. Besides conducting technical analyses, the church should be permanently monitored to understand the conditions and all factors affecting the settling and interior climate of the church.

3. Project Evaluation

Three methods were used to evaluate four reuse proposals. A SWOT® and Multi-criteria Analysis® were conducted by conservation experts, and a survey was conducted to determine stakeholders’ opinions. This last item took the form of a social survey carried out during a church “open house”; the survey was completed by 80 participants. The combined results of the various evaluations strengthened and supported the final evaluation.

Based on the results, a two-fold program was proposed: the church could host both a museum and a community center. The crypt would support the latter function by providing a polyvalent space to meet the different needs of the neighborhood.

4. Refurbishment Proposal

Restorations were proposed based on the church’s current state of conservation. The conceptual proposal uses a zoning scheme, based on the research conducted by the heritage experts, to implement new interventions, respect high-value elements, and provide the building with appropriate accessibility and services. The proposal suggests an elongated shape for the community center, accentuating the central axis of the church.

The architectural principle used is a box-in-a-box system, where the enclosed units function independently from the church. The church would act as a covered public space and exhibition space, while the crypt would serve as a polyvalent place.

Currently the church is not the social center of the neighborhood. The neighbors’ low awareness of its value complicates assessments of whether the church can be repurposed as a community center and museum. Raising awareness and sensitizing people will be crucial before a determination can be made on whether to move forward with implementing the church’s new function. Therefore, the reuse project needs to become a reuse process considered in time. Phasing should be based on the restoration advice and the conceptual proposal. At first, a soft approach should be taken, with the church used as a public space without additional interventions. The project can then evolve toward the final reuse proposal in small steps.
CONCLUSIONS

The aim of this study was to use research to find ways to preserve and transmit the St Joseph church to the next generation. The resulting proposal attempts to show the potential of the monument as a community center and museum, thus positioning the church as the creative, cultural, and social heart of Rabot. However, merely proposing such a reuse project does not guarantee its success. A neglected monument cannot become a gathering space overnight. Returning the church to the neighborhood is a process that will take time.

CURRICULUM VITAE

Evy Bouwen is a Belgian architect who gained experience in the field of restoration during a two-year internship at Architectuur Atelier. She is currently an advanced master’s student at the Raymond Lemaire International Center for Conservation, Katholieke Universiteit, Leuven.

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Jelena Perusinovic is a Croatian architect who gained knowledge on built heritage through professional experience at TU Vienna and several architectural offices. She is currently an advanced master’s student at the Raymond Lemaire International Center for Conservation, Katholieke Universiteit, Leuven.

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2 Scheldt Gothic is an early Gothic style used in Flanders during the thirteenth and fourteenth centuries. See Lemaire, R., Gids voor de kunst in België, Antwerp, Prisma boeken, 1964, p. 34.
3 Reformed Gothic was part of the second phase of neo-Gothic (1850–1914) and a reaction to the idealistic and romantic character of the first phase. Based on local styles, it combined with influences from other regions. See De Maeyer, J., Wouters, W., Verpoest, L., and Bauer, R. De Sint-Lucasscholen en de Neogotiek 1862–1914, Leuven, Universitaire pers Leuven, 1988, pp. 43–45.
6 Multi-criteria Analysis is a nonmonetary evaluation method that uses multiple criteria to compare various projects with one another. See Bouwen, E., Perusinovic, J., and Van Meerbeek, L., Saint Joseph Church, Reconversion Project, Leuven, 2016, p. 201.
Hygrothermal Study of Mixed Masonry Walls in the Franciscan Conceptionist Convent of Toledo, Spain

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INTRODUCTION

To find new solutions and technologies to restore traditional walls, their hygrothermal behavior needs to be better understood. An ongoing research project, “The Aparejo Toledano: Energy Retrofitting of Traditional Masonry Walls” aims to address this problem in the context of a type of mixed masonry wall called aparejo toledano. The aparejo toledano is made of stone and brick and dominates Toledo’s facades and architectural landscape. It derives from the roman opus mixtum or listatum and was widely used in Toledo from the 10th to 19th centuries. The wall includes three layers: an inside and outside made of brick and stone and an interior of lime, sand, and gravel. Depending on the historical period, different compositions were used and are classified by Rojas and Villa into five types based primarily on the number of stone rows and brick bands present. The building selected for the research project was the Concepción Francisca convent (Toledo, 13th–16th centuries), as it includes examples of three types of aparejo toledano.

The city of Toledo is in the center of the Iberian Peninsula, on a hill bordered on three sides by the Torno del Tajo, a bend in the Tagus River. From a small town founded in the Bronze Age, the city has grown over the centuries, embracing diverse cultures and communities. During the Roman Empire, it grew in importance, later becoming the seat of the Visigoth kingdom. From 711 to 1085 it was part of Al-Andalus, then of the Castilian kingdom, and finally of modern Spain.

Toledo’s climate is characterized by cool winters, hot summers, and an annual average temperature of 15.8°C. According to the Köppen classification, it is considered semi-arid-cold (Bsk). Relative humidity is low, and evapotranspiration thus helps reduce the sensation of heat in summer. The prevailing winds are from east and west.

METHODS & METHODOLOGY

Building envelopes regulate energy exchanges between inside and outside air. The main factors involved in this process are:

1. External climatic conditions, such as temperature differences between inside and outside air (θi–θe), solar radiation, wind, and, particularly in summer, humidity;
2. Envelope heat transfer capacity, which can be quantified by total thermal resistance and its inverse, thermal transmittance (the mechanisms involved are conduction, convection, and radiation); and
3. Thermal storage capacity, which is directly related to thermal inertia; that is, a body’s resistance to changing its temperature, which can be expressed as:

\[
C = m \ast c = (V \ast r) \ast c = S (c \ast r) \ast c
\]

where

- \(C\) = stored heat per temperature difference degree (J)
- \(m\) = mass (kg/m³)
- \(c\) = specific heat (kJ/kg.°K)
- \(V\) = volume (m³)
- \(r\) = density (kg/m³)
- \(c\) = thickness (m)
Since February 2016, the mixed brick and stone walls of the Concepción Francisca convent have been monitored using nondestructive techniques. The measuring equipment includes, among other instruments, thermal imaging cameras, data loggers, transmittance meters, and solar radiation meters. The main purpose of the monitoring is to collect air temperatures, wall surface temperatures, and relative humidity data that reveal the heat flow “time lag” and “decrement factor” of the convent walls. The decrement factor is defined as:

\[
 m = \frac{u_i}{u_0}
\]

where \( u_i \) and \( u_0 \) are the wave amplitudes on, respectively, the outer and inner surfaces of the wall.

The time lag is defined as:

\[
 f (h); \text{ time elapsed from the moment the thermal wave enters a wall surface until it reaches the opposite surface.}
\]

RESULTS & DISCUSSION

Data collected so far show daily oscillations of the outside temperature from 8 to 14°C between February and May 2016 and the mean relative humidity ranging from 65% to 75%. Under these conditions, the inside wall surface temperatures and the indoor air temperatures remain fairly constant, with variations of less than 1°C. The outer surface temperature ranges from 6 to 16°C, depending on the wall orientation, sun exposure, and time of day. Solar radiation favors the increase of these temperatures at noon on sunny walls (Table 01).

Table 02 summarizes the main thermal properties of the aparejo toledano materials.

The aparejo toledano’s high thermal storage capacity is primarily due to significant wall thickness (60–80 cm) and high material density, leading to a wall mass of more than 650 kg/m³. The time lag can be estimated from these characteristics to be more than nine hours, and the decrement factor is around 90%. The first results obtained from monitoring the walls of the Concepción Francisca convent are consistent with these estimates. Only small oscillations (less than 1°C) were detected in the indoor air temperature and the internal wall surface temperatures, which reflects a high level of heat flow damping. Due to this, the building is naturally kept at a constant temperature. Energy costs for heating and cooling the building to a comfortable temperature are thus low.

The surface thermal behavior differences between the materials that make up the wall—stone, brick, and lime mortar—were also analyzed. In the early hours of the morning and in the afternoon, the stone zones reach their highest temperatures, while the brick

<table>
<thead>
<tr>
<th>WALL SHEET</th>
<th>MATERIAL</th>
<th>( e ) (m)</th>
<th>( r ) (kg/m³)</th>
<th>( c_p ) (kJ/kgK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interior and exterior</td>
<td>Gneiss (masonry)</td>
<td>0.20 – 0.30</td>
<td>2400 – 2700</td>
<td>1000</td>
</tr>
<tr>
<td>All three sheets</td>
<td>Brick (XIII to XVI ctrs.)</td>
<td>0.60 – 0.80</td>
<td>1000 – 2400</td>
<td>1000</td>
</tr>
<tr>
<td>Middle</td>
<td>Lime mortar</td>
<td>0.15 – 0.20</td>
<td>1600</td>
<td>1000</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>60 - 80</td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>RH</th>
<th>MS Ø ext.</th>
<th>MS Ø int.</th>
<th>MS Ø sur. ext.</th>
<th>MS Ø sur. int.</th>
</tr>
</thead>
<tbody>
<tr>
<td>65% – 75%</td>
<td>8 – 14 ºC</td>
<td>&lt; 1 ºC</td>
<td>6 – 16 ºC</td>
<td>&lt; 1 ºC</td>
</tr>
</tbody>
</table>

RH: mean exterior relative humidity (%)
MS Ø ext.: daily outside temperature mean swing (ºC)
MS Ø int.: daily inside temperature mean swing (ºC)
MS Ø sup. ext.: daily outside surface temperature mean swing (ºC)
MS Ø sup. int.: daily inside surface temperature mean swing (ºC)

Table 01. Concepción Francisca convent monitoring summary (February–May 2016): mean values for different wall orientations and radiation exposure degrees
bands reach their lowest. At noon this relationship is reversed in 80% of the walls studied. These results are consistent with the higher thermal capacity and conductivity of stone relative to brick (Fig. 01; Fig. 02).

CONCLUSIONS

The first results of the hygrothermal monitoring of the mixed stone and brick walls of the Concepción Francisca convent confirmed the theoretical estimates. The small variations detected in indoor air temperature and inner wall surface temperatures confirmed the high heat flow decrement factor of the walls. Outside surface temperatures varied between the materials and were consistent with their thermophysical properties.

New monitoring data of the convent walls will be obtained and hopefully will provide additional insights into the hygrothermal behavior of the aparejo toledano. This should lead to a better understanding of the bioclimatic strategies used in the construction of these heritage buildings, information that is essential for performing sustainable restoration work.

CURRICULUM VITAE

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INTRODUCTION

The demolition of the archiepiscopal palace of Burgos Cathedral (named a United Nations Educational, Scientific and Cultural Organization World Heritage Site in 1984) took place in 1914 after decades of attempts by the authorities, who had the support of the people but were opposed by artists and intellectuals. The reasons given for the elimination of this element had to do with the embellishment and isolation of the architectural monuments, and the search for perspectives of the monument (influenced by the appearance of photography and travel books).

Taking advantage of the appointment of Archbishop Cadena y Eleta, the mayor, D. Manuel de la Cuesta, who had supported the demolition for years, was finally able to move ahead. He entrusted the work to D. Vicente Lampérez y Romea, the chief architect of the cathedral.

Using the palace of the Castilian kings as a base, Fernando VI gave the order to construct the cathedral in the 11th century. The Romanesque structure was replaced with...
the Gothic one in 1221. The archiepiscopal palace, which might coincide with the former royal palace, is documented as a residence from the beginning of the 13th century. Not only did the palace form a part of the cathedral, development throughout the centuries of the overall complex occurred on the basis of the palace. The cathedral of Burgos is situated on a hillside that descends toward the south, and the palace is located on its western lower front (Fig. 01).

For his restoration, Lampérez had to (1) combine existing precedents for embellishing the cathedral with new perspectives (as well as the strong opposition); (2) join his restoration criteria (in an era with marked differences between the various theories of restoration and opponents of the isolation of monuments); and (3) deal with major problems of consolidation of the demolished part and the emergence of important elements (such as installations and ancient remains) that modified the project. So great was the pressure that, once the intervention was finished, he attempted to justify his decisions in the form of a report.

METHODS & METHODOLOGY

The present work outlines a study of the consolidation Lampérez carried out after the demolition and describes the use of nondestructive technologies (NDT) and minor-destructive technologies (MDT) in the analysis of heritage interventions, with a goal of establishing a clear methodology of intervention in restoration where the consolidation and the reintegration have a predominant role.

No proof exists of the final project dossier of the demolition and later consolidation of the cathedral (numerous authors, including the present author, have searched without success for the documentation of Lampérez’s restoration project). No investigation exists from the constructive point of view of Lampérez’s restoration, for which the only supporting document is the restored monument itself.

The study of reintegration in historic masonry using NDTs and MDTs is based on the work of Luigia Binda and the recommendations of the Onsitemasonry Project. The methodology involves a preliminary investigation: visual inspection, geometric survey, photographs, a crack pattern survey based on the geometric survey, archive survey, and analysis of structural evolution. The preliminary study allows the strategic points of study to be determined. In the present study, these were the number of leaves and the connections between them, along with the morphology of the wall, density of the section, thickness of the layer and its attachments, and type of infill. Collection of this data allowed the typology of the masonry to be identified, including the presence of inclusions and voids: reinforcements, hidden utilities, decorative elements. Any disconnections or lack of continuity in the wall also had to be identified, as well as the presence of materials or interventions that have remained hidden. Quality of the wall was determined by the compactness of the cross-section of the wall, homogeneity of the masonry, and the effects of past restorations. These data provided the necessary information to calibrate the intervention and carry out the structural analysis. A final step was to detect the presence and content of moisture.

Therefore, the purpose was to apply on-site investigation techniques to a reference example where almost all information was provided by the building itself, to develop graphical documentation, and to determine the constructive characteristics of the intervention. This is essential for the knowledge of masonry and the adequacy of future intervention.

RESULTS & DISCUSSION

The perspectives generated with these interventions are new in most cases, because the monuments were situated in dense urban centers whose origin and growth frequently
paralleled that of the monuments themselves. Lampérez later recognized* that the cathedral and the attached chapels were supported by the palace. Years later, he even proposed reinforcements in the buttresses. In addition, the demolition uncovered elements of previous epochs, and Lampérez wanted to include these in the consolidation work to leave evidence of what was found (Fig. 02).

Using our knowledge of the masonry from both before and after the demolition, as well the different surveys (geometric, damage, materico), we identified problems in need of resolution. (The simple, nondestructive visual inspection had already provided many clues that were useful in the selection of future places for investigation; see Fig. 03.) A suitable place of application was selected, and appropriate NDTs and MDTs were chosen. The NDTs and MDTs were grouped based on (1) morphological information; (2) structural monitoring; (3) mechanical evaluation of masonry; (4) control of intervention; (5) moisture. For each technology, the limits and advantages were noted.

CONCLUSIONS

The demolition, undertaken for an aesthetic purpose at the beginning became the resolution of major structural problems and masonry reintegration. It brought about an important change in the structural configuration and, therefore, a different mechanical behavior of the monument. The implications of this modification for the cathedral as a whole must be understood and taken into account when planning any future action.

A reintegration must achieve compatibility between the existing masonry and the new constructive system. Unnecessary technologies and tools or those that might cause more damage should be avoided (with the consequent economic savings, besides the success of the intervention). Furthermore, once all the elements have been identified for study, intervention priorities can be established (from the point of view of urgency, budget, etc.).

The different tools and technologies must come after the following methodology: first, thorough knowledge must be gained of the masonry and the damage to be solved; later (together with other determining conditions: economics, accessibility of tools, availability of qualified personnel, etc.), the most suitable technology for studying the element must be selected. Problems arise when technology decides the methodology to be followed.

A good level of knowledge of masonry allows for structural analysis to be completed, along with suitable interventions of reinforcement and repair.

Lampérez, by correcting the initial ideas about the demolition of a single element, solved the problem of how to consolidate the remains of the palace, and his reintegration is perfectly compatible with the cathedral.

ACKNOWLEDGMENTS

I am grateful for the help, collaboration, and good disposition of the Canónigo Fabriquero of the cathedral of Burgos D. Víctor Ochotorena.

CURRICULUM VITAE

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(Endnotes)
3 In the same year, consolidation of the Patio del Yeso in Reales Alcázares, Seville, was performed.
INTRODUCTION

The fortification of Montella is in Avellino Province in inland Campania (Italy). Archaeological research under the scientific direction of Marcello Rotili (1980, 1992–2005, 2007) highlighted a settlement that, since the sixth century, has been characterized by several occupancy phases.1

The archaeological research highlighted complex stratification and made possible the public use of the fortified area. Together with the castle structures from the 12th and 13th centuries, structures belonging to a fortified enclosure dating to the ninth century have been revealed.

Moreover, houses dating to the sixth and seventh centuries were discovered with coeval burials located in an area in which a house of worship once stood (it was demolished in the ninth century), as well as cemetery that was in use from the 11th to 13th centuries.

A residential tower built during the Norman period (12th century) stands on the highest part of the hill on which the fortified settlement of Montella is located.

The residential magna turris (donjon) has been the fulcrum of the settlement since the 12th century. The donjon has a cylindrical shape (diameter 14 m) and at its peak is 14.70 m higher than courtyard level (courtyard altitude: 821.96 m above sea level). It shows a vertical trend despite the offset and the polygonal scarp at the highest point.

The building is divided into four floors. The first floor coincides with the cistern (for the building water supply), and the second is composed of two rooms for foodstuffs. On the third and fourth floors are toilets, fireplaces, ovens, and the entrance door (located on the third floor for defense reasons). Such services and comforts suggest a residential function for the building, thus placing it among examples of donjons residentiel found throughout Europe,2 including elsewhere in Italy (where some donjons may predate the Montella model), Scandinavia,3 and France.4

The monumental nature of Montella’s magna turris is attested by its remarkable size: its external diameter is just one meter smaller than the Grosse Tour du Louvre in Paris. The French tower, discovered after the archaeological excavations of the Cour Carrè, had a maximum height of about 30 m.

Restoration of the Montella tower was carried out from 2005 to 2007 and was preceded by several interventions designed to refurbish the magna turris and the whole Montella fortified area. The first of these interventions dates to 1987, when the “Soprintendenza ai B.-A.-A.-S.” of Salerno-Avellino launched restoration works intended to repair the damage caused by the 23 November 1980 earthquake. Subsequent environmental interventions (for rainwater drainage, terracing, and paths restoration and rescue) were led by the Comunità Montana Terminio-Cervialto from 1987 to 1992.
The building is characterized by walls in *opus incertum*, with both average and large limestone ashlars joined by gray mortar. Renovation work involved the inside of the tower, the door, the access staircase, and the roof of the building. The restoration works allowed the monument and the wide fortified area to be opened to the public. This article highlights the importance of the restoration work, which was fundamental both for the valorization and preservation of the building.

**METHODS & METHODOLOGY**

After Rotili completed the initial archaeological dig and study, renovation was focused on salvaging and rearranging the external curtain of the cylindrical fortified tower. An undercut was made to distinguish the original masonry sections from the restored ones. For this purpose, stones recovered during the excavation of the *donjon* were used.

Inside the tower, walkways of wooden decking were built on the third floor. Steel balustrades were placed close to the inner wall, and the floor and ceiling were redone (Fig. 01). The fourth floor had a residential purpose, too, and was formerly characterized by a ligneous floor placed on wooden supports held up by three large central beams. Under these restoration works lamellar wooden beams were used, with six square arrangement holes (40 x 40 cm) shaped for square beams (20 x 67 cm) and arranged to meet the current building requirements.

To make usable the large cistern located on the first floor of the tower, a steel “cage” staircase (Fig. 02) was built using the previous trapdoor entry. In addition, an access staircase was constructed from the floor of the castle courtyard to the tower (Fig. 03). The project and the construction of the access system were preceded by the dismantling of a provisional multiflight staircase built during the 1990s, which obstructed views of the tower.

The provisional structure was replaced by a lighter steel structure fastened to the tower using the original, 12th-century staircase mounting holes. This intervention was made in coherence with the original access system to the tower made up by a wooden staircase placed in the same way as the current one; that is, the steel staircase was made to resemble the medieval wooden access structure.

Furthermore, the interior of the tower was covered in a lamellar wood lowered vault structure with bronze foils mounted on the outside to imitate the original sandstone vault. The vault masonry is different from the masonry of the tower and castle structure, which is in limestone. The use of sandstone helped to reduce weight and make the vault lighter.

Preservation efforts also involved the securing of the masonry staircase that led from the third to the fourth floor, the closure of several gaps (doors, windows) with glass and iron structures, and the installation of a lighting system made up of chandeliers to provide a suggestive and warm light to the rooms.

**RESULTS & DISCUSSION**

Restoration is always risky, often necessary, and, in some cases, inevitable. In the case of the Montella tower, an abandoned structure that had lain in ruins for many centuries, restoration was unavoidable. The restoration addressed all factors contributing to the degradation of the masonry, and the applied solutions will afford the structure more protection against atmospheric agents.
Among the restoration activities, the reconstruction of the donjon’s roof is notable. In contrast to Rocca San Felice (Avellino), where the renovation of the donjon’s roof was not considered to be essential (despite its fundamental role in preserving the inner walls), in Montella the construction of a roof has prevented the accumulation of rainwater in the tower and preserved the walls from damage.

Restoration of the building has also allowed it to be viewed in its original historical context. Visitors can now enjoy a fully accessible building. Moreover, the restoration work allows easy interpretation of the various structural elements of the tower and helps visitors understand the many transformations that have changed the appearance and function of the tower over the centuries.

CONCLUSIONS

The renovation interventions at the fortified settlement of Montella were all related to a more general project of salvaging and refunctining the entire fortified complex. The project has involved an architectural renovation, a refunctuation, and a new setup aimed at redeveloping the overall archaeological area and its donjon and thus making them available for public use again.

Conservation, valorization, and promotion of the social uses of donjons residentiel allow visitors to gain a better understanding of a little-known aspect of the military and civil architecture of 12th- and 13th-century Central European and southern Italian settlements.

CURRICULUM VITAE

Assunta Campi is a PhD student in architecture, industrial design, and cultural heritage at the Università degli Studi della Campania “Luigi Vanvitelli,” Naples. For many years she has taken part in activities conducted by Professor Marcello Rotili (chair of the Department of Christian and Medieval Archaeology). She catalogs and studies medieval and postmedieval archaeological finds from inland Campania and has participated in various archaeological surveys and excavations in Italy.

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(Endnotes)
Building Stones of the Convent of Trinitarias Descalzas de San Ildefonso in Madrid

David Martín Freire-Lista,* Rafael Fort*

* Instituto de Geociencias (CSIC, UCM), Madrid, Spain

INTRODUCTION

The Trinitarias Descalzas de San Ildefonso Convent (TDSIC) was installed in houses on Cantarranas Street (today Lope de Vega Street) in Madrid in 1612. The first work was the construction of a small provisional church where Miguel de Cervantes Saavedra was laid to rest in 1616.

The demolition of this first church started in 1673, and a new church was finished in 1697. The church facade comprises three arcades occupying its entire width. These arcades are carved in granite. The second level includes a bas-relief and coats of arms carved in Redueña-Tamajón dolostone¹ and embedded in the brick wall. The crowns, placed later above the coats of arms, are of Colmenar de Oreja limestone. A central window with jambs and lintels of granite is at the third level. The temple is finished with a triangular pediment brick with a circular granite-curbed window at its center. The frontispiece is bordered by granite ashlars and crowned with a central cross and lateral decorative granite elements. Granite corner stones are to the lateral sides of the church facade.

Once the church had been completed, the actual convent was built. For this purpose, adjoining houses were acquired until the 18th century. The plinth is the structural...
element in which the most types of building stones have been used (Figs. 01, 02). Thus, the convent has plinth sections with flint masonry and granite ashlars.

The aim of this study was to determine the origin of the building stones used in the convent and what type of decay is affecting its granite plinth.

The durability of building stones is determined by their geological history, petrographic and petrophysical characteristics, as well as by weather, pollution, and conditions of use, in conjunction with other factors. When building stones are subjected to temperature changes, humidity, and urban environment, they are more susceptible to decay.

METHODS & METHODOLOGY

The granite petrology of the TDSIC plinth was characterized. A thin section of granite was impregnated with fluorescein and characterized under an Olympus BX 51 polarized light microscope equipped with an Olympus DP digital camera (6 V / 2.5 Å). Microcracks were characterized with the same equipment plus an Olympus U-RFL-T mercury burner fluorescence microscope.

Polarized-light and mercury-burner-light photomicrographs were made, resulting in a mosaic of 120 photomicrographs with an area of approximately 4 cm² (Fig. 03). Six equidistant lines of 1.5 cm each were drawn on fluorescence micromosaic to count the number of microcracks intersecting the lines. Linear microcrack density (microcracks per millimeter) was calculated using the methodology proposed by Sousa. The provenance of dolostone and flint stone was determined by studying the literature and historical documents of the convent.

Granite color was measured with a Minolta CM-700d spectrophotometer. Once the granite plinth sample had reached a constant mass, 10 color measurements were taken, then averaged. CIELAB system color parameters were used: luminosity (L*), red to green coordinate (a*), and blue to yellow coordinate (b*). Spanish and European standard UNE-EN 15886, 2011 yellow (YI*) and white (WI*) indices were obtained.

RESULTS & DISCUSSION

The stones used in the construction of this convent were ones traditionally used in Madrid. The granite plinth of the convent had similar characteristics: a hypidiomorphic, equigranular monzogranite with fine to medium crystals, gray to yellowish gray in color, mostly presenting transcrystalline and intercrystalline microcracks (Fig. 02 C). The linear microcrack density was 0.7 microcracks per millimeter.

Chromatic parameters of the granite plinth were L* (D65) = 62.6 ± 7.1; a* (D65) = 1.0 ± 0.3; b* (D65) = 9.9 ± 1.1; WI (E313-73) = 6.0 ± 3.7; YI (E313-73) = 20.6 ± 2.1.
Petrographic characteristics of the granite were identical to Alpedrete granite. The granite of the plinth had yellow tones because it was extracted from a surface area of the quarry and therefore was more altered (Fig. 03 A, B). Alpedrete granite has suitable properties to combat humidity and capillary rise. However, the granite plinth presented scaling, saline efflorescences, soiling, granular disaggregation, and rounding due to the loss of quartz crystals and feldspar alteration. Other types of decay were caused by biological colonization by microorganisms and human activity (graffiti and black crusts).

Ornamental elements of the building were carved from Redueña-Tamajón dolostone and showed loss of cohesion and soiling.

The flint masonry came from outcrops southeast of Madrid. The flint had a better performance against the agents of decay and generally was the best preserved of the convent’s building materials.

CONCLUSIONS

The convent retained most of its original traditional building stones.

Knowledge of building stones, historic quarries, and causes of stone decay is necessary for conservation interventions, especially for the reintegration of damaged ashlars and the replacement of original stone with compatible materials.

Studying the historical documentation of heritage buildings, along with petrographic and fractographic techniques, provides data that are useful for dating historic buildings and may prove useful for other disciplines, such as history, archaeology, restoration, fine arts, architecture, and forensic science.

Generally, the facing plane of granite ashlars follows the direction of exfoliation microcracks, so that microcracks are perpendicular to the ground. The capillary rise of water along the exfoliation microcrack planes is an important factor of decay.

The type of maintenance and cleaning to be applied to these centuries-old stones will be conditioned by the type of decay, finish, and mineralogy. Special care should be taken with older ashlars, which can be further altered. Based on its petrological characteristics, the granite used in TDSIC was extracted from quarries in the Alpedrete area, and the flint came from ancient quarries near Madrid or the ancient Muslim wall.

ACKNOWLEDGMENTS

This study was funded by the Community of Madrid under the GEOMATERIALS-2CM research Program (S2013/MIT-2914).

CURRICULUM VITAE

David Martin Freire-Lista has a master’s degree in environmental geology and geological resources and a PhD in geology and geological engineering from Universidad Complutense Madrid. His research focuses on the decay of building stones, and he works at the Applied Petrology for Heritage Conservation research group of the Instituto de Geociencias (CSIC, UCM).

Rafael Fort has a PhD in economic geology from Universidad Complutense Madrid. He is a senior scientist, head of the Applied Petrology for Heritage Conservation research group of the Instituto de Geociencias (CSIC, UCM). He is specialist in the characterization of building materials (stone, bricks, mortars, etc.), quality and durability of building stones, conservation treatments, and provenance of materials.

BIBLIOGRAPHY


(Endnotes)


Characterization and Structural Analysis of the Main Facade of Palazzo Pignatelli in Fiumefreddo Bruzio, Italy

Giulia Forestieri*, Alessandro Tedesco*, Maurizio Ponte*

* University of Calabria, Arcavacata di Rende, Italy

INTRODUCTION

The focus of this study is an analysis of the petrophysical and mechanical properties of sandstone from the Palazzo Pignatelli in Fiumefreddo Bruzio, Italy. The deterioration and structural damage to the sandstone were evaluated both in situ and in laboratory using nondestructive techniques (NDT) and structural analyses.

The case study was chosen by considering three criteria: architectural importance; the building material’s historic role; and deterioration level and structural instability. Palazzo Pignatelli is an example of the Renaissance architecture of the royal Naples style (fifteenth to sixteenth centuries), known as “durazzesco-catalano.” Its building material, commercially known as “Fuscaldo” or “sweet stone” due to its easy workability, was largely employed by the most important Calabrian schools of stonemasons. Geologically it belongs to the sedimentary Miocene successions of the coastal Thyrrhenian Range that include sandstones, calcarenites, arkoses, conglomerates, clays, marls, gypsiums, and evaporitic limestones, from 200 m to over 1,500 m in thickness. The building presents different problems due to the deterioration processes affecting the building material and structural elements.

Representative specimens of the portal (main facade) were selected and compared to unweathered quarry specimens of the same lithology to establish possible relationships. Quarry samples belonged to historic sandstone outcrops of Località Scarcelli in Fuscaldo.

METHODS & METHODOLOGY

The alteration forms’ description was performed through a 10X Canon EOS 750D camera. The petrographic analysis was carried out using a Zeiss Axioskop 40 polarized optical microscope.

The in situ tests included strength measurement of the sandstone surface and weathered parts by Schmidt hammer (Geohammer L-type) to assess the hardness characteristics of the rocks. For each point, twelve impact readings were recorded. Correlations between uniaxial compressive strength and Schmidt hammer rebound values were determined by Bieniawski’s relationship. Values of porosity and unit weight refer to fresh, unaltered Fuscaldo quarry specimens.

P-wave velocity measurements were obtained through the ultrasonic MATEST Meter Ver, with an accuracy of 0.1 microseconds, equipped with two 55 kHz frequency transducers. Six measurements were obtained in each ashlar to describe the P-wave velocity’s spatial variability and to compare to the ultrasonic values of four cubic quarry specimens (A1–A4). Tests conditions were dry surfaces and indirect mode.

Laboratory tests included chemical analysis with a JEOL JXA 8230 electron probe micro-analyzer and morphological analysis by scanning electron microscopy (SEM) with energy-dispersive X-ray spectroscopy microanalysis on an FEI Quanta 200 instrument equipped with an EDAX Si (Li detector).
The analyzed sample C was taken from the right abutment of the portal at a height of 1.20 m above ground (Fig. 01).

Linear and nonlinear kinematic structural analyses were performed to define seismic vulnerability indices, considering a mechanism of simple overturning of the main facade. The no-linear and linear kinematic analyses led to the determination of the displacement factor ($f_d$) and the acceleration factor ($f_a$), respectively, for two limit states LS: a “damage” state (DLS) and a “safeguarding of life” state (LLS). Structural analysis conditions were: (1) unconsolidated system (actual condition); and (2) consolidated system (applying metal tie-rods).

RESULTS & DISCUSSION

The following types of deterioration were detected on the portal surface (Fig. 01): back weathering due to the loss of scale; alveolar weathering; missing parts and due to the break out; efflorescence; superficial deposits/crusts; delamination; and granular disintegration. A mechanism of collapse detected on the structure showed a strong displacement in the horizontal direction of the facade, more intense in its high parts.

Macroscopically, Fuscaldo sandstone (AF) is compact, yellow/brownish in color, and contains 1–6.5 mm fossils. Its composition is 50% clasts and 50% carbonate matrix (Fig. 02 a). Composition and texture are homogenous, with
distinguishable pores and subrounded fragments of granitic rocks. Composed of quartz, plagioclase, k-feldspar, biotite, and accessory minerals such as zircons and apatite, it can be classified as a graywacke.6 Pignatelli sandstone (PS) (Fig. 02 b) shows the same petrographic characteristics but with a higher level of deterioration. Thus, petrographically, the two analyzed materials are similar. Morphochemical analyses by SEM (Fig. 02 c, d) of sample C confirmed the macroscopic weathering analysis and revealed the presence of Cl, Na, and K. It showed the presence of crystals of salts of 5–10 × 5–10 μm, a medium level of porosity, and an altered substrate. Furthermore, visible fossils and salts were concentrated along deteriorated areas. The sample consisted of 73.50% CaO, 10.69% SiO2, 3.30% Al2O3, 5.28% Na2O, 2.98% Cl, 2.32% K2O, 1.06% MgO, and 0.87% FeO.

Schmidt hammer rebound (Hs), uniaxial compressive strength (σc, MPa), and ultrasonic pulse velocity mean values (Vp) showed average values of 27 ± 4.3 (Hs), 28.3 ± 5.5 MPa (σc), and 2.308,07 ± 711,50 m/s (Vp) for Pignatelli sandstone (PS); and 33 ± 2.9 (Hs), 36.8 ± 4.3 MPa (σc), 2.808,31 ± 380,80 m/s (Vp) for quarry samples (AF). (See Table 1.)

The right part of the portal was the most deteriorated due to lower resistance values. Its lower parts (point A) were more affected by deterioration than the higher ones (point B). The mean values obtained for the quarry samples and the Pignatelli were similar. So, Fuscaldo sandstone can be used to replace the deteriorated parts of Palazzo Pignatelli. Replacement blocks should be placed in the lower parts where the highest concentration of salts were recorded, along with others forms of deterioration. Data agreed with the structural analysis performed (Table 02). The low seismic safety values obtained for the unconsolidated system indicate that the examined wall needs an improved “box effect” (i.e., connections with other walls), to avoid an overturning mechanism of collapse. Safety could be improved by introducing metal tie-

<table>
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<th>ashlar/sample</th>
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<th>σc (MPa)</th>
<th>Vp (m/s)</th>
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<td></td>
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Table 01. Schmidt hammer rebound values (Hs), uniaxial compressive strength (σc, MPa), and ultrasonic pulse velocity mean values (Vp) for Palazzo Pignatelli and Fuscaldo quarry samples.
Four metal tie-rods of B450C steel were considered for this purpose, applied next to the eave line, with a diameter of $\Phi = 24$ mm. Such a design would satisfy a safety check, ensuring that the “consolidated system” met all important limit states (see Table 02).

CONCLUSIONS

This study, which started from a knowledge of the petrophysical, chemical, and mechanical properties of building stones, has highlighted the importance of considering the compatibility and similarity of original and replacement materials.

Highly deteriorated building materials will affect structural stability. The prolonged action of salts can lead to the formation of microcracks and fractures, provoking total material detachment where salt concentrations are higher. The less-weathered parts of the Palazzo Pignatelli exhibited higher resistance values and better physical-mechanical properties. In contrast, the sandstone in the deteriorated areas was weakened by salts and exhibited reduced durability.

The analyzed quarry samples were similar to the materials used in the palazzo. Thus, Fuscaldo sandstone could be used to replace the original building material. The use of local stone for restoration activities has many advantages, such as the sustainability of the intervention and compatibility with the local environment, as well as compatibility with local cultural and historical traditions. Moreover, using sustainable local materials from active quarries could be useful for the economic development of neighborhoods. The suggested minimal design intervention shows that the structural elements can be strengthened in a way that is compatible with the architectonic features of the main facade, without altering its aesthetic characteristics.

ACKNOWLEDGMENTS

This research was carried out through laboratory tests at the University of Calabria (DiBEST), Cosenza, Italy, using techniques learned at the IGEO Petrophysic Laboratory (CSIC-UCM), Madrid, Spain. The study was supported by “Programa de Geomateriales 2 (S2013/MIT–2914)” and “Fondi 5 per mille D.P.C.M. 23/04/2010.”

CURRICULUM VITAE

Giulia Forestieri is a graduate in construction engineering and architecture and a PhD student in the Sciences and Engineering for Environment, Buildings and Energy program at the University of Calabria.

<table>
<thead>
<tr>
<th>Kinematic analysis</th>
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<td>b)</td>
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<td>LLS</td>
<td>$a' &gt; a_T S/q$</td>
<td>Satisfied</td>
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<tr>
<td></td>
<td>Not Linear</td>
<td>$d' &gt; f_{j_{\text{a}}}(T_u)$</td>
<td>Satisfied</td>
</tr>
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</table>

Table 02. Results of safety check for different limit states and values of the vulnerability factor evaluated for the main facade of Palazzo Pignatelli as: (a) unconsolidated system; (b) consolidated system using metal tie-rods.
Alessandro Tedesco is a graduate in construction engineering and architecture and a PhD student in the Sciences and Engineering for Environment, Buildings and Energy program at the University of Calabria.

Maurizio Ponte is a specialist in applied geology at the University of Calabria.

BIBLIOGRAPHY


(Endnotes)


The Donjons Residentiel (Inland Campania, Italy): From Knowledge to Conservation and Enhancement

INTRODUCTION

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To make usable the large cistern located on the first floor of the tower, a steel “cage” staircase (Fig. 02) was built using the previous trapdoor entry. In addition, an access staircase was constructed from the floor of the castle courtyard to the tower (Fig. 03). The project and the construction of the access system were preceded by the dismantling of a provisional multiflight staircase built during the 1990s, which obstructed views of the tower.

The provisional structure was replaced by a lighter steel structure fastened to the tower using the original, 12th-century staircase mounting holes. This intervention was made in coherence with the original access system to the tower made up by a wooden staircase placed in the same way as the current one; that is, the steel staircase was made to resemble the medieval wooden access structure.

Furthermore, the interior of the tower was covered in a lamellar wood lowered vault structure with bronze foils mounted on the outside to imitate the original
sandstone vault. The vault masonry is different from the masonry of the tower and castle structure, which is in limestone. The use of sandstone helped to reduce weight and make the vault lighter.

Preservation efforts also involved the securing of the masonry staircase that led from the third to the fourth floor, the closure of several gaps (doors, windows) with glass and iron structures, and the installation of a lighting system made up of chandeliers to provide a suggestive and warm light to the rooms.

RESULTS & DISCUSSION

Restoration is always risky, often necessary, and, in some cases, inevitable. In the case of the Montella tower, an abandoned structure that had lain in ruins for many centuries, restoration was unavoidable. The restoration addressed all factors contributing to the degradation of the masonry, and the applied solutions will afford the structure more protection against atmospheric agents.

Among the restoration activities, the reconstruction of the donjon’s roof is notable. In contrast to Rocca San Felice (Avellino), where the renovation of the donjon’s roof was not considered to be essential (despite its fundamental role in preserving the inner walls), in Montella the construction of a roof has prevented the accumulation of rainwater in the tower and preserved the walls from damage.

Restoration of the building has also allowed it to be viewed in its original historical context. Visitors can now enjoy a fully accessible building. Moreover, the restoration work allows easy interpretation of the various structural elements of the tower and helps visitors understand the many transformations that have changed the appearance and function of the tower over the centuries.

CONCLUSIONS

The renovation interventions at the fortified settlement of Montella were all related to a more general project of salvaging and refunctioning the entire fortified complex. The project has involved an architectural renovation, a refunctioning, and a new setup aimed at redeveloping the overall archaeological area and its donjon and thus making them available for public use again.

Conservation, valorization, and promotion of the social uses of donjons residentiel allow visitors to gain a better understanding of a little-known aspect of the military and civil architecture of 12th- and 13th-century Central European and southern Italian settlements.

CURRICULUM VITAE

Assunta Campi is a PhD student in architecture, industrial design, and cultural heritage at the Università degli Studi della Campania “Luigi Vanvitelli,” Naples. For many years she has taken part in activities conducted by Professor Marcello Rotili (chair of the Department of Christian and Medieval Archaeology). She catalogs and studies medieval and postmedieval archaeological finds from inland Campania and has participated in various archaeological surveys and excavations in Italy.

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New Visions for Conservation in Mexico: Case Study of the Exhacienda de San Diego del Jaral

Angélica González-Franco  Ricardo Muñoz

INTRODUCTION

The current theoretical and practical approaches to the conservation of edified heritage are facing new kinds of challenges: how to attend to their physical deterioration as well as the uses and values that societies assign to them. At this moment, when change is the common denominator, it is important to ask whether the purpose of conservation is to “stop time” or, in addition, to recreate and modify heritage according to the needs of the societies that interact with it. Because of this, new approaches for conservation should be considered in which the reuse of the edified heritage comes into play, not as a practice that follows the logic of recycling, but as a methodological strategy that starts with recognizing the values in these buildings in order to preserve their heritage characteristics and satisfy the needs of users.

The research presented in this article was conducted from a mixed approach, using qualitative and quantitative information. To understand the role of the reuse of edified heritage as a methodology that addresses some of the contemporary challenges for conservation in Mexico, the research focused on a case study of the Exhacienda de San Diego del Jaral, located in Jaral de Berrios, San Felipe, Guanajuato.

METHODS & METHODOLOGY

The Reuse of Edified Heritage

During much of the 20th century conservation methodology focused on restoration techniques. Today it is also important to consider new comprehensive conservation strategies that include methodological tools that contemplate not only immediate necessities and requirements but social welfare and environmental and economic sustainability.

The reuse of edified heritage represents a new approach for contemporary architecture because it does not begin with an empty space but with an architectural object that must be analyzed, interpreted, and respected. The outcome, in addition to conservation, must include enhancement, complementation, or modification to satisfy the needs of a particular social group.

Consequently, the field of action for the reuse of edified heritage includes both monuments and contextual or minor architecture. Proper reuse can provide functional and therefore social and economic relevance to the edified heritage. Three fundamental qualities of reuse can be enunciated.

First, a methodological strategy for conservation can be determined by a reuse proposal that recognizes the value of the edified heritage by respecting its heritage character. This must be done with an awareness that designating new uses to a preexisting building entails the possibility of enhancing certain elements and aspects; that is, it values some while minimizing others. Multiple international documents, such as the Athens, Venice, Burra, and Zimbabwe charters, refer to the reuse of edified heritage as an important part of conservation, so long as the values contained in these objects are respected.
Second, reuse can catalyze the development of social welfare, since it protects the identity of a site by not changing its urban image, thus preventing the loss of buildings and the dispersion and relocation of groups of people and, by extension, preventing further expansion and exploitation of developable land. This is linked to economic sustainability because the conservation of a site’s edified architecture creates the conditions necessary for the further development of the immediately surrounding area.

Finally, the design, construction, and maintenance of any building represents a considerable expenditure of energy, materials, and money—resources that should be used so as to derive the maximum benefit for society. Reuse is a strategy that provides a solution to the actual needs of today’s society while simultaneously decreasing environmental degradation.

RESULTS & DISCUSSION

Case Study: Exhacienda de Jaral de Berrios

In the Bajio of Mexico, at the north of Guanajuato, is located the Exhacienda de San Diego del Jaral, which operated from the middle of the 17th century to 1940 as an agroindustrial economic model. Since the 1940s the *exhacienda* has been neglected and looted, leading to its current deteriorated state. Attempts to conserve the property have been frustrated by uncertainty about the rightful owner. Because of these problems, the community has been largely indifferent to the *exhacienda*’s ruins, despite its role in the collective memory of the community. Furthermore, even though it is considered part of the industrial heritage of Mexico, the regulatory bodies responsible for cultural heritage (Instituto Nacional de Antropología e Historia,

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Fig. 01. Edified heritage of the Exhacienda de San Diego del Jaral. Prepared by the authors, 2015.
Jaral de Berrios, like most *exhaciendas* in the region, is located in a small rural town that is in the midst of a social and infrastructural transformation. The social transformation has resulted from the migration of the town’s population to urban centers to study, work, and generally improve their quality of life. The infrastructural changes have involved the transformation from a rural town to an urban settlement in order to enhance mobility in the region and provide the community with previously lacking infrastructure networks. In light of these changes, the *exhacienda*’s context obliges us to question what is the best way to integrate the conservation of edified heritage with the contemporary needs of the community? (Fig. 02).

CONCLUSIONS

The case study of the Exhacienda de San Diego del Jaral and the rural town of Jaral de Berrios suggests the need to reexamine paradigms around conservation and update public policies for the regulation of conservation in Mexico. Also needed are new management models and plans that consider social, environmental, cultural, and economic areas. Together with conservation of edified heritage, these can be a boon for localities rather than a burden on public and private finances. Government programs should be integral and specific to each place, and edified heritage should be viewed as a potential site of not just culture or tourism but of a variety of activities depending on the needs of the community and the capabilities of the building.

Therefore, proposals for the urban revitalization of Jaral de Berrios and for the reuse of the *exhacienda* must be premised on an understanding of the existing buildings’ value. From this starting point, new uses can be proposed for the underused buildings as part of a commitment to sustainable development.

**Curriculum Vitae**

Angélica González-Franco holds a master’s degree in architecture and is a practicing architect with experience in the
reuse and conservation of edified heritage. She is a teacher and private consultant in architectonic design and construction.

Ricardo Muñoz holds a master’s degree in architecture and is a practicing architect with experience in the reuse of edified heritage. He is dedicated to the conservation of edified heritage, the documentation of cultural heritage, and the development of management plans for conservation.

BIBLIOGRAPHY


(Endnotes)
1 Included in this is every kind of structure that has been built to satisfy human needs.
Methods to Evaluate Shelters for Archaeological Sites: Review and Recommendations

Cristina Cabello Briones

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INTRODUCTION

Shelter Performance Assessments

Appraisals of shelters in the literature have generally been based on the idea that covering a site will always be better than leaving it exposed to the environment. However, shelters do not fully reduce environment-damaging factors or keep the microclimate stable in most cases. Furthermore, shelters may have a negative impact on archaeological features. A survey conducted by the Israel Antiquities Authority found that half of the 106 mosaics covered with shelters were still deteriorating and that, in some cases, the shelters exacerbated the damage.1

The most common method to evaluate shelters has been a point factor system based on a qualitative assessment. More than 100 sheltered archaeological sites in Italy were evaluated with this system.2 Aspects such as the morphology of the archaeological area and materials used for shelter construction were studied. Only 38.7% of the shelters were found to be efficient. For example, the transparent roofs of the House of Ariadne at Pompeii were classified with a score of 5.5 (intermediate protection). However, subsequent microclimatic monitoring found unacceptable temperature levels.3 This demonstrates that visual assessments, when used on their own, rarely provide a complete understanding of the problems affecting a site.4 However, to date, few studies have

Fig. 01. (a) Hagar Qim (Malta); and (b) the Bishop’s Palace (Witney, England).
provided a scientific explanation of the decay processes at sites with shelters. This could be due to project limitations such as those related to budget or duration.

**Geomorphological Methods**

In situ assessments, laboratory tests, and exposure trials are the most common geomorphological approaches used in the conservation field. In situ assessments are based on direct measurements and analyses of materials from the site and may provide more-reliable information about weathering than other methods. However, original materials are usually altered by past interventions or past deterioration patterns, which can change the response to current weathering conditions. This makes observed weathering phenomena difficult to extrapolate to other cases or even to other parts of the same site. In addition, the use of destructive or invasive techniques has been largely disapproved in the field of conservation.

Laboratory tests simulate the impact of certain degradation factors on specially prepared specimens under controlled conditions. They are designed to measure decay in a replicable way so results benefit from comparison with other studies. However, they have been criticized for their lack of representativeness of historic buildings.

Exposure trials consist of placing stone samples in real-life conditions. Their behavior is employed as an indicative sensor of decay under complex environmental conditions. Additionally, the specimens can be brought into the laboratory at intervals for evaluation, which can provide a link between laboratory simulations and field observations. Modern replicas and test structures can potentially offer more realistic representations of the deterioration of real buildings. However, they are time-consuming and expensive to construct.

**METHODS & METHODOLOGY**

The methodology proposed for Ħaġar Qim (Malta) and the Bishop’s Palace (Witney, England) (Fig. 01) was intended to be simple and low cost so it could be applied by nonexperts with budgets ranging from high to low. To study the protective role of the shelters, three categories were considered: (1) visual surveys of stone remains and shelters; (2) environmental assessments; and (3) analytical investigations of stone samples.

Four replicates (90 x 90 x 30 mm) of chalk, coralline, Cotswold, Globigerina, and Portland limestones were placed outside, on the periphery, and inside the shelters (Fig. 02). Standard tests were undertaken to determine their expected durability (Table 1). Change in properties was documented periodically at regular intervals for a year using nondestructive techniques. The results were compared with the control samples. Changes in the following stone properties were studied: weight (Sartorius AG balance), elasticity (M-K5, Grindosonic), hardness (Equotip 3, Proceq), ultrasonic pulse velocity (UPV) (Pundit Lab, Proceq), ultrasonic pulse velocity (UPV) (Pundit Lab, Proceq), color (CM-700d, Konica Minolta), and general appearance (USB optical microscope VMS-001, Veho).

<table>
<thead>
<tr>
<th>BS EN 3755:2008</th>
<th>Portland</th>
<th>Cotswold</th>
<th>Chalk</th>
<th>Globigerina</th>
<th>Coralline</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS EN 3755:2008</td>
<td>Water absorption at atmospheric pressure (Ab)</td>
<td>6.96%</td>
<td>12.52%</td>
<td>18.51%</td>
<td>14.75%</td>
</tr>
<tr>
<td>BS EN 1936:2006</td>
<td>Open porosity (Po)</td>
<td>14.46%</td>
<td>22.02%</td>
<td>31.17%</td>
<td>31.18%</td>
</tr>
<tr>
<td>BS EN 1936:2006</td>
<td>Apparent density (b)</td>
<td>2100 Kg/m3</td>
<td>2375 Kg/m3</td>
<td>1773 Kg/m3</td>
<td>1789.72 Kg/m3</td>
</tr>
</tbody>
</table>

Table 01. Physical properties of the stones used in the study
Temperature, relative humidity, and wetting events were measured using data loggers (i-button® hygrochrons and Tinytag® leaf wetness loggers). The number of NaCl crystallization events and frost events were derived from temperature and relative humidity data. This information was supplemented with data related to solar radiation as determined by computer modeling and dust deposition as determined by image processing techniques.

Additionally, twelve Portland limestone tablets (50 x 50 x 20 mm) were attached to freely rotated carousels, inside and outside the shelter at Witney (Fig. 03). Results were compared with those obtained from the National Materials Exposure Programme, which aimed to assess the impact of acid deposition on building materials. Detailed examination by scanning electron microscope (JSM 5910 SEM, Jeol) was complemented with a study on salt content (Dionex ion chromatograph), pH of the rain (pH meter, Orion Model 410A), and NO₂ and SO₂ concentration levels (Gradko® combined diffusion tubes).

RESULTS & DISCUSSION

Exposure trials were adapted to determine the effectiveness of shelters on the preservation of archaeological sites. Short to medium exposure trials provide evidence of early stages of decay and represent

<table>
<thead>
<tr>
<th>Equipment and purpose</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance: material loss/deposition</td>
<td>Precise, easy to use, low cost, can detect changes in short time periods, non-destructive</td>
<td>Highly affected by handling errors, laboratory conditions and dried samples needed</td>
</tr>
<tr>
<td>Elasticity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grindosonic: change in EMOD (increase in pores and inner cracks)</td>
<td>Easy to use, non-destructive</td>
<td>Only good for homogenous stones, more than 1 year of exposure may be needed for significant results, influenced by environmental conditions, samples of specific shape needed, high variability between replicates</td>
</tr>
<tr>
<td>Hardness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equotip: change in surface hardness (weathering / deposition)</td>
<td>Easy to use, field work equipment</td>
<td>Many measurements needed (large sample surfaces), micro-destructive, more than 1 year of exposure may be needed for significant results, influenced by environmental conditions, high variability between replicates</td>
</tr>
<tr>
<td>UPV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pundit: change in UPV (increase in pores and inner cracks)</td>
<td>Easy to use, field work equipment, non-destructive</td>
<td>Stain samples, no good for samples with irregular surfaces, more than 1 year of exposure may be needed for significant results, influenced by environmental conditions, dried samples needed, high variability between replicates</td>
</tr>
<tr>
<td>Colour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spectrophotometer: colour change (soiling/ biofilms)</td>
<td>Precise, easy to use, field work equipment, non-destructive</td>
<td>Influenced by environmental conditions</td>
</tr>
<tr>
<td>Visual changes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DSLR camera and USB microscope: Surface erosion/ soiling</td>
<td>Easy to use, good for field work, non-destructive, good for before/after measurements</td>
<td>Only visible changes, low magnification</td>
</tr>
<tr>
<td>Salts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ion chromatography: salt content (amount and type)</td>
<td>Precise</td>
<td>Requires preparation of samples (time consuming and expertise required), micro-destructive</td>
</tr>
</tbody>
</table>

Table 02. Summary of techniques used to monitor stone property changes
a compromise between the time available for the project and the time necessary to obtain significant results. The main advantages are that the method is not destructive for the ruins themselves, allows both destructive and non-destructive techniques to be used, the use of replicates for strong statistical results, and simultaneous monitoring in different parts of the same site or different sites. In addition, the method does not require the site be closed to the public, because samples are small and discreet. However, decay mechanisms seen in the stone samples may be difficult to match with those on the ruins.

Weight loss and changes in elasticity, hardness, and UPV can be used to detect physical weathering in terms of material loss (cracks, erosion, and increase in porosity). In addition, analyses of salt content and gain in weight can provide information about chemical weathering processes and soiling. Color and changes in general appearance can be used to corroborate the presence of biological films as well as signs of physical weathering and soiling. A summary of the techniques used to determine stone decay in the samples is presented in Table 2. An overall evaluation refers to the author’s recommendations after taking into consideration the simplicity of use and the results obtained.

CONCLUSIONS

The use of stone indicators has been found to be a suitable option for monitoring the effect of shelters at archaeological sites when comparisons are required and direct tests on original surfaces should be avoided. Stones with low apparent density, high water absorption, and high open porosity, such as chalk and Globigerina limestone, are effective indicators of decay. Additionally, dry weight and color changes are good options for comparing degrees of weathering at different locations and sites. They are suitable for sites with low budgets, and significant results might be obtained in short exposure times.

ACKNOWLEDGEMENTS

I thank my PhD supervisor, Prof. Heather Viles, for her guidance and encouragement. For financial support, I thank La Caixa Foundation and the Engineering and Physical Sciences Research Council.

CURRICULUM VITAE

Cristina Cabello Briones holds a PhD in geography and the environment from the University of Oxford. She also has an MA in preventive conservation from Northumbria University, a BA in heritage conservation from Escuela Superior de Conservación y Restauración de Bienes Culturales de Madrid and a BA in art history from Universidad Autónoma de Madrid.

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Archaeologists and Conservator/Restorers: Teamwork Needed for the Study and Conservation of Archaeological Heritage: The Example of an Iberian Funerary Urn

Anna Bertral, Maria Carme Belarte, Jaume Noguera

INTRODUCTION

The Iberian necropolis of Les Esquarterades was discovered in the southern counties of Tarragona in 2013. Archaeological excavations were subsequently conducted (2014–2015) on a surface of approximately 30 square meters, where around 20 burials with varying levels of preservation were recovered. The urns on the northern side had been destroyed or displaced by the tractor’s plowshare. On the southern side, however, nine relatively well-preserved urns, damaged only by the pressure of the soil, were recovered (Fig. 01).

These burials consisted of urns of handmade or wheel-thrown pottery, with a ceramic cover, and were placed in pits sealed with a stone slab. The urns contained the skeletal remains of cremations, following the typical ritual of the Iberian period. Some personal bronze ornaments (pendants, chains, fibulas, etc.) were also placed inside, while iron objects were found on the outside, underneath, or beside the urns, especially weaponry (spearheads, spears, ferrules, knives, etc.).

Fragments of black-glaze Athenian Castulo cups related to the burials were documented, allowing us to date the
The use of the necropolis to between the middle of the fifth century and the beginning of the fourth century BCE.

During the fieldwork, a conservator/restorer was present to supervise the extraction, storage, and eventual transportation of the archaeological remains to the University of Barcelona. Once the pieces arrived at the laboratory, further collaboration occurred between archaeologists and restorers.

The aim of this article is to present the results of the work jointly undertaken on the archaeological material recovered from the necropolis by the archaeologists, conservators/restorers, and anthropologists (together with other specialists). To do this we shall focus on describing the tasks undertaken to study the funeral urns and the associated metal grave goods recovered from the site, from fieldwork to laboratory work, with a particular focus on urn SP19. We shall therefore present the main problems encountered with the recovered materials, as well as the specific actions and treatments applied to solve them.

The intent is to develop the idea of a multidisciplinary approach to work in the field of archaeological conservation/restoration, with a focus on the role of conservators/restorers within the research team. Close collaboration between all researchers involved in the study of this necropolis was necessary to extract the maximum amount of archaeological information and provide the right conditions for the conservation of the discovered materials.

METHODS & METHODOLOGY

Onsite Work

We counted on the presence of a restorer, indispensable for securely recovering the many objects dispersed throughout the necropolis. In some cases, due to the poor state of preservation, objects required a preventive treatment (specific gauzes or Paraloid B-72® consolidations) before they could be lifted and securely transported.
Each relatively well-preserved urn was prepared for transport as a whole to the laboratory, which is where the microexcavation of its contents took place. Depending on its state and the presence of grave goods in its vicinity, each urn was removed with a buffer of surrounding earth to improve its protection. The urns were wrapped in transparent film, then deposited in plastic boxes, which were covered and reinforced with bubble wrap to stabilize them during transportation.

The objects in iron, bronze, pottery shards, and so on, were stored separately (according to their material) in polyethylene bags with hermetic seals and perforated, awaiting convenient treatment in the laboratory.

**Laboratory Work**

1. Work prior to microexcavation of the urns: X-rays and CT scans were taken of the completely preserved urns. An image of their contents was obtained to determine the shape, layout, and size of the bones, metal objects, and ceramics within, and this information then informed the planning of the intervention used in each case (Fig. 02).

2. Excavation of the urns: Information obtained from the X-rays and CT scans allowed the archaeologists, conservators/restorers, and anthropologists jointly to identify three scenarios that then informed the microexcavations, from the point of view of the conservation/restoration work.

   A. Urns with no (or only small amounts of) metal grave goods inside to interfere with retrieval of the skeletal remains.

   B. Urns with metal grave goods inside that would interfere with retrieval of the skeletal remains.

   C. Urns with metal grave goods present only within the surrounding earth buffer.

   **Methodology used in each case:**

   A. The archaeologist performed the microexcavation with occasional help from the conservator/restorer. A stratigraphic method was followed, separating the upper layer from the lower, which usually contained most of the bones. Bones found in isolation were deposited in a bag. Once the archaeologist reached a section comprised mainly of bones, they were removed as a block and sent to the anthropologist, who finished excavating them in the most convenient way for extracting a maximum amount of information. If any metal objects remained within the block of bones, the restorer helped the anthropologist recover them. The state of preservation of these objects was usually quite bad, requiring immediate treatments to conserve them and facilitate future treatment.

   B. The best course of action was agreed with the anthropologist. To retrieve both metal objects and bones in the best possible condition, the restorer was put in charge of excavating from the moment the two types of objects began to appear together. A photograph was taken, and all visible items were flagged and numbered. One by one they were extracted and stored in separate, clearly labeled bags. In cases where the bones had come into contact with the consolidant for the metal (Paraloid B-72®), this was indicated on the bag to provide additional information for the anthropologist.

   C. The restorer oversaw the excavation and retrieval of the metal objects on the outside. Once they had been extracted, the excavation continued using the methodology described for scenario A.

3. Conservation/restoration work on the remaining materials retrieved: Materials exhumed from the urns (in iron and bronze), as well as the ceramics, were treated in the laboratory as necessary to ensure their correct interpretation and long-term conservation.
RESULTS & DISCUSSION

Thanks to the conservation/restoration treatments undertaken in the laboratory on some of the exhumed pieces (iron, bronze, and ceramic), the archaeologists were able to observe details not noticeable to the naked eye; for example, discerning decorations or finishes in other materials. The cleaning and reconstruction work gave valuable information to the archaeologists in charge of the overall study of the necropolis (Fig. 03).

The CT scans performed prior to the microexcavations were useful as guides for that work, as well as for making an initial diagnosis of the layout and difficulty of extraction of the objects, which allowed for courses of action to be determined in advance. A good example is SP19, which was surrounded by a fine and richly decorated layer of bronze, already detected onsite. Once at the laboratory, and thanks to the CT scan image, it was extracted with precise knowledge of its layout, dimensions, and cracks, thus facilitating the conservator/restorer’s task.

Because of the large quantity of remains that still need to be treated, this work is ongoing. This article lays out the broad outlines of what is being done. Our preliminary assessment is that the collaboration between different disciplines and professionals has delivered optimal results, since working shoulder to shoulder is encouraging a wider view of the task being undertaken.

CONCLUSIONS

Joint work between specialists in different fields has contributed to improving the quality of information obtained in the study of various archaeological materials, since more detailed information can be retrieved, especially concerning the shape and manufacturing technique of the various objects. At the same time, collaboration allowed the bones to be isolated from the metal items, facilitating the subsequent work of the anthropologists.

ACKNOWLEDGEMENTS

This research was funded by the research project 2014–2017: “The First Millennium BC in the Territories of the Lower Ebro River: Formation, Development and Dissolution of the Iberian Culture” (Government of Catalonia) and the Town Council of Ulldecona (Tarragona, Spain). We thank the archeology degree students of the Universitat de Barcelona for their participation in the fieldwork as well as in the laboratory work.

CURRICULUM VITAE

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Jaume Noguera is a senior archaeology lecturer at the Universitat de Barcelona. He researches the evolution of the protohistoric population on the lower course of the Ebro, the protohistoric cremation necropolises in Catalonia, and the military settlements of the Roman Republic era in the northeast of the peninsula.

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From Excavations to Conservation: Evidence from the Latin Colony of Norba (Lazio, Italy)

INTRODUCTION

The ancient city of Norba is situated in the Lazio region at 500 m above sea level on a plateau of the Lepini Mountains that dominate the Pontine Plain. The historical record tells of the foundation of the city in ancient times, when Norba took part in the Latin League. The historian Livy recalls that in 491 BCE a colony was established “quae arx in Pomptino esset.”

The walls and the four access doors to Norba are known. The former encircle an area of 44 hectares, inside which topographic research and excavations have uncovered an urban layout with orthogonal axes, punctuated by polygonal masonry terrace walls. Four focal points of the city have been outlined: the sacred areas of the Major Acropolis, the Minor Acropolis, the area of the Forum, and the Sanctuary of Juno complex.

Since 2005, the city has undergone systematic excavations carried out by a research group from the Seconda Università...
degli Studi di Napoli, which, under the scientific direction of Stefania Quilici Gigli, has excavated two of the 44 hectares, including 12 houses and several roads.4

METHODS & METHODOLOGY

Conservation and enhancement mark the end of an archaeological research lifecycle, constituting the act by which cultural heritage is preserved and restored for social use. In Norba, the need both to conserve the excavated structures and to allow them to be used by the public posed a significant problem because of the reduced amount of the land that covered the walls as well as a lack of preserved walls.

Intervention strategies privileged streets and the domūs that overlooked them, so as to accommodate both conservation activities and tour routes.

The excavations identified a series of major road networks perpendicularly intersected by minor side roads that are punctuated by a series of blocks that host the 12 excavated domūs.

The domūs have a canonical layout: a central atrium with an impluvium, rooms to the side, and reception rooms at one end (Fig. 02), characterized by regularly punctuated flagstone-based cement floors with irregular limestone tiles that are sometimes enriched with geometric shapes and inserts that have images on them.

Several types of low-elevation walls were identified: with a limestone base and a mud-brick elevation; with compressed-earth blocks; with a limestone base and a clayey earth elevation (Fig. 01); with limestone blocks set into the ground with a mortar finish—a variety of techniques that speaks to a variety of intervention choices.

Conservation of the walls, floors, and roofs was the main problem to be solved. Following the opposing views of a succession of superintendent archaeologists within the Lazio region, a decision was made neither to provide the houses in Norba with roofs nor to backfill them but to blend conservation with communications to the public by means of choices that would immediately rebuild the house plant as well as the organization of the spaces.

RESULTS & DISCUSSION

The adopted solution to preserve the site and make it available for tourism was to renovate the floors, which were subsequently covered with red volcanic stone chippings in the closed environments and with pink Carrara marble in the open spaces, so that they would be protected against inclement weather while still conveying their function within the house layout (Fig. 03).

Walls with a rock-fill plinth were renovated or reintegrated with Scotch pine poles. For walls with a clayey earth elevation, a consolidation of the walls was carried out, and protective roofs were constructed using wooden formwork with cavities as well as a brown impregnating agent to highlight the color of the clayey earth-based walls (Fig. 03).

For walls where only the foundations or a few centimeters remained, the superintendent archaeologist directed that they be reconstructed to a height of 35–40 cm, which would protect the floors from run-off rainwater and allow the house to be visited by tourists.5

CONCLUSIONS

The intervention strategies adopted for Norba fully satisfied the need to conserve the structures while enhancing their value by means of solutions that also facilitated opening the ancient city to the public.

For this purpose, the entire route was subsequently delimited by means of wooden Cumaru decking walkways and fencing to guide visitors along the route.

The edges of the walkways coincided with the edges of both the excavated area and houses. To give the idea of the presence of wooden doors, wooden gates were placed...
at the entrances. The gates acted as a further means of protection for the structures while still allowing visitors the widest possible view of the site (Fig. 03).

Although the conservation approaches protected the structures, they rendered certain elements, such as the original floors, “lost heritage” by hiding them from visitors.

This problem was solved by a university project involving engineers and archaeologists who created a location-aware platform that has proved to be not only an aid to tourists but a means of providing them with a fuller experience during guided tours of the site. Thanks to a Web-based application that uses the latest generation of multimedia supports, tourists, simply by positioning themselves near the domūs, can view the original floors of the houses on the display, read about them, and retrace the excavations and the conservation interventions that have taken place there.6

**Curriculum Vitae**

Margherita Di Niola is an archaeologist and PhD student studying ancient topography in the Department of Arts and Cultural Heritage of the Università degli Studi della Campania “Luigi Vanvitelli.” She has conducted and collaborated on topographical and archaeological research projects in Italy, including the archaeological excavations of the ancient city of Norba.

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1 *Dion. Hal.* V, 61, 3.
Hades’s Head: A Greek Hellenistic Masterpiece from Morgantina, Sicily

INTRODUCTION

Morgantina (Fig. 01), an impressive Greek city of Sikel origins in the center of Sicily,1 figures prominently among the world archaeological sites damaged by illicit excavations and the illegal trade of antiquities. Sacked again and again by tombaroli, especially in the late 1970s, Morgantina has since 2007 been much in the international news because of the repatriation to Italy of a group of Greek art masterpieces looted and acquired by American collectors and museums. These include the two Greek Archaic acrolithic statues repatriated in 2009, the Greek Hellenistic silver treasure returned by the Metropolitan Museum of Art in 2010, and the Greek Late Classical statue of a goddess, best known as “the Getty Aphrodite,” repatriated in 2011.2 As a result of 20 years of criminal investigations and diplomatic negotiations, these repatriations are today a symbol of the victory of legality over the international illicit traffic in stolen antiquities. They also prove the new trend of some museums for antiquities acquisitions and collection management, a direct consequence of the 2005 criminal trial in Rome where Marion True, former curator of antiquities for the Getty Museum, was indicted by an Italian court for conspiring to acquire stolen art for the museum. Thanks to the repatriations, Morgantina,

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Fig. 01. Morgantina (Aidone, Italy). Panoramic view of the Greek Hellenistic agora. (Author Serena Raffiotta, with the permission of Servizio Polo Regionale di Piazza Armerina, Aidone ed Enna per i Siti Culturali. Parchi Archeologici della Villa del Casale e di Morgantina).
once known mostly to archaeologists and scholars, is today one of the most popular tourist destinations in Sicily, along with the Museo Archeologico di Aidone.

Not long after the repatriation of the “Getty Aphrodite,” Morgantina again came into the limelight as the Getty returned another stolen object. On 10 January 2013, an official press release by the museum announced the “voluntary” return to Sicily of a Greek Hellenistic polychrome terracotta head (Fig. 02), acquired in 1985.

The press release was diplomatic: “Joint research with colleagues in Sicily over the past two years has yielded previously unknown information on the likely provenance of the sculpture suggesting that it was appropriate to return the object.” This “voluntary” return was officially the first step of a large project to review the museum’s antiquities collection with the aim of verifying the ownership history of 45,000 objects and publishing the results in the museum’s online database.

The announcement was a great surprise for Italy. Nobody had heard of any Italian investigations into this unique Greek sculpture or of objects looted in Sicily having recently been claimed. Why did the Getty Museum suddenly announce a new return? The press release declared, “the decision to transfer this head is based on the discovery of four terracotta fragments found near Morgantina in Sicily, similar in style and medium to the Getty head.” For the first time, undeniable archaeological evidence had led to an important decision on the repatriation of a looted object. The archaeological evidence in this case was a group of small fragments of terracotta sculpture, unknowingly housed for years in the Museo Archeologico di Aidone store.

**METHODS & METHODOLOGY**

The recently repatriated object is a life-size terracotta male head (29 cm high) with a long, thick, light-blue beard and a thick, reddish-brown hairstyle. Both beard and hair consist of hand-worked spiral curls modeled one by one and applied to the head before firing. Deep incisions, probably for metal eyelashes, define the almond-shape eyes. The lips are barely open. Together with the vivid, well-preserved pigments of both beard and hair, Egyptian blue and red hematite, these features give to the head an impressive realism. The head once belonged to a Greek Hellenistic cult statue of Hades dating to the fourth or third century BCE from the extraurban sanctuary of Contrada San Francesco Bisconti in Morgantina, dedicated to chthonian deities. Here Hades, god of the underworld, was part of the divine chthonian triad, together with Demeter, goddess of agriculture; and Persephone, her young daughter and Hades’s bride.

How was the head attributed to Morgantina? In 2004 and 2005 I was studying in the Museo Archeologico di Aidone for my post-degree thesis, classifying Greek terracotta figurines from the Contrada San Francesco Bisconti sanctuary. The site had been discovered and looted by tombaroli in 1977 and 1978, and many of the fragments broken and abandoned on the ground by tombaroli were immediately collected by the site attendants. Among them were numerous fragments—drapery, limbs, and a small, blue-painted terracotta curl—from life-size terracotta statues (Fig. 03). In 2007, I published my research in a book with a catalogue and many images. Because of the rarity of its color, that unique blue-painted curl had its own space in the attached tables. In 2009 I presented my book as a present to Lucia Ferruzza, an archaeologist working at Assessorato dei Beni Culturali, the Sicilian Department for Cultural Heritage. From 1985 to 1986 Ferruzza had been studying as a graduate intern at the Getty Research Institute. Scrolling through the pages of my book, she saw the blue-painted curl and remembered the blue-bearded head in the Getty collection. We met in Aidone, discussing technical details of the curl, suspicious
that the blue-painted fragment in Aidone might belong to the Getty head. Our suspicion proved correct. The blue-painted curl was very similar to the blue beard of the Getty sculpture. The moment was not right, however, to claim a new object in the Getty collection: The museum was challenging the return of the “Getty Aphrodite,” so coming forward with a new request would not have been prudent.

After the Morgantina goddess was repatriated to Italy and housed in the Museo Archeologico di Aidone, destiny helped Hades return to Morgantina. While reorganizing the museum store in August 2011, three more terracotta curls were found, collected in 1988 during a survey of the sanctuary. Now was the right moment to officially claim the head. But the Getty Museum wanted to examine the four curls, so in September 2011 the fragments travelled to Los Angeles along with a group of objects on loan for an exhibition dedicated to Morgantina at the Getty Villa in Malibu. The official comparison conducted by the Getty’s Antiquities Conservation Department confirmed that the bearded head came from Morgantina.

RESULTS & DISCUSSION

How and when the sculpture arrived in the Getty collection can now be answered. The sculpture was looted from Morgantina in 1977–1978. The four curls were broken during the illicit excavation, falling to the ground where they were collected by the site attendants (the first curl in 1978, the others in 1988).

Placed on the antiquities black market, the head was acquired by Maurice Tempelsman, a Belgian-American businessman and diamond merchant and the longtime companion of Jacqueline Kennedy Onassis. In 1985, through the London art dealer Robin Symes, the head was sold for $530,000 to the Getty Museum and there remained on display until 2011, when it was removed after suspicion of its illegal provenance came to light.

After the museum’s official declaration of “voluntary” return in 2013, two years of effort, deal attempts, and international letters rogatory passed before Italian officials could arrange for the sculpture’s homecoming. But the return could not be “voluntary.” Italian authorities had to go to the Getty Museum to seize the object as evidence in a crime.

Finally, on January 29, 2016, the Hades head was repatriated thanks to the effective collaboration between the Enna Public Prosecutor’s office, the Carabinieri Command for the Protection of Cultural Property, the Italian general consulate in Los Angeles, and the Getty Museum.8

CONCLUSIONS

This case is clear evidence of the value and importance of archaeological research, demonstrating that archaeologists—not just criminal investigators—can play an important role in the fight against international art crime.

CURRICULUM VITAE

Serena Raffiotta is an archaeologist. She studied classical archaeology at the Università degli Studi di Catania. She has participated in excavation programs in Italy and abroad. Currently an independent researcher, she also offers consultancy services for archaeological research and excavation and develops didactic programs for students. Her passion for Sicilian cultural heritage led her to become a tourist guide.

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Valorization of the Roman Dock of Castellabate

Marco Russo*  
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INTRODUCTION

This study tries to identify a way to valorize an underwater archaeological site in Castellabate, testing the collaboration between architects and archaeologists. The project was developed with the Soprintendenza Archeologica della Campania, under the supervision of Maria Tommasa Granese, director of the archaeological site of Velia, and with the collaboration of the underwater archaeologist Alessandra Benini, a researcher interested in submerged Roman archaeological sites and author of a paper on the Roman dock of San Marco di Castellabate.1 The collaboration of Arturo Rey da Silva, associate program specialist at the United Nations Educational, Scientific and Cultural Organization and the historical and bibliographical contribution of Gennaro Malzone,2 author of a book focused on the historic development of the coast over the centuries, have been a great asset to this paper. The main aim is to identify one or more possible guidelines for the enhancement of the underwater site of Castellabate, which is nowadays deserted and unprotected.

THE ROMAN DOCK OF CASTELLABATE

San Marco di Castellabate is the suburb of Castellabate, a small town of 1,200 inhabitants along the Cilento coast, in southern Italy. It is located between two important Greek archaeological sites, Paestum to the...
north and Velia to the south. During the last 30 years, three excavations have taken place, but the underwater archaeologist Benini has provided the most complete study of the ruins, identifying their original functions and discovering some unpublished elements of the sites, including the holes in the foundation of the pier.

During the Roman age, the dock stretched the length of the town’s coast, with several piers along the seaside to protect the shore. A huge archaeological area was partially destroyed during the construction of a tourist dock in the 1960s. The tourist dock is a great opportunity but is not well used except in summer. During winter the waterfront is almost empty. In 2013, a luxury thermal bath was constructed near the archaeological site that might help to guarantee visitors throughout the year, but it alone is unable to ensure a sufficient number of tourists. A building to enjoy the archaeological site could provide an opportunity for the development of the abandoned waterfront.

ARCHAEOLOGY AS EXPERIENCE

The original idea for this project was developed after a meeting with Tommasa Granese, director of the archaeological site of Velia, 40 kilometers from Castellabate, at the offices of the Soprintendenza Archeologica di Salerno. The goal of the meeting was to identify possible guidelines for the restoration and valorization of the cultural heritage and to determine whether a valorization policy existed in Campania.

Many challenges are linked to the difficult situation of the archaeological sites in Campania, the low number of visitors, and the low budget for each site. Castellabate is a small town invaded by too many people during summer and inhabited by only the residents in winter. A museum in such a place would be risky, an expensive structure that is difficult to manage and too expensive to build. Castellabate needs a simple, measured solution for its site, based on the principle of fast construction, fewer problems to manage, and achievable with a small budget. The municipality does not have this budget at the moment, so the operation could supported by a private sponsor or EU funds for the development of cultural heritage. An ephemeral structure would be more practical than a “traditional” building due to the strong mistral wind that affects the site.

During the meeting, the attention was also paid to contemporary valorization and museumification projects involving archaeological heritage. International case studies are unlimited and various, including glass-bottom boats, a solution used for an underwater archaeological site in Ischia by Alessandra Benini, or the expansive, complex solutions used in two Chinese museums on underwater cultural heritage, the Chinese Baiheliang Underwater Museum and the Guangdong Maritime Silk Road Museum.

The study of international best practices is an opportunity to think on past projects in the same field and to understand possible visions for the future. The wish was to gain knowledge of global solutions, even those that would not be suitable for Castellabate, without denying the contextualization of the architectural proposals.

STRUCTURE AND EXHIBITIONS

The solution proposed for Castellabate was inspired by some projects of small to medium dimensions, based on
sustainability concepts, speed of construction, a partly funded budget, and the possibility of building all or part of it during a workshop or by volunteers. In the last five years, some new architectures were built following these concepts, such as the Makoko Floating School in Lagos by Nlé Architects (2012), the Jellyfish Barge in Florence by Studiomobile (2015), and Antiroom II in Valletta by Elena Chiavi, Ahmad El Mad, and Matteo Goldoni (2015). All these buildings were developed from geometric forms, such as hexagons and circles. The use of these shapes allows an architecture made of recurring structural components to be built and easily expanded.

Our design proposal is a ring-shape building, the plan of which is divided into two concentric sectors. The outer ring is an environment with dynamic functions inside. This space is organized around the Roman amphorae found during dives in the area and today “hosted” in the warehouse of the abbot’s castle. Its privileged location in the sea will make the structure a horizontal platform, a free-view area from which to enjoy the marine landscape. The space can be used as a support for the main exhibition, represented by the submerged remains of the Roman breakwater. All contemporary exhibition spaces are designed to enhance the visitor experience, a direct consequence of the modern relationship between the artwork and the observer.

The main exhibition is the central part of the circular structure, a space where visitors can see the underwater remains of the Roman breakwater. The structure was built with the same techniques used for the east-west dock, with traces of the wood artifacts still visible inside the concrete mass. A few of the architectural elements were inspired by the first experiments in creating an underwater structure, carried out by Jacques Cousteau in the 1970s, such as the “liquid door,” a connection between the architectural environment and the underwater world.

This space could be used during underwater archaeology courses or to display videos on the archaeologist’s work during an underwater excavation. From the platform, visitors can dive and visit the remains, an immersive space where exhibitions could be easily changed.

CONCLUSIONS

The solution is based on a medium-size building that allows the remains to be “visited” all year (night tours are possible too) and is integrated with the local economy and with local boaters. The structure has no physical connections to the archaeological site and perfectly overlaps the Roman breakwater. Similar structures include the floating bridge realized by Christo over Lake Iseo or the OCNO archipelago for the Lago Inferiore in Mantova. My idea is to reach the structure with a small boat from the tourist port. The structure would remain in position thanks to removable anchors.

The wooden building is part of the landscape, a common feature of these projects, such as some museums designed by Peter Zumthor in Norway. The structure is removable; for example, it might be moved and protected in the tourist dock during a coastal storm or for maintenance work.

The goal of this noninvasive proposal is to become a new symbol for citizens, who could use the waterfront in an active way.
CURRICULUM VITAE

Marco Russo is an Italian architect and a PhD student focused on the impact of architecture on the valorization of cultural heritage and archaeological sites.

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4 This is the public office that manages the archaeological sites; its jurisdiction is provincial. For more, see http://www.archeosa.beniculturali.it/.
7 “A liquid door, created just by the pressure of the air inside the house, used to be the only untouchable surface dividing the intimacy of the domestic from the wildness of the oceans: an ever-calm lake, a magic mirror that reflects the bottom of the sea.” Isola & Norzi. Hilario Isola and Matteo Norzi dedicated an exhibition to Jacques Cousteau’s utopian dream of living underwater in the New York Aquarium at Coney Island (2010).
MATERIALS
Study of a Numismatic Collection Combining Electron Microscopy, Nanoelectrochemical, and Spectrophotometry Techniques

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d Universitat de València, Spain

INTRODUCTION

From their introduction through the seventh century BCE, coins scarcely changed. They represent a large percentage of pieces exhibited in many archaeological museums and have become important case studies for research.

Analytical studies of ancient coins have mostly involved silver coins, with analyses of coins made from copper alloys much scarcer. Among the latter is Griesser et al. who analyzed the different states of corrosion of bronze coins with a high lead content using a variety of instrumental techniques, including neutron diffraction. Other studies have proposed a possible correlation between the coin composition and the geological site of the extracted mineral. He et al. studied bronze coins from different places and periods in ancient China, Moreno-Suarez et al. analyzed roman leaded copper coins, and Torrisi et al. characterized Egyptian bronze coins.

The present article reports on a study of a portion of a numismatic collection; namely, ten copper-based coins from different countries and dating from the 18th to the 20th century.

A multitechnique methodology was used to study the coin collection, including cataloging, characterizing the elemental composition by using X-ray microanalysis combined with scanning electron microscope (SEM-EDX), performing a colorimetric study using spectrophotometry, and characterizing corrosion products using “one touch” voltammetry of microparticles (VMP).
METHODS & METHODOLOGY

The analysis was performed without prior preparation by combining the noninvasive SEM-EDX and visible spectrophotometry (VIS spectrophotometry) and the quasi-noninvasive “one touch” VMP electrochemical technique. Colorimetric measurements of VIS spectrophotometry and X-ray microanalysis performed by SEM-EDX were carried out in restricted parts of the surface of the coin. Areas used for performing the analyses were in the range of 5 x 5 mm. The experimental procedure carried out for performing the analyses is described elsewhere.6

RESULTS & DISCUSSION

The studied coins were minted in Malta, France, the United Kingdom, Portugal, and Switzerland and were produced from 1776 to 1962 (see Fig. 01 for details).

Table 1 shows the diameter and thickness of each coin. The average elemental concentrations and standard deviations of the main elements of each coin were calculated from the measurements carried out by SEM-EDX. The ratio of Zn (Sn) to Cu was determined by SEM-EDX of the surface of the coins (a few mm deep) (see Table 2). Apart from the coin minted in Malta, copper was alloyed with zinc and tin irrespective of the minting site. For the full series of coins, element mass ratios ranged from 1.4 to 2.8 for the m(Sn)/m(Cu) ratio and from 4.2 to 8.6 for the m(Zn)/m(Cu) ratio. These values reflect the composition of the corrosion layer or patina rather than the bulk composition of the coin. In the patina (which was a few mm deep), the three elements that compose the coin were present not only in metallic state (Cu(0), Zn(0) and Sn(0)) but in oxidized states (e.g., Cu2O or CuO). This composition was in agreement with the notable presence of oxygen that was also evidenced in the X-ray spectra obtained from the patina. This oxygen is chiefly associated with the formation of oxidized corrosion products from the metallic atoms of the core coin.

An examination of the coins with SEM-EDX showed the micromorphology of their surface (Fig. 02a). Micropores and cracks from use and handling were observed in all coins. Crystalline materials associated with corrosion products and particles deposited as a result of the use of the coins were observed to have accumulated in these irregularities as well as in the convexities formed by the edges of the features in relief on the coins. These corrosion products were characterized by VMP (see Fig. 02b). In the set of coins studied, cuprite (reduction peak I at −100 mV) was the primary corrosion product identified, followed by tenorite (reduction peak II at −350 mV). Also found, but in small amounts, were atacamite, malachite, and brochantite.

In prior studies, a satisfactory correlation was found between the object’s age and the composition of its corrosion layer for copper-based objects that had been conserved in an atmospheric environment, because the transformation of cuprite into tenorite is a thermodynamically spontaneous process.7 In the coins studied here, this correlation is illustrated in Fig. 03a, which depicts the ratio of the peak area of tenorite to the peak area of cuprite versus the age of the coins.

The composition of the patina of the coins determined their visual appearance, as shown in Fig. 03b, which depicts the average value for the CIE coordinate b* versus the peak area of tenorite and the peak area of cuprite. The older coins exhibited lower a* (data not shown) and b* values (grayish chroma), in agreement with the higher tenorite content, whereas the coins minted in the late-19th and early

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<th>Thickness (cm)</th>
<th>Mass (g)</th>
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<td>2</td>
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<td>10</td>
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Table 01. Classification of the ten analyzed coins submitted to SEM-EDX, VMP, and colorimetric measurements by diameter, thickness, mass, and density

<table>
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<th>3</th>
<th>4</th>
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<td>1904</td>
<td>1916</td>
<td>1916</td>
<td>1924</td>
<td>1962</td>
</tr>
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<td>100xelement mass ratio</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>m(Zn)/(Cu)</td>
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<td>6.6</td>
<td>8.6</td>
<td>8.4</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Table 02. Element mass ratio of Zn (Sn) to Cu, obtained by SEM-EDX of the surface of the studied coins
20th centuries exhibited increasing $a^*$ (data not shown) and $b^*$ values that correlated with a brownish chroma due to the predominance of cuprite in the corrosion layer.

CONCLUSIONS

Elemental analysis by SEM-EDX confirmed that, apart from the coin minted in Malta in 1776, the studied coins were mainly composed of copper with variable amounts of tin and zinc. Voltammetry of microparticles enabled characterization of the corrosion products (mainly, cuprite and tenorite) that formed the thin corrosion layer on the surface of the coins and was responsible for the dark color they exhibited. These products were found in variable proportion and in satisfactory correlation with the age of the coin. Finally, crossing these results with those from colorimetric measurements found a correlation between chroma and the age/composition of the corrosion layer.

ACKNOWLEDGEMENTS

Financial support is gratefully acknowledged from Spanish “I+D+I MINECO” projects CTQ2014-53736-C3-1-P and -2-P, supported by ERDEF funds. The authors also thank Manuel Planes and José Luis Moya, technical supervisors of the Electron Microscopy Service of the Universitat Politècnica de València.

CURRICULUM VITAE

Carla Álvarez-Romero is a graduate in history from the Universidad Autónoma de Madrid, holds a master’s degree
in conservation and restoration of cultural heritage from Universitat Politècnica de València, and is a grant holder researching the corrosion and composition of metals for her PhD.

María Teresa Doménech-Carbó has a BSc and DPhil in chemistry from the Universitat de València. She is a professor of conservation science at the Universitat Politècnica de València and director of the Instituto de Restauración del Patrimonio. She has published more than 150 papers.

María Luisa Martínez-Bazán has a PhD in fine arts. She is a professor in the Department of Conservation and Restoration at the Universitat Politècnica de València and head of the Laboratory of Optics and Colorimetry of the Instituto de Restauración del Patrimonio.

Trinidad Pasíes-Oviedo has a PhD is in the conservation of cultural heritage from the Universitat Politècnica de València and is a restorer with the Museu de Prehistòria de València and a researcher in the Servicio de Investigaciones Prehistòricas.

Milagros Buendía-Ortuño has a PhD in the conservation of cultural heritage from the Universitat Politècnica de València. She is a conservator at the Museo Nacional de Arqueología Subacuática, Cartagena, and her research focuses on waterlogged ivory.

Antonio Doménech-Carbó has an iPhD in chemistry and is a professor of analytical chemistry at the Universitat de València. He is a member of the editorial board of ChemTexts and is topical editor of the Journal of Solid State Electrochemistry.

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INTRODUCTION

In restoration work, the use of products compatible with the materials that compose the cultural heritage artworks is crucial. Ceramics, mosaics, mortars, and stones are made of natural inorganic raw materials. Thus, when interventions are necessary, inorganic compounds with a chemical composition, microstructure, and porosity similar to those of the original materials should be used. The research described in this article focuses on setting up geopolymers that simulate natural porous materials. Geopolymers are artificial inorganic polymers synthesized by alkali activation of materials rich in SiO₂ and Al₂O₃ (e.g., metakaolin, fly ashes, natural minerals such as tuffs, blast-furnace slags). In comparison to traditional ceramics, geopolymerization takes place at relatively low temperature (< 300°C), and the structure of the obtained materials can be either amorphous or semicrystalline with nanocrystals. The geopolymeric binder (also called the “matrix” or “gel”) is based on some important ratios—Si/Al, alkalis/Al₂O₃, and H₂O/alkalis—and is organized in a 3D network in which SiO₄²⁻ and AlO₄ tetrahedral units are linked alternatively to yield polymeric precursors by sharing all oxygen atoms between two tetrahedral units.

The main characteristic of geopolymers is the ability to tailor them according to their final application.

In the restoration field, geopolymers can be used to replace missing pieces, to reinforce weak structure, to make copies, and to manufacture new art objects.

The present article reports on two possible uses: lightweight panels, designed as an alternative support to traditional ones such as the aluminum panel honeycomb (Aerolam); and colored geopolymers for mosaic completion.

METHODS & METHODOLOGY

Two types of geopolymeric binders were made to obtain different final products. Commercial kaolins (BS4 and BS6, AGS Mineraux, Clèrac, France) were activated by thermal treatment at 650°C for three hours in an electric kiln. To verify the reactivity of BS6, the modified Chapel test was performed. A Polymer Thermal Science STA 1500 with a heating rate of 10°C/min was used to determine pozzolanic reactivity. A Panalytical Axios Advance WD X-Ray fluorescence spectrometer (WD-XRF) was used to analyze the chemical composition of the kaolins, while a Bruker D8 Advance diffractometer with CuKa radiation was used to determine their crystalline phases.
Potassium silicate solutions were prepared by dissolving KOH pellets (purity 85%, Sigma Aldrich) into commercial solution (KSIL35-35 INGESSIL S.r.l.) with SiO$_2$:K$_2$O molar ratio equal to 3.22 and H$_2$O:K$_2$O molar ratio equal to 31.43.

The two geopolymeric binders with SiO$_2$/Al$_2$O$_3$ molar ratio equal to 3.6 were prepared by mixing (approx. 15 minutes) the metakaolin powder and the KOH/K$_2$SiO$_3$ aqueous solution (Fig. 01).

The obtained slurries were poured into silicone molds and then placed into punched plastic bags for the curing process. It had a duration of 28 days and consisted of two steps. Firstly, the specimens were kept at a temperature of 60°C for 24 hours, then they were left at room temperature for the remaining period.

The microstructure of the obtained products was observed by means of an environmental scanning electron microscope E-SEM (FEI Quanta 200, FEI Company). Mechanical tests were performed by using uniaxial compression strength, according to the standard method UNIEN12390-3 for concretes. Flexural strength data were obtained by the standard method UNIEN12390-5 (used for concretes) and UNIEN843-1 (used for monolithic ceramics). Specimens were prepared according to the guidelines of the standard method UNIEN12390-1. Due to the regular dimensions of the specimens, the density was determined using the volume (mathematically calculated) and the mass.

Metakaolin BS6 was chosen as a raw source material for casting lightweight panels, while metakaolin BS4, white in color after calcination, was selected for preparing colored tablets. The higher iron content (1.59% by weight Fe$_2$O$_3$) of BS6 gives a light-pink coloration to the powder that prevents it from being used as a base for perfectly colored products.

**Lightweight Panel**

Two methods of production were followed for making these panels: pouring the geopolymeric slurry directly on the back of the mosaic or wall painting fragments, or pouring it into a purpose-designed mold. Both solutions are easy to prepare and easy to apply (Fig. 02). The lightweight elements to be introduced into the geopolymeric binder were chosen by considering their density, grain size, and behavior with respect to the binder. Geopolymeric specimens for each filler were prepared by considering the two grain sizes. Thus, perlite, pumice, and Poraver® grains were mixed with geopolymers based on BS6-MK. The first consideration was that all of these fillers favored a decrease of the binder density; however, SEM analyses showed that the best interaction between “gel” and filler was obtained by adding perlite. To increase lightness of the final product, a small amount of perlite was substituted with a corresponding volume of polystyrene pearls. A 55 x 55 x 3 cm precast panel was prepared with the following composition: 8% by weight of perlite and 1% by weight of polystyrene (diameter 2 mm).

**Colored Geopolymers**

Starting with metakaolin BS4, some tablets of colored geopolymers were prepared. Commercial inorganic pigments were introduced as powder into the BS4-MK and mixed with alkaline solution, while the organic ones were mixed with the geopolymeric slurry. In both cases, the coloration occurred during casting. The curing procedure and the characterization of the final products were similar to those for the lightweight panel. Tests to verify the colorfastness and the release of soluble salts under standard BS EN 16455:2014 and different environmental conditions are in progress. To improve our knowledge of the behavior of the colored geopolymers, a small mosaic (Fig. 03) was set out. The colored pieces were cut in suitable shapes and placed in the bedding mortar.
RESULTS & DISCUSSION

Lightweight Panel

The density measurements showed that our primary target was achieved. The chosen filler allowed a reduction in density of around 50% with respect to the real density of the geopolymeric binder. SEM observations showed generally good interaction between filler and binder. The best response was attributable to the perlite grains, which were perfectly absorbed by the gel. Notwithstanding the presence of fillers, which were clearly a source of weakness, the mechanical properties of these products can be considered good, and the products themselves are thus suitable for use in restoration work. The occurrence of polystyrene did not seem to reduce the workability of the mixture, but questions remain about its fire resistance. Mechanical and adhesion tests gave good response in terms of resistance to the stresses and in terms of reversibility of the intervention.

Colored Geopolymers

The colored tablets showed high performance both in mechanical properties and in colorfastness. In addition, the experiment allowed for evaluation of this material as a replacement for the glass or resins that are commonly used in mosaic restoration. Results showed that the tesserae used in laboratory mosaic reproductions accorded perfectly with the stone tesserae and that no problems arose with the bedding mortars. And after one year of direct exposure to the environment, no visible modifications in coloration could be seen. Regarding the extraction and determination of soluble salts under standard conditions, ion chromatographic analyses showed that BS4-based geopolymer powders released very low amounts (w/w%) of anions and cations, mainly Cl\(^-\) and SO\(_4^{2-}\) (< 0.3%) and K\(^+\) and Na\(^+\) (< 1.2%) respectively.

CONCLUSIONS

The obtained results support the possible use of geopolymer composites in the restoration field and for specific applications. The addition of fillers and/or pigments can be controlled as a way to design products with characteristics (color, porosity, mechanical properties) similar to original materials.

CURRICULUM VITAE

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Elena Bernardi has a PhD in industrial chemistry from the Università di Bologna, where she is assistant professor in environmental chemistry and chemistry for cultural heritage in the Department of Industrial Chemistry. Her research mainly focuses on the interaction among atmospheric pollutants, environmental conditions, and materials constituting cultural heritage, with or without protective products.

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Comparison of Traditional and Sustainable Methods for Cleaning Rust Stains on Mosaics of the Cottanello Roman Villa

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INTRODUCTION

In the restoration field it is necessary to define not only new methods and products that are compatible with the constitutive materials of artworks but to assess their environmental impact and their long-term effects on the health of workers in this sector (restorers, conservators, etc.). Recently, much interest has been given to the replacement of toxic chemicals (e.g., ammonium thioglycolate) 1 used to remove chromatic alterations induced by corrosion products of iron and its alloys on stone substrates, in rocks with a high prevalence of carbonates. Recent studies report the use of sulfur-containing essential amino acids—that are safe, cheap, and commercially available—mixed with a reducing agent as an effective treatment to remove rust stains. (where the rust consists of hydrated iron (III) oxides Fe₂O₃·ₙH₂O and iron (III) oxide-hydroxide (FeO(OH), Fe(OH)₃) of high stability and low solubility).

In particular, the use of cysteine and sodium dithionite mixed in poultices has been investigated. 2 Sodium dithionite is a fast reducing agent able to reduce Fe (III) to Fe (II). When mixed with cysteine, a very good ligand of Fe (III) and Fe (II), they have proved their efficiency for rust removal. 3 A recent laboratory study demonstrated that the effectiveness of this process can be increased by the combined use of two sulfur-containing essential amino acids, such as cysteine and methionine, and a reductant such as sodium dithionite. The aim of the work presented in this article is to evaluate in situ the effectiveness of the cysteine-methionine method compared to only cysteine and to a traditional method (ammonium citrate) for removing iron stains. The experiment was carried out on rust stains on the mosaics of the Cottanello Roman villa (Rieti, Italy). The stains were caused by an obsolete metal roof.

This villa (its main phase dates to the first century CE) is particularly relevant in the territory of the Sabina Tiberina for its architectural plan and the richness of its decoration (mosaic floors, marble, architectural terracotta, mural paintings). 5 The mosaic tesserae are black (volcanic rock), white (limestone), and red (a local calcareous red stone: the so-called Cottanello marble). After their discovery (1969–1973), the mosaics were removed, placed on a reinforced concrete support, and covered with a metal roof that became damaged and gave rise to rust stains on the mosaics (Fig. 01).

METHODS & METHODOLOGY

Three pilot areas (A, B, C) among the stained mosaics were selected (Figs. 02 and 03).

In the first phase of the study, the presence of iron compounds was detected by using the potassium ferrocyanide test. The cleaning systems used for the experimentation are listed in Table 1. Taking into account that the Fe(III) compounds present low solubility, they require a very low pH to be dissolved. Low pH values have a damaging effect on calcareous stone,
so the pH must be carefully monitored to preserve the carbonate stone. Furthermore, most chelating agents are unstable at low pH values, whereas at high pH values metals tend to form insoluble hydroxides, which are less accessible to chelating agents.

Sulfide-containing chelators similar to thioglycolate were examined. The chelating ability of methionine and cysteine—two sulfur-containing essential amino acids—is well known. These amino acids can act as chelating ligands toward metal ions through their three coordination centers: oxygen, nitrogen, and sulfur. In particular, they form complexes with Fe(III) and Fe(II) with high stability constants, and only very weak complexes with Ca(II) and Mg(II).

Then in the second phase of the experiment, the selected “green” solutions (based on amino-acids like cysteine and methionine) were compared with a traditional method based on the use of ammonium citrate.

The cleaning tests of rust-stained tesserae were performed on the three pilot areas by applying the three solutions to each area with a poultice for 30 minutes at a time. All three areas were treated twice.

Their efficiency was evaluated by measuring the colorimetric variations of the treated surfaces with a Konica Minolta CM-2600d spectrophotometer. The adopted color space was CIELAB (L*a*b 1976), and the color difference was evaluated by ΔE. For each selected colored section in the three pilot areas, 10 measurements were performed.

RESULTS & DISCUSSION

The potassium ferrocyanide test showed iron compounds to be present on the stone tesserae. After the cleaning tests were performed, colorimetric data showed that the treatment with cysteine, methionine, and sodium dithionite (area B of Fig. 02) was more effective in the removal of rust stains than treatment with only cysteine and sodium dithionite (area A of Fig. 02). Both methods are, however, more effective than treatment with only ammonium citrate.

After the cleaning treatment, the color of stained white tesserae in area B came back to the original color of unstained tesserae (ΔE = 2.33, which is below human perception). The result was confirmed by the cleaning of the black tesserae: The value of a* changed from 12.33 before cleaning to 2.51 after cleaning, data that are comparable to those of unstained tesserae (a* = 2.43).
Regarding the white tesserae in area A, the decrease in the efficiency of the cleaning treatment was highlighted by the still-relevant difference in comparison to the colorimetric data of the unrusted tesserae ($\Delta E = 8.38$). The slight cleaning action of the ammonium citrate treatment was confirmed in area C (Fig. 03) by the considerable distance of the colorimetric coordinate values compared to those of the reference tesserae ($\Delta E = 22.70$).

CONCLUSIONS

Among the three cleaning methods tested in situ—with identical times and modalities of application—the most effective treatment was with L-cysteine, DL-methionine, and sodium dithionite.

The synergetic effect of the reductant and the two sulfur-containing essential amino acids that behave as ligands toward the iron ions was indicated by the evident rust discoloration of the stone tesserae. The outcome of the experiment, when combined with the reduced environmental and health concerns of the new treatments, suggests that ammonium thioglycolate should be replaced as a treatment method for removing rust discoloration. The easy application and low cost of the tested products should also be an incentive, and their use should be encouraged when planning future restoration projects.

ACKNOWLEDGMENTS

The authors express their gratitude to Alessandro Betori, Soprintendenza Archeologia Belle Arti e Paesaggio per le province di Frosinone, Latina e Rieti; to Franco Piersanti, mayor of the municipality of Cottanello; and to Monica Volpi, councilor, for their availability and support in helping us carry out this study.

CURRICULUM VITAE

Andrea Macchia is a conservation scientist with a PhD in science applied to environmental protection and cultural heritage conservation. He is the founder and president of Youth in Conservation of Cultural Heritage, Rome, Italy.

<table>
<thead>
<tr>
<th>Cleaning systems</th>
<th>pH</th>
<th>Concentration</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-cysteine + SD</td>
<td>8</td>
<td>0.1M + 0.1M</td>
<td>pH value adjusted with ammonium hydroxide</td>
</tr>
<tr>
<td>L-cysteine + DL methionine + SD</td>
<td>8</td>
<td>0.1M + 0.05M + 0.1M</td>
<td></td>
</tr>
<tr>
<td>Ammonium citrate</td>
<td>10</td>
<td>2% (w/v)</td>
<td></td>
</tr>
</tbody>
</table>

Table 01. Cleaning systems and concentrations

SD = sodium dithionite
Loredana Luvidi is a chemist at the Istituto per la Conservazione e Valorizzazione dei Beni Culturali del Consiglio Nazionale delle Ricerche. Her research interests include the development and evaluation of new protective and consolidating materials (nanomaterials and eco-friendly products).

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Eleonora Maria Stella is a restorer at the Istituto per la Conservazione e Valorizzazione dei Beni Culturali del Consiglio Nazionale delle Ricerche. She is the editor of the *Journal of Cultural Heritage*.

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Conservation of a Colossal Statue of Zeus from Soluntum: Scientific and Historical Remarks about the Previous Restorations

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INTRODUCTION

The ancient town of Soluntum was one of the earliest Phoenician settlements to be influenced by Greek and Roman culture. A Commission for the Antiquities and Fine Arts was created in 1827 to protect the historical-artistic heritage of the Kingdom of Sicily. Interest in the ruins of Soluntum had increased with a fortuitous discovery by local peasants, and the commission halted a clandestine excavation started in 1825. Many interesting structures, architectural elements, and sculptures were found, including fragments of a statue of Zeus (Fig. 01), and all discoveries were brought to the museum of the Royal University in Palermo.

In 1826 the neoclassical sculptor Valerio Villareale (1773–1854), a great connoisseur of archaeology, restored the fragmented statue of Zeus, and it was conserved at the Royal Museum. But over the years, scholars did not always appreciate his restoration work.

Our team sought to investigate the prior restorations to determine a suitable course of conservation. A closer observation of the statue’s surface revealed a second restoration after Villareale.

The poor condition of the statue prior to the conservation treatment did not permit identification of the remade portions. The presence of deposits and the alteration of a protective layer confounded efforts to differentiate the original from the restoration portions. An analytical observation of the stucco portions was completed and revealed both an overlay of two types of stucco filling of different quality and composition and two layers of red-orange color covering stone and stucco.

METHODS & METHODOLOGY

Diagnostic analyses were carried out to improve the knowledge of the restoration materials used over time and to gain a deeper knowledge of the conservation history of the statue. In addition, a better understanding of the nature of the materials has permitted a suitable conservation of both the statue and Villareale’s restoration.

A preliminary step in the diagnostic investigations was carried out with ultraviolet fluorescence imaging, infrared thermography, and a cover meter relief.

Then, a noninvasive chemical technique involving X-ray fluorescence (ED-XRF) was carried out in situ to investigate the different polychrome layers and the different types of stuccos macroscopically recognizable on the original and restoration surfaces.

To investigate more deeply the several covers observed, significant samples were taken for laboratory analyses.

Stereoscopic microscopy, polarizing optical microscopy, scanning electron microscopy (+ EDS analysis)
on cross sections, and Raman spectroscopy were employed on three fragments—ZS 1 (Villareale restoration), ZS 2 (unknown restoration), and ZS 3 (limestone)—to understand in a more complete way the nature and composition of the substrates and coverings of each analyzed sample.

RESULTS & DISCUSSION

The IR thermography facilitated the creation of a map of the different materials showing their relationship to the various restorations. For the cover meter survey, when metal pins were not detected for joining the pieces, the use of wooden elements was hypothesized and then confirmed when the statue was disassembled.

Concerning materials used in earlier restorations, the XRF analysis revealed clear markers that allowed two phases of intervention to be distinguished. A comparison of the XRF spectra acquired on the original stone material (P2), on the known restoration (P1, Villareale intervention, 1826), and on those not documented (P3 and P6) is shown in Fig. 02.

The higher Sr content in P3 (Zeus’s drapery) suggested the use of a gypsum plaster different from that used in the Villareale restoration.

The P6 point was acquired from a reddish paint layer and was characterized by the presence of Zn, Ba, and Fe, supporting the assumption that it was made using lithopone or a barite and zinc white mixture and an iron oxide red pigment (mineral or synthetic). The presence of Zn, constituting the white zinc pigment (ZnO) commercially available in the second half of the nineteenth century, indicates a terminus post quem for the placement of one of the undocumented restorations.

Laboratory analyses of the samples completed the preliminary portion of the noninvasive investigations. Polarizing optical microscopy allowed the differentiation of two kinds of coverings in sample ZS 1 over a limestone substrate with a dark orange color. In the orange layer, gypsum crystals were observed attached to pores inside the film (Fig. 03). SEM-EDS showed the presence of Mg, Si, Al, and Fe attributable to red ochre and earths pigments. Sample ZS 2 showed a
similar covering to the orange layer revealed on sample ZS 1, although in ZS 2 no large pores were observed. The substrate showed the presence of gypsum (CaSO4) and calcite (CaCO3), indicating the original stucco was made of gypsum and lime. SEM-EDS revealed that the orange covering had a different elemental composition, constituted by Zn, Ba, Fe, S, and Ca. The presence of Zn and Ba can be correlated to the use of white pigments. To understand the Fe content, a Raman analysis was performed; it showed vibration bands from Fe2O3· nH2O + Al2O3 (a synthetic mineral inorganic pigment produced as a precipitate of Fe and Al hydrate oxide, Mars orange). Finally, sample ZS 3 was limestone with a gypsum covering and another iron-rich film on top. The SEM-EDS and Raman analyses confirmed the evidence of the ZS 2 sample.

The coverings of the three samples had traces of phosphorous. Because of this, we cannot rule out the existence of a calcium phosphate covering below the external colored covering and on the substrate. In our experience, this is where such calcium phosphate films appear.

CONCLUSIONS

Conducting research on a large statue like this one is not easy, especially when several interventions might have changed the appearance and the aesthetic perception of the statue. The laboratory analyses identified the restoration materials used at each historical phase. Thanks to the investigation, new archival research was completed, resulting in the discovery of new records. This multidisciplinary research provided the opportunity to master restoration techniques used in the restoration of a nineteenth-century statue of Zeus in Sicily, while also integrating historical and scientific information about the statue.

CURRICULUM VITAE

Maria Francesca Alberghina is a conservation scientist with a PhD in applied physics. Her scientific research involves noninvasive or microdestructive in situ techniques. She currently has an active work collaboration with S.T. Art-Test.
Monica Álvarez de Buergo is a senior scientist who has been working in cultural heritage stone materials for 25 years. She is director of both the Geomaterials Department and the Petrophysics Laboratory of the Instituto de Geociencias (CSIC-UCM).

Sagragio Martínez-Ramírez is a tenured scientist with Consejo Superior de Investigaciones Científicas (Madrid). Her research interests include the durability of building materials and the application of spectroscopic techniques (Raman, FTIR) to the study of those materials.

Giuseppe Milazzo is a conservator of cultural heritage. Since 2014 he has collaborated with the Cambodian National Commission for UNESCO on training activities and has served as administrator of the Milazzo Restauri S.R.L.

Salvatore Schiavone is a conservation scientist with a PhD in applied geophysics. Since 2011, he has served as administrator of the S.T. Art-Test, which provides noninvasive diagnostic services for characterizing and monitoring cultural heritage artifacts and environments.

Francesca Spatafora is director of the Museo Archeologico Regionale “Antonino Salinas” di Palermo.

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STONE ALTERATION ON THE FACADE OF A BUILDING IN OVIEDO

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INTRODUCTION

When tackling the rehabilitation of the facade of a building, all factors of possible influence must be taken into account, including its location and history; its relationship and interaction with the immediate environment; and its design, structure, materials, and coloration.

The building analyzed here is located in the center of Oviedo, on Suárez de la Riva Street, which is the result of the parcel fragmentation that took place in the early 20th century in the proximity of the circle that forms the medieval city.1

The medieval city (Fig. 01)2 is mainly built of limestone extracted from the Cretaceous rocks that underlie the city and its surroundings. Two varieties are distinguished: a coarse-grained one of yellow color (Piedramuelle) and a fine-grained one of more reddish color (La Granda) that has largely replaced the former variety since the 17th century.3

The street where the building is located follows the coloring of the medieval city, using brick to replace the reddish limestone and cement rendering instead of light-colored stone types. The building at number 4–6 Suárez de la Riva, completed in 1992, consists of five floors and a penthouse and was designed by architect Javier Blanco Pérez (1942–1992).4 It is characterized by the stone materials of the facade, which contrasts with the rotundity of the fully glazed galleries (Fig. 02). According to the land-use regulation of 2006, still in force, it is not a listed building.

The facade of the building, covered with natural stone slabs, presents a poor state of preservation that is generating moisture inside the apartments. The community of owners in charge wished to assess whether to rehabilitate the damaged stone elements or to replace the existing skin with a new one.

METHODS & METHODOLOGY

The variability of stone behavior (regarding type and degree of alteration) in different zones of the facade was an issue to consider. The stone appeared sound in large areas, while in other zones different kinds and levels of alteration appeared.

The aim of the research was to reveal the factors causing this difference in behavior, the importance of the stone, and the influence of its position in the building. The characteristics of the stone and its decay were thus analyzed, and the different damaged areas of the facade were mapped (Fig. 03).

To characterize the stone, both the sound areas and the altered areas of the facade were sampled. The macroscopic and microscopic petrographic description was completed with X-ray diffraction analyses of the mineralogical composition.

By renting a crane, a thorough analysis of all the stone elements was possible. Their alteration state was assessed and mapped on the plan of the facade.
RESULTS & DISCUSSION

Stone Characteristics

The rock was a finely granular, compact, coherent, and apparently isotropic calcareous sandstone. Its color was medium gray with a slight bluish tint and of medium clarity. Water absorption was very slow (drops hardly penetrated inside the rock), indicating the existence of small and poorly communicated pores and a dominating microporosity. With dilute hydrochloric acid, the stone reacted slowly with little effervescence, due to the presence of dolomite as the dominant carbonate.

Texture was granular clastic and had several components, with silicates and carbonates in similar proportion. The stone presented three major grain types: quartz, rock fragments (siltstone, chert, etc.), and carbonates (mono- to microcrystalline), and its binding phase was carbonate cement. The average grain size was fine sand (0.2–0.3 mm), and the grains were well calibrated and slightly oriented.

X-ray diffraction indicated that the principal minerals were dolomite and quartz, with lower amounts of muscovite, chlorite, and calcite. The rock was a sandy dolomite.

Deterioration Characteristics

The stone presented various types of damage but mostly chromatic alteration and, to a lesser extent, addition and loss of material. The additions were deposits of dirt (blackening) and soluble salts (efflorescence), while the loss of material was present as disintegration, spalling, and peeling.

Chromatic alterations were mostly damp stains, sometimes forming reddish rings due to the mobilization of Fe oxides. The blackening occurred discontinuously because of differential washing, and it was not normally associated with crusts. It was characteristic of the protected areas. The greatest damage was due to material losses and was typical of areas with moisture retention. Often a film or layer could be found on the stone surface. In some areas blisters had developed, leading to material loss when breaking and revealing disintegrated (sandy) underlying material. Disintegration associated with efflorescence was also observed.

Deterioration Mapping

After analyzing the alteration state of each element of the facade, a map of deterioration was developed (Fig. 03). Its interpretation yields the following conclusions:

All elements in the plane of the galleries (located on the first and fourth floors) had significant chromatic alteration, with blackening, differential washing, and occasional loss of material. Hitting the stone elements with a hammer exposed cavities caused by missing mortar, which decreased adhesion to the substrate (Fig. 03, type IV).
Elements above the pavement and the galleries of the first and fourth floors were exposed to water uptake by capillarity and were greatly deteriorated. Their surface was undergoing a decomposition process, and in some areas the degree of sanding was high (Fig. 03, type I).

All elements placed on walls affected by water running from the roof were also damaged, and in some cases they had poor adhesion to the substrate and were at risk of falling. Water had produced chromatic alteration, with blackening, differential washing, and occasional loss of material (Fig. 03, type III).

The elements placed under overhanging structures were in good condition, except for the last row on the exhibition hall and the entrance to the garage on the ground floor, where poor adhesion to the substrate was found (Fig. 03, type II).

In some exceptional cases, a risk of detachment was noted. Some elements were disintegrating or had even moved out of their place, exposing the supporting hooks (Fig. 03, type V).

Molds, live plants, and leaves were deposited in the gutters, clogging drainpipes and causing the water to flow over the facade. The community decided to install a “visor” (white metal shield) over the roof to divert water off the facade.

CONCLUSIONS

The stone used on the facade had low porosity and low permeability and was suitable for cladding. It was in good condition in the absence of permanent moisture, and the observed chromatic alterations should be easy to remove. However, several areas showed disintegration and significant material loss.
Poor waterproofing of the roof of the galleries and water running over the facade had created a continuous or frequent supply of moisture for the stone. Chemical processes had taken place that generated changes in clays and dissolution and reprecipitation of carbonates. This provoked the formation of a surface layer that tended to separate as a film or by blistering, with disintegration of the underlying material. The formation of the surface layer was possibly caused in part by a treatment applied to stone at an earlier date.

Since the precise origin of the rock was unknown, damaged parts should be replaced with a stone that possesses similar characteristics. However, among the possible alternatives, there are differences in composition and texture between the new and original stone and, consequently, likely differences in durability. Chromatic changes should also be considered, since the evolution of the new stone will largely differ from that of the original, which has already endured a quarter century of exposure. Therefore, total replacement of the stone facade seemed advisable.

**Curriculum Vitae**

Francisco de Zuvilaga del Busto is an architect with a specialization in conservation, restoration, and rehabilitation from the Universidad Politécnica de Madrid and a specialization in sustainability in architecture from the Universidad de Oviedo. Formerly working for TAU Architects and Borja Bordiu, he started his career as an independent professional with Zuvilaga Architecture.

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Salt Weathering and Hygric Expansion of Tuff Rocks in Archaeological Sites in Central Mexico

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INTRODUCTION

Natural stones have been used worldwide and across cultures as raw material for construction and artistic applications for hundreds of years. Due to their large-scale availability in the trans-Mexican Volcanic Belt (TMVB), volcanic tuff stones are popular building stones all over Mexico. They were used to build churches, pyramids, and other important monuments and have been used in more recent construction works. Volcanic tuffs are relatively soft and workable even with simple tools, and their broad spectrum of appearance gives them a large variety of applications.

However, because of their complex geological past, volcanic tuff stones are often a heterogeneous material, and since their suitability as building stones strongly depends on environmental conditions such as climate, location in the building, and so on, general statements about their application are not always possible. The same properties that cause the easy workability of the volcanic tuff stones can lower their resistance to weathering and deterioration, especially when the rocks are exposed to humidity and moisture.1

Salt crystallization2 and moisture expansion3 are recognized as two main damaging factors in the weathering and deterioration of volcanic tuffs used in construction. Common types of deterioration caused by them are fracturing, scaling, and back weathering (Fig. 01).

Fig. 01. (a) View from the south over the ballgame court to the main pyramids; (b) west side of the central pyramid with the main entrance; (c) extensive fracturing and craquelé; (d) scaling, back weathering of clasts and components.
Understanding the processes that lead to such damage and weathering is indispensable when choosing materials to sustainably and effectively preserve and conserve valuable cultural assets made of natural stone.

The present article reports on an investigation of the main building of the pyramids of Plazuelas in the federal state of Guanajuato, Mexico. Built in approximately 450 CE by the Chichimecas, a sophisticated predecessor culture of the Aztecs who populated the adjacent Bajio region, the temple complex was abandoned around 900 CE. After being buried for several centuries due to sedimentation, it was rediscovered and excavated in 1998.

METHODS & METHODOLOGY

Seven different tuffs and volcanic rocks used in the construction of the pyramids were analyzed. The set of samples consisted of Toba rosa (TR), Toba blanco laminado (BL), Toba lapilli amarillo (LA), Andesita oscura (AO), Toba lapilli beis (LB), Tezontle de Plazuelas (TE), and Toba lapilli rosa (LR). Mineralogical
composition and whole rock chemistry were analyzed by both optical and geochemical methods (polarized light microscopy, X-ray diffraction [XRD], and X-ray fluorescence [XRF] spectroscopy). Matrix, bulk density, and porosity were measured by hydrostatic weighing in accordance with DIN 772-4. The pore radii distribution was determined by mercury intrusion porosimetry. The moisture expansion of the rocks was determined by hydric wetting of cylindrical samples under watersaturated conditions. To investigate the resistance of the rocks to salt stress, a salt-weathering test was performed in accordance with DIN EN 12370. As an index of salt resistance, test cycles were used until 30% weight loss was achieved. The specimens for the laboratory experiments were prepared both parallel and perpendicular to the lamination to distinguish potential effects of anisotropy.

RESULTS & DISCUSSION

The volcanic rocks ranged in age from Paleogene to Quaternary, with chemical compositions that varied from basaltic andesite to rhyolitic tuff.

The rocks showed medium to high porosities, with values up to 32.7% and a broad spectrum of microporosity, ranging from 9% to 85% (Table 01). (Micropores are pores <0.1 µm, and capillary pores are pores in the 0.1–1,000 µm range.) The pore radii distributions showed either a unimodal distribution (e.g., AO, LB, and LR) or a bimodal unequal distribution (e.g., TR, BL, LA, and TE). The hydric expansion of the rocks along the x and z axes ranged from 0.007 mm/m for LR to 0.736 mm/m for LA. In general, the rocks showed higher values for the z direction, and anisotropy was very high for TE (64%) and LR (68%) (Table 01). Every rock reached maximal expansion after a short time. Figure 02 shows a higher hydric expansion when the rock had a high amount of micropores.

The salt weathering test showed a low resistance in LA, with 11 cycles until destruction, and in TR and BL, with 19 cycles. LR provided a medium resistance, with 33 cycles, and AO, LB, and TE were not affected by salt bursting even after more than 40 cycles. Except for AO, the salt weathering behavior of the rocks showed a clear correlation with microporosity, indicating that a high amount of micropores led to a lower resistance to salt loading (Fig. 03).

CONCLUSIONS

In the field investigation, the building stones showed serious damage due to salt weathering and hydric expansion. The data indicated a clear connection between high hydric expansion and low resistance to salt loading when the stones provided a bimodal pore radii distribution with an increased amount of micropores. Pore space properties were a key factor for the durability of these rocks. Both clay minerals and microporosity play an important role in moisture expansion in volcanic tuff stones. Still unclear is the extent to which these
factors influence the expansion and the extent to which salt crystallization influences the process.

**Acknowledgments**

This research was supported by the Consejo Nacional de Ciencia y Tecnología (CONACyT), Projects Ciencia Básica (CB–130282) and Cooperación Bilateral (191044). The authors are grateful to G. Hartmann and K. Wemmer of the Georg-August Universität Göttingen for their help with the mineral analysis.

**Curriculum Vitae**

Christopher Pötzl has a BSc and MSc in geoscience from Georg-August-Universität Göttingen, where he is currently a PhD candidate working on weathering behavior, technical properties, and conservation strategies for tuff stones in monuments and historical architecture, with a focus on hygric expansion and salt loading.

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6 Further information about mineralogical composition, pore space, water transport and retention properties, mechanical properties, and weathering behavior, as well as a field survey, can be found in Pötzl, C., “Las Casas Tapadas de Plazuelas—Bauschäden, Verwitterungskaracteristik und gesteinstechnische Eigenschaften von Tuffsteinen in Guanajuato, Mexiko”, MA thesis, Georg-August-Universität Göttingen, 2015, pp. 36–163.


Development of Compatible and Sustainable Render Systems for Salt-Contaminated Brick Masonries

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INTRODUCTION

In a marine environment, renders are subjected to severe forms of degradation mainly due to the penetration of salt water and crystallization/dissolution cycles of salts. Rendering systems, properly calibrated, can tackle rising damp effects by adjusting water flow and salt transport within the wall-render system. The effectiveness of the rendering system is linked to the substrate/plaster interactions and depends on the relative pore structure, hydrophobic properties, plaster thickness, and the presence of several layers. Render systems suitable for use in the restoration field can be obtained by selecting the right starting materials and by using admixtures. This article discusses the formulation of double-layer rendering systems based on natural hydraulic lime. The systems were added with air-entraining agents in the first layer and water-repellent admixtures in the outer layer to regulate the render structure and water transport. Moreover, recycled crushed mortars were used to partially substitute the aggregates of the internal layer to obtain environmental-friendly systems. To verify the systems’ behavior, the renders were applied on bricks that underwent absorption and drying cycles with salty water. Both singular-render mixtures and systems constituted by a double render layer on bricks were studied.

METHODS & METHODOLOGY

Table 01 summarizes the systems composition discussed in the article.

Red-fired bricks (dimensions: 25 x 12 x 3 cm) were chosen as a substrate for the render application. The first internal layer was constituted of natural hydraulic lime (NHL) and limestone-siliceous sand, partially substituted (1/3 by volume) by crushed recycled old mortars (size fraction 0/5 mm). Sodium alkyl sulfonate was used as an air-entraining agent at 0.03% or 0.09% by weight on the binder weight. The first ratio is a commonly used percentage, while the second assures the formation of a macroporous structure. The second layer was composed of NHL 3.5, by limestone-siliceous sand (size fraction 0/2 mm). Eventually, calcium stearate (SIGMA Aldrich) was added as a water-repellent admixture at 0.3% or 0.5%. The components were mixed at low speed (100 rpm) for 10 minutes with tap water to obtain a good workability of the mixtures.

Prismatic specimens (4 x 4 x 4 cm and 5 x 5 x 2 cm) were produced of each render mixture, while double-layer systems were prepared and exposed to salt absorption/drying cycles according to the COMPASS protocol. The first layer was applied on moist bricks to form a layer 1 cm thick and patted to enhance the adhesion of the second layer, cured overnight at 95% relative humidity (RH) and 20°C before the application of a 0.5 cm second layer. All specimens were cured in environmental atmosphere at 95% RH and 20°C for 28 days, then dried at room temperature to constant weight (55% RH, 23°C). Three independent replicates were prepared for each mixture or system.

Once hardened, the double-layer systems were subjected to four wetting-drying cycles by capillary rise of NaCl solution (3% by weight) without removing...
efflorescence or debris from the surface of the specimens. Each cycle consisted of 24 hours absorption followed by six days drying at 65% RH and 23°C.

The formation of debris after the cycles was recorded by photographic documentation.

Capillary absorption, drying behavior, and water vapor permeability were determined both on mono-material specimens and on exposed double-layer systems.

For highlights, the salt transport behavior, salt distribution profiles of the systems were obtained by cutting the layers in four slices and by measuring their conductivity with the EC-meter GLP31 (Crison). The disruptive effect of salts on the render microstructure in the 0.06–20 µm range was estimated by mercury intrusion porosimetry (Carlo Erba Instrument Unit Modern 120 and a 2000 Unit).

RESULTS & DISCUSSION

After 28 days of curing, one replicate of N9_wr and one of N3_wr detached from the bricks, pointing out the lack of flexibility and insufficient adhesion, possibly caused by the use of NM as recycled aggregate.

The exposure to NaCl solution cycles caused recurring patterns: a slight presence of salt efflorescence without substantial loss of material for Ccast3_wr, C9_nwr, and Ncast9_wr; a diffuse presence of salt efflorescence but without erosion of the surface for N9_nwr; spalling and surface delamination for C3_wr; and serious crumbling and/or erosion of the entire surface for N9_wr and N3_wr.

Table 02 reports the results of water uptake behavior obtained from the single mixtures (D = first layer; Up = external layer) and the double-layer systems.
All samples were nearly saturated within four hours of capillary water absorption.

An intrinsic difficulty was identified in the individuation of the correct slope in the absorption profile of the DL, since the absorption of brick, first layer, and second layer overlapped. A common trend was that the capillary absorption coefficient of DL was lower than D or Up and that a slower absorption rate occurred whenever water-repellent material was present, in particular in the first layer. The water absorption speed was independent of the total amount of water absorbed Qimax, which in turns seems to be correlated more to the render structure than to the presence of water repellent.

The drying behavior (Ang. Coeff.) was similar for all samples and was significantly slower in the double-layer systems than in the single mixtures: brick acted as a water reservoir, strongly influencing the drying behavior.

Generally, permeability showed values in line with the use of NHL as a binder, and the permeability of the double layers corresponded to the value of the single layer with higher µ.

Outer layers were less permeable to water vapor than the internal layers, which often had higher porosity (in particular, when 0.09% of air-entraining agent was present).

Regarding porosity and salt distribution after the cycles (Fig. 01, Fig. 02, Fig. 03), the lower layer was observed to have a greater porosity and higher average pore radius. Additionally, most of the specimens accumulated salts in the upper layer or at the interface between the two layers.

In N9_nwr the conductivity profile of DL showed a nearly uniform accumulation of salts. The porosity was slightly greater in the inner layer, which might explain why it quickly absorbed water from the brick (high Qi and CA).

In C9_nwr, Ccast3_wr, and N9_wr the outer layer absorbed the water quickly thanks to the presence of smaller pores (compared to the underlying layer). The C3_wr series, with similar structure, behaved in the opposite way, probably due to the presence of water repellent. In the Ncast9_wr and N3_wr series, greater porosity was observed in the bottom layer, with larger pores that favored the accumulation of water and salts.

CONCLUSIONS

The results demonstrated that the correct dose of water-repellent and air-entraining agents is critical. In particular, higher percentages of air-entraining agent (0.09%) allowed for a plaster with higher resistance to salt crystallization, while a higher percentage of water-repellent prevented solution flow, promoting internal salt deposition and detachments.

In general, whenever the two render layers presented different microstructure and permeability properties, a better resistance to salt crystallization.
and fewer degradation features were observed. Instead, when the two layers had a similar structure, slow transport and deposition of salt at the brick-render interface was observed.

Based on our results, the render systems studied can be divided as follows:

salt-accumulating plasters, such as $C_{cast3\_wr}$ and $Ncast9\_wr$, allowed the salts to crystallize within the mortar;

salt-transporting plasters, such as $C_{3\_wr}$, $C_{9\_nwr}$, and $N9\_wr$, transported the salt by advection toward the surface; and

salt-blocking plasters, such as $N3\_wr$, allowed only the passage of water vapor; thus, salt deposition occurred at the plaster/substrate interface or within the masonry.

<table>
<thead>
<tr>
<th>Render System</th>
<th>CAff Std.Dev. (mg/cm²s⁻¹/²)</th>
<th>Qi max Std.Dev. (%)</th>
<th>Ang. Coeff.Std.Dev. (mg s⁻¹/²)</th>
<th>µ Std.Dev.</th>
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<tr>
<td>$C_{3_wr}$</td>
<td>D 14.39±0.83</td>
<td>13.70±0.38</td>
<td>-0.45±0.01</td>
<td>5.31±0.40</td>
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<tr>
<td></td>
<td>Up 5.10±1.82</td>
<td>13.14±0.43</td>
<td>-0.38±0.02</td>
<td>9.28±0.71</td>
</tr>
<tr>
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<td>DL 4.05±1.93</td>
<td>7.76±3.47</td>
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<td>$C_{cast3_wr}$</td>
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Table 02. Capillary absorption coefficient CA, maximum water uptake Qi, drying coefficient Ang. Coeff, resistance to water vapor permeability µ. D = down lower layer mixture, Up = Up external layer mixture, DL = double layer on brick.

Curriculum Vitae

Laura Speri is a conservation scientist with a degree in chemical sciences for conservation and restoration from Università Ca’ Foscari Venezia.

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Laura Falchi is a fellow-researcher in the Department of Environmental Sciences, Informatics, Statistics, Università Ca’ Foscari Venezia, and a member of the Chemical Sciences for the Conservation of Cultural Heritage research group.
Martina Zuena is a PhD student in the Department of Environmental Sciences, Informatics, Statistics, Università Ca’ Foscari Venezia, and a member of the Chemical Sciences for the Conservation of Cultural Heritage research group

**BIBLIOGRAPHY**


(Endnotes)


5 The permeability of the system was tested on the two layers separated from the brick, and the different properties were determined according to UNI 10859, Normal 29/88, Regulations Nordtest, UNI EN 1208 respectively

INTRODUCTION

In architecture, the recognition of space is about more than just engaging correctly with our surroundings. In historical architecture, spatial recognition involves the reliable understanding of the original three-dimensional intentions of space. Understanding space and its physical construction must be the main concern of architectural restoration, so it is necessary to understand its qualities and its parameters, adjusting ideas and possibilities for a preservation project the demands of the historical space. Choices for a given material must transmit not only the original physical quality but the original architectural intention.

These were the criteria that were developed from the preliminary research conducted for the restoration of the Sandoval chapel in the Mudéjar La Peregrina church in the Franciscan convent in the Leonese town of Sahagún.1

The Franciscan church was constructed in 1257 by craftsmen who were Spanish Muslims at an important stop on the pilgrimage route to Santiago. The temple housed the image of the Virgin Mary dressed as a pilgrim. In the 15th century Diego Gómez de Sandoval rebuilt the chapel as his burial place (Fig. 1). The convent was abandoned in 1835, when religious properties were expropriated by the government. In 1931 the building was declared a “Property of Cultural Interest.”
METHODS & METHODOLOGY

In the late 19th century, William Morris developed a theory of materials based on the differentiating notions of ornament and decoration. He recognized these as important expressive elements in the creative process, as elements for determining the choice of materials and the techniques for shaping them. The restoration architect’s challenge is to recover the expressiveness in the materials’ physical structure and to reflect the qualities and skill of the craftspeople who applied them. This recognition is the criterion we develop for the restoration of the Sandoval chapel.

RESULTS & DISCUSSION

Inside Sandoval’s chapel polychrome plasterworks stand out. Carved in plaster and facing east and west, these plasterworks express a powerful architectural idea with the help of light. Their natural qualities are enhanced by other architectural decisions that onlookers can perceive as they move about the chapel. The technique that shaped the plasterworks was closely tied to its creative purpose. From the dialogue between the craftsman’s work and his plaster medium emerged a clear expressive purpose, highlighting both the intrinsic and extrinsic qualities of the materials used. For this reason our goal for the restoration of the polychromed plasterworks was not only their material and formal recovery but the recovery of their original architectural expression. Following Morris’s interpretation, our restoration project proposed to recover the perception of the plasterworks as elements of a space that unified the proportion and directionality of the diagonal access of light.²

First, during our research we sought to determine the site of the main door and thereby discover the historical access to the chapel and the date the access was built. This investigative process started by carefully removing, layer by layer, the brick and paint covering the original walls, eventually revealing door frames and a layer of red and yellow paint. Raw plaster was discovered in the locations of each of the existing door moldings. Analysis of this plaster revealed the presence of limewash and gypsum plaster, an unusual feature for that time. We attribute this presence of “slaked lime” to a mortar that was used for repair work during the later Middle Ages, meaning that it was much more modern than the plaster used during the original construction of the chapel’s interior. All the same, this was the original access point to the chapel (Fig. 2).

Second, we applied lime mortar to the interior walls, whose bricks had been bare since the 19th century. Only in this way could the chapel’s original plasterwork be recovered.

The chapel’s four walls are divided by two bands of similar width. The geometry of the first band is articulated by a series of Gothic arches with eight-point stars. Beneath this band and to the sides is a repeated pattern of stars, Arabic plant decorations, radiant star motifs, and rosettes.

The second band is dominated by polylolated arches whose interstices are filled with geometric shapes, further embellished with 8- and 16-point stars. On the chapel’s east wall is an epigraphic cartouche over this second band, locating the main axis of the chapel and orienting the diagonal access from the door. The epigraphic frieze is in Gothic script. On the left it reads, “DOMINE: IHS: XPE: FILI DE[I],” and on the right, “[P]ECATORI: QMORIBU.”³

The wall paintings, executed by Mudéjar artisans in their own style, are clearly different from normal Christian artwork. The Mudéjar polychrome plasterworks are composed of colored symmetrical geometric arrangements. The color palette consists of red, green, blue, and black pigments on a white gypsum plaster underlay showing the usual features for red ochre, limewash, gypsum, and black at the surface. The importance and meaning of these polychrome plasterworks concern not only their colors but the textured impression of movement that is produced by their carved decoration on geometric shapes.

Finally, our work on these plasterworks involved preservation processes that scrupulously respected the basic principles of legibility, reversibility, compatibility, and minimal invasiveness. The interventions we performed on the plasterworks can be removed. No aesthetic damage was caused, and, because of the protocols used, all physical or chemical incompatibilities were avoided. Our only volumetric reconstructions were performed on damage caused in the 20th century, thereby maintaining the chapel’s 19th-century appearance. For the chapel, we used a cooler tone of plaster, distinct from the tone of the plasterworks. Thus, our intervention is distinguishable, facilitating its recognition as such without becoming an element of the plasterwork (Fig. 3).

CONCLUSIONS

The technique that shaped the plasterworks was intimately tied to its creative purpose. The dialogue between the craftsman’s skill and the plaster became the medium of a clear expressive purpose, highlighting the intrinsic and extrinsic material qualities of the plaster. For this reason, our restoration of the polychrome plasterworks of the La Peregrina Chapel in Sahagún did not just intend a material or technical recovery but the recovery of its genuine architectural expression based on historical, architectural, structural, and material research that enabled us to understand its essence and, accordingly, plan the best options for preservation.
The usual goal for such projects, whether traditional or contemporary, is physical preservation. However, we understand spatial restoration to be an essential criterion for any project. This criterion enabled us to understand the creative expression of the past within the framework of its cultural, historical, and religious references, rather than taking it out of its contexts and thereby opening the possibility of imposing irrelevant architectural models. Safeguarding spatial perception is a way to understand the intangible cultural heritage of the past.

**Curriculum Vitae**

José Ramón Sola Alonso has a PhD in architecture from the Universidad de Valladolid. He is a professor of projects in the Escuela Técnica Superior de Arquitectura de Valladolid, as well as a professor of postgraduate restoration courses at the universities of Alcalá, Salamanca, Valladolid, and Alfonso X el Sabio). He received the 2008 AR&PA International Award for Historical Heritage Actions.

**BIBLIOGRAPHY**


(Endnotes)
Protecting Adobes by Increasing Their Hydrophobicity Using Alternative Methods

Maria Stefanidou, Aspasia Karozou, Maria Kapsimani

INTRODUCTION

Earthen construction is an ancient technique found in all parts of the world. It is the simplest way to build, has comparatively low cost, and is environmentally friendly.

Construction with adobes probably started in Mesopotamia about 9,000 years ago.1

In earthen constructions, the primary cause of problems is water, which can reduce strength, cause detachments, and lead to material loss.2 Since moisture particularly affects the interior of masonry, its consequences are often not visible. The most affected areas can usually be detected at the bottom of the masonry, due to soil moisture elevation via various physical mechanisms.3 To prevent water from affecting earth constructions, many waterproofing techniques have been studied and applied. Surface protection of clay-based materials is one of the oldest techniques, along with strong compaction and the use of additives such as resins. Linseed oil possesses hydrophobic properties and therefore has been widely tested for use as a water-repellent coating.4

This article reports on an effort to test whether a recycled oil coating made by a local oil recycling company possessed hydrophobic properties similar to those of an alkosiloxane solution. Additionally, the water-repelling abilities of a modified solution of alkosiloxane, which in one study presented the most satisfactory results in relation to the physical properties tested, was tested and compared with the recycled oil coating. Since the ability of nanoparticles to fill voids in porous materials is known, the alkosiloxane coating was modified with silica nanoparticles. The use of nanotechnology in structural materials has been widely studied.5

METHODS & METHODOLOGY

The adobe samples made in the laboratory were shaped into blocks of approximately 4 x 4 x 16 cm. Their compressive strength was calculated as 5.19 MPa with a mean tension of compression of 5 N/mm² and a load rate of 0.66 N/mm²/min for a loading length of six minutes. The coatings used were the recycled oil solution and the alkosiloxane solution enriched with nanosilica. The nanosilica was 14 nm in diameter, and B.E.T. was 250±25 m²/g. The nanosilica was used in 1.5% w/w of the solution. In total, the solutions used were:

• recycled oil diluted with heptane in a 1:1 ratio to reduce its viscosity (R);

• silane/alkosiloxane with 1.5% w/w silica nanoparticles (SN).

The solutions were applied twice each by brush, and after the applications the samples were left at room conditions to dry for seven days before any test was performed.

The following tests were used:

• capillary absorption by EN1015-18:2002;
porosity based on RILEM CPC11.3; Karsten tube test; and stereoscopic observation using a LEICA WILD M10 microscope to macroscopically examine the penetration depth of the solution.

Additionally, optical macroscopic observation of the color change of the specimens was conducted using Munsel charts, while in each test untreated samples (M) were kept for comparison reasons. The results of the physical properties of the specimens are reported in Table 01.

In the treated samples the porosity and water absorption tension were lower than in the untreated sample, but in the case of the R specimen the values of both factors were closer to the reference values. Moreover, the value of the capillary coefficient factor was relatively low compared to the reference sample, with the R sample presenting a low capillary coefficient factor, despite its relatively high water absorption. This indicates that the water absorption rhythm was relatively slow compared to the untreated sample M.

The capillary absorption test found the lowest rate of absorption in the SN specimens, while the recycled oil solution R presented a higher absorption according to the SN sample, but still kept a lower rhythm compared to the untreated sample M, which, as expected, was partially destroyed (Fig. 01).

For the Karsten tube test, tubes were applied to the surface of the samples using soft clay and were filled with 2 ml of water. Every five seconds the water absorbed by the surface of the samples was recorded (Fig. 02). The duration of the test was 10 minutes for each sample.

Color change caused by the solutions was indicated by Munsel charts for both R and SN samples (Table 02).

Microscopic examination of the surfaces showed that the surface of the SN sample was more stable and consistent compared to the R sample (Fig. 03 a, b), a fact that justifies the results shown in Table 01.

RESULTS & DISCUSSION

The coating of the alkosiloxane with nanosilica (SN) appeared to have the best results; however, the color of the SN specimen changed significantly (whitening effect). The SN specimen showed the lowest water absorption and porosity values, while the capillary coefficient was also relatively low in comparison to the other treated specimens. The Karsten tube test also indicated that the

<table>
<thead>
<tr>
<th></th>
<th>Water absorption %</th>
<th>Porosity %</th>
<th>Capillary Coefficient g/cm²·min⁻¹/²</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN</td>
<td>5.60</td>
<td>14.04</td>
<td>0.04</td>
</tr>
<tr>
<td>R</td>
<td>6.51</td>
<td>15.38</td>
<td>0.23</td>
</tr>
<tr>
<td>M</td>
<td>6.80</td>
<td>16.13</td>
<td>2.33</td>
</tr>
</tbody>
</table>

Table 01. Values of the three samples of the physical properties recorded

<table>
<thead>
<tr>
<th>Hue</th>
<th>Value</th>
<th>Chroma</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN</td>
<td>7.5YR</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>R</td>
<td>7.5YR</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>M</td>
<td>7.5YR</td>
<td>4</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 02. Color variation after the treatment based on Munsel charts
SN samples absorbed little or no water throughout the test. The microscopic examination revealed a more stable and consistent surface in comparison to the other two pieces.

The recycled oil solution (R) had a protective effect on the specimens treated and lowered the water uptake during the capillary test. Moreover, the Karsten tube test showed that the R samples absorbed less water than the untreated M samples but more water than the SN samples. Compared with the SN samples, though, the color of the R samples did not alter significantly. These results agreed with the stereoscopic observation that revealed a much less stable and less consistent surface.

CONCLUSIONS

Protection against water penetration in highly porous and hydrophilic materials such as adobes seems possible using the tested coating technique. Among the solutions tested, alkoxisilanes modified by 1.5% w/w nanosilica particles proved to be more efficient. Treated adobes presented high resistance to water uptake both by capillary action and by other mechanisms such as gravity (in Karsten tube tests) or under vacuum (based on the RILEM method).

Recycled oil seemed to offer no real protection, although some of the results indicated that further studies should be conducted to test its effects more thoroughly, perhaps with the addition of nanoparticles or even using it as an additive inside the clay mass.

BIBLIOGRAPHY


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(Endnotes)


Characterization of Patinas on the Main Facade of the Palacio del Infantado (Guadalajara, Spain)

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*Instituto de Geociencias (CSIC-UCM), Madrid, Spain

INTRODUCTION

The Palacio del Infantado (Fig. 1a) is located in Guadalajara, a city 40 km northwest of Madrid, Spain. Part of Guadalajara’s history is closely associated with the fortunes of the Mendoza family, who relocated there from Álava (Spanish Basque Country) in the 14th century.

Íñigo López de Mendoza, second Duke of Infantado and third Marquis of Santillana, built the palace, to which he brought the Renaissance art he had seen/acquired during his travels in Italy.1 Its construction in a period of transition led to a unique mix of Gothic, Mudejar, and Renaissance styles. Juan Guas headed the works from 1480 to 1483 and was succeeded by Lorenzo de Trillo from 1484 to 1497.2 The palace remained unchanged until the fifth dukedom, when, from 1570 to the end of the century, Íñigo de Mendoza enlarged it to better accommodate his family.3 That King Philip II wedded Isabel de Valois there is an indication of the importance of the palace and the city in the sixteenth century. In the 17th century, however, Guadalajara underwent decapitalization and was gradually depopulated.4 In the 19th century the 15th duke squandered the family fortune, accumulated over centuries, saving only the Palacio del Infantado, which was partially donated to the state to house a college for female war orphans.5 In 1961 the palace was restored by the Ministry of Education and Science. Its Lions’ Courtyard was restored in 2007 and 2008. Presently it houses the Provincial Historic Archive and Provincial Museum.

Fig. 01. (a) Palacio del Infantado, main facade; (b) remains of patina on limestone. Author: Rafael Fort, Carmen Vázquez. Image owner: Rafael Fort, Carmen Vázquez.
Interestingly, the literature reviewed mentions the presence of patinas on the palace. Layna Serrano reported that it was "hewn in fine Tamajón limestone with a handsome patina in shades of old gold attributable to centuries of sunlight."

Herrera Casado, in turn, wrote, “like those who in the fifteenth century carved golden Tamajón stone. . . the façade should be viewed at dusk, when the setting sun gleams obliquely on the venerable stone, accentuating its golden hue and highlighting the genuine value of its ornaments with light and shadows.”

While Layna Serrano assumed the tone was due to a patina, Herrera Casado believed the stone itself was gold-colored. This example clearly illustrates the misinterpretations that may arise when stone is poorly understood, as well as the decorative and evocative importance of patinas.

The foregoing informed the study of the scant remains of patinas on the palace facade to determine their typology and put forward considerations to be borne in mind in possible future interventions. The samples of patinas used in this study were taken from the palace facade.

### METHODOLOGY

To that end, flakes measuring less than 1 cm² were removed from the rims around the ornamental nail heads on the columns flanking the main entrance (Fig. 1b). Their chromatic parameters were determined with a spectrophotometer (illuminant CIE-D65, 10° observer), mineralogical analysis was undergone by means of Fourier transform infrared spectroscopy (FTIR), and the samples were characterized under polarizing optical microscopy (POM) and fluorescent (FM) microscopy, as well as by scanning-electron microscopy–energy dispersive X-ray spectroscopy (SEM-EDS).

### RESULTS & DISCUSSION

Table 1 lists the means and standard deviations for L*, a*, b*, C*, and yellowness (YI) indices for the patinas and the stone substrate (the stone substrate was measured on site on parts of the facade not covered with patina). The patina exhibited a high yellowness index (40 units) and higher a* and b* values than the substrate, indicative of an orange hue, as well as a higher chroma. The substrate was lighter than the patina.

<table>
<thead>
<tr>
<th>Sample</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
<th>C*</th>
<th>YI</th>
<th>WI</th>
</tr>
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<tbody>
<tr>
<td>Patina</td>
<td>63.33±0.01</td>
<td>5.41±0.01</td>
<td>21.22±0.01</td>
<td>21.89±0.00</td>
<td>40.30±0.01</td>
<td>-20.09±0.01</td>
</tr>
<tr>
<td>Stone substrate</td>
<td>77.36±0.02</td>
<td>2.80±0.02</td>
<td>14.64±0.03</td>
<td>14.91±0.03</td>
<td>25.20±0.04</td>
<td>-0.62±0.09</td>
</tr>
</tbody>
</table>

Notes: red hues (+a*); green hues (-a*), yellow hues (+b*), blue hues (-b*)

Table 01. Means and standard deviations for chromatic parameters L*, a*, b*, C*, and whiteness (WI) and yellowness (YI) indices measured on Palacio del Infantado samples
Mineralogical analysis showed that the main components of the patinas were calcium oxalate (whewellite, \(-\text{Ca}_2(\text{C}_2\text{O}_4)_2\cdot\text{H}_2\text{O}\)-), calcium phosphate (hydroxyapatite, \(-\text{Ca}_5(\text{PO}_4)_3(\text{OH})\)-), calcite, and gypsum. The microscopic study revealed the presence of up to three constituent layers of the patina (Fig. 02). The nonuniform, darker, outer layer had minimum, mean, and maximum thicknesses of 40, 70, and 200 mm respectively and lacked any clear internal structure. The more uniform intermediate orange layer was in turn tiered with sheets lying parallel to the outer surface. Its minimum, mean, and maximum thicknesses measured 60, 70, and 100 µm respectively. While the two outer layers did not follow the external substrate morphology, the innermost layer did. When observed with parallel nicols, this layer could be mistaken for altered substrate, but with crossed nicols (with polarizer) its isotropic nature made it clearly distinguishable. The minimum, mean, and maximum thicknesses were 110, 150, and 200 µm respectively. The intense green in the outer layer observed under the fluorescence microscope (Fig. 2c) denoted its high porosity, whereas the innermost layer was observed to have incipient cracks at the interface with the substrate.

The SEM study showed that the outermost layer comprised a variety of particles, including quartz, feldspar, and mica (Fig. 03),9 surrounded by the epoxy resin used to coat the sample. This layer was also Fe-rich, which explained the orange color. With the fluorescence microscope, a high porosity was noticed. The intermediate layer had cracks parallel to the outer surface, was Ca-, Si-, and Al-rich and contained some iron. The P- and Ca-rich inner layer had a fairly uniform, nonporous structure.

Comparison of the results with previous studies10 showed that the studied patina—composed of three layers—was of the calcium phosphate and oxalate variety,11 similar to many others found in Spain, Italy, and Greece.12

CONCLUSIONS

The study suggested an artificial origin for the calcium phosphate and oxalate patinas, which should be conserved, as recommended by several international charters. The recommendation for any future cleaning of the facade of the Palacio del Infantado is therefore to leave these patinas intact.

ACKNOWLEDGMENTS

This research was funded by the Regional Government of Madrid’s EU Geomaterials 2 (S2013/MIT-2914) Programme.

CURRICULUM VITAE

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Rafael Fort has a PhD in economic geology from Universidad Complutense Madrid. A senior scientist with Consejo Superior de Investigaciones Científicas, he specializes in petrological techniques to determine the quality and durability of stony materials and conservation treatments.
BIBLIOGRAPHY


(Endnotes).


9 Several analyses—not shown in this paper—have been undergone to determine the mineralogical composition that together with the morphology let us know the kind of mineral.


Monitoring the Traditional Gypsum Calcination Process

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b Escuela de Estudios Árabes (CSIC), Granada, Spain

INTRODUCTION

Gypsum is typically used as a finishing material; its function is primarily aesthetic. However, despite its assumed poor mechanical behavior, it has been found to have been used as a structural material in several ancient constructions.1

In Spain, several buildings include structural gypsum. They are mainly located in the eastern and southern areas of the Iberian Peninsula, including Tarragona, Zaragoza, Teruel, Valencia, Albacete, Murcia, Almeria, and Granada. Examples of such buildings include:

- The Torres Mudejares in Teruel and castles in Calatayud, Maluenda, and Cadrete. Rammed earth with gypsum instead of lime.
- Cathedrals in Zaragoza, Tarazona, Teruel. Structural nerves or massive walls made from pure gypsum.
- Albarracín. Facades and indoor floors made of pure local gypsum.
- Comarca del Jiloca in Teruel. A typical construction system using walls and columns made of pure gypsum, like the Salón del Cuco in Burbáguena.2
- Alhambra in Granada. Domes made with bricks and gypsum mortar.

During the processing of the gypsum-based material, the specific conditions during calcination can yield different products from the same original raw gypsum (CaSO₄·2H₂O) stone (Table 01) and many multiproduct mixtures. Depending on the calcination product(s), the properties of set gypsum (after rehydration) can vary significantly. For instance, set α-hemihydrate can achieve a compression strength four times higher than concrete.3

Unfortunately, once rehydrated, the mineralogical composition of the original calcined product is impossible to estimate. This is a handicap to replication of the specific properties of gypsum used in the past.

Because of the current high demand for gypsum in heritage restoration/conservation, we focused our investigation on how to obtain a calcined product with properties similar to those of the structural gypsum found in the above-mentioned ancient structures. For this task, we analyzed the conditions (T, pCO₂, and pH₂O) for the traditional production of gypsum in an oven built according to the ancient traditions transmitted over generations in the area of Teruel. Research on gypsum calcination using traditional ovens4 provided detailed information that we could compare with the know-how of old masons who still calcinate gypsum in traditional ovens in this northeastern region of Spain.

In this study we show how this type of traditional oven was dimensioned and constructed and how such information enabled us to determine temperature, pressure, and moisture parameters during the calcination process and the relationship between these parameters and the final properties (including strength) of the set gypsum.
The study thus represents the first step in replicating conditions for improving gypsum performance as a structural material in heritage conservation interventions.

METHODS & METHODOLOGY

After analyzing the ovens used in Comarca del Jiloca, we found gypsum ovens with similar design and dimensions in Leciñena (Zaragoza), Belchite (Zaragoza), La Almunia (Zaragoza), and Baza (Granada).

Phase 1: How to Build a New Oven
Representative of the Traditional Ones

Bibliographical Study

Researchers and ethnographers have collected large amounts of information on this topic. After analyzing the existing literature on the extraction and processing of gypsum, including its calcination, a field survey of the area showed no significant differences in know-how related to the construction of the gypsum oven among masons who worked in the Comarca del Jiloca (Teruel).

Interviews with Old Masons

Four local masons who were dedicated to gypsum production using traditional ovens in the area (until approximately 1950) were interviewed. They inherited their knowledge from their ancestors and testified that such know-how had been transmitted from parents to children for generations. In some areas, however, this “transmission” had been disrupted, and knowledge had been lost.

Elaboration of Remaining Ovens and Gypsum Industry

Nine traditional gypsum ovens were located near the historical quarry of Navarrete. All of them display similar morphology and dimensions. Five more traditional ovens were located in the area of Leciñena (Zaragoza), one of them fully set to be fired and another already calcined but still standing (Fig. 01).

Phase 2: Obtaining Material for Combustion

In the analyzed literature, we also found references to the amount and type of wood used. Such information was contrasted with that provided by the interviews with the local masons.

Phase 3: Instruments for Monitoring

Defining the limit threshold of parameters and ranges (T, pCO₂, pH₂O) for monitoring the calcination procedure required the collaboration of specialists in the field of measurement and monitoring.

<table>
<thead>
<tr>
<th>Calcinations T</th>
<th>Mineral phase</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>120-180ºC</td>
<td>→ CaSO₄·1/2H₂O</td>
<td>β-hemihydrate</td>
</tr>
<tr>
<td>100-120ºC (autoclave oven,↑Pressure)</td>
<td>→ CaSO₄·1/2H₂O</td>
<td>α-hemihydrate</td>
</tr>
<tr>
<td>220-380ºC</td>
<td>→ CaSO₄</td>
<td>anhydrite III-Soluble</td>
</tr>
<tr>
<td>380-1200ºC</td>
<td>→ CaSO₄</td>
<td>anhydrite II-Not soluble</td>
</tr>
<tr>
<td>1200-1350ºC</td>
<td>→ CaSO₄</td>
<td>anhydrite I</td>
</tr>
<tr>
<td>&gt;1350ºC</td>
<td>→ CaO + SO₂</td>
<td>hydraulic gypsum</td>
</tr>
</tbody>
</table>

Table 01. T-dependent products obtained after the calcination of raw gypsum
Choosing the right instrument was difficult because this experiment has never been done or measured before. There was great uncertainty about the maximum temperature.

RESULTS & DISCUSSION

Phase 1: How to Build a New but Traditional Oven

Excavation of the casa: The casa (house) was a hollow (or trench), with square proportions (approximately 2.5 m x 2.5 m) and with three sides dug into the hillside and a height of about 2 m (Fig. 02).

Larger, denser gypsum stones were placed in areas receiving the greatest weight and intensity of fire; that is, the base and central structure of the oven, as well as the areas around the shaft. Smaller stones were placed in areas less exposed to the fire.

Phase 2: Obtaining Material for Combustion

Combustion material was typically collected from the surroundings near the oven and was freshly cut a month before calcination began. In general, rapidly growing bush species were used, including *Rosmarinus officinalis*, *Quercus coccifera*, *Genista scorpius*, *Salsola vemiculata*, and *Santolina chamaecyparissus*.

Phase 3: Instruments for Monitoring

Temperature: Various types of data loggers capable of recording temperatures up to 1,000°C were used. This provided a wide safety margin, which was necessary because of the uncertainty regarding the maximum temperatures to be obtained.

Pressure: Instruments to reliably measure $p_{CO_2}$ and $p_{H_2O}$ at temperatures greater than 200°C were not commercially available. As an alternative, a hollow tube was inserted inside the oven structure. A pressure gauge was then placed on the tube. This alternative allowed us to determine the maximum pressure that might be reached during calcination.

Humidity: Although an LDS 6 continuous gas analyzer would have allowed on-site analysis, the cost of such equipment, €15,000, was beyond the scope of our budget. Therefore, for reference purposes, the wood used as fuel was weighed before being placed in the oven and then compared to the weight of the waste left after burning.

Discussion: α-Hemihydrate Presence in the Products

The formation of α-hemihydrate as a product during calcination is possible (see Table 01). Plugging the oven with mud and using green wood for combustion produced the needed pressure, like a primitive autoclave oven.

CONCLUSIONS

Plugging all openings of the oven with clay and mud (except a small shaft area) and using as fuel green wood with a high water content that was released during combustion led to high $p_{H_2O}$ during traditional gypsum calcination.
Conditions during traditional plaster preparation were similar to those in an autoclave oven: high humidity and pressure.

In traditional ovens, a-hemihydrate can be obtained with specific properties that enable its use as a structural material with high strength and durability.

CURRICULUM VITAE

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BIBLIOGRAPHY


(Endnotes)


Mechanical Properties of Lime Mortar with Additions of Powdered Cactus Fibers and Mechanical Masonry Contribution


INTRODUCTION

Excavations at Khafajah (Diyala Province, Iraq) of the ruins of a furnace used for lime production indicate the practice of limestone calcination was known as early as 2450 BCE in ancient Mesopotamia. Moreover, the use of gypsum mortars in the Middle East lasted for more than 4,000 years. From the Middle East, mortar technology likely spread to the Greeks and then to the Romans.

Since ancient times, lime has been used in building construction internationally because of its strength and durability (examples of important building projects that used lime include the Appian Way, the pyramids in Egypt, the Great Wall of China, the Roman Colosseum, the Teotihuacan and Mayan pyramids, and ancient Toltec buildings).

Mortars and concretes employed in ancient structures are composite materials comprising a binding material (or mixture of binders), natural or artificial aggregates (or mixtures thereof), and pozzolanic additions (natural or artificial) so as to ameliorate lime-based mortars and prolong their longevity. Sometimes, in order to improve rheological and mechanical characteristics, organic additives and vegetable and animal materials were used as reinforcement.

The Mexican pre-Hispanic cultures used high-quality mortars that included organic additives, mainly derived from plants. Mexico has the highest number of United Nations Educational, Scientific and Cultural Organization–protected heritage areas in the Americas and has many challenging environments for buildings made of stone. Therefore, the national budget for restoring historic buildings and monuments is sizable.

In modern times, researchers have attempted to replicate the materials used by pre-Hispanic or missionary builders. These attempts have tried to use ancient building processes without losing sight of their environmental and cultural contexts.

METHODS & METHODOLOGY

Lime mortars were prepared with cactus powder additions, and 5 x 5 x 5 cm cube and 1.5 x 2.5 x 7.5 cm briquette specimens were fabricated.

River sand was extracted from the Pucuato River located on the road to Morelia-Ciudad Hidalgo in Michoacán near the town of Huajumbaro. Granulometry analysis was performed using #16 and #30 sieves per ASTM standard. A commercial lime (Cal Muro brand) was used as binder. A lime-to-sand ratio of 1:3 by weight was used as base content. Water for mixing mortar in this work met the specifications of the NMX-C-122 norm. For this study, the quantity of water was not fixed, however, but was determined by experienced masons to ensure suitable workability.

Cactus powder was added in proportions varying from 1% to 10% of the amount of lime (by lime mass).
Lime mixtures were selected based on expected stability (i.e., in terms of contraction and physical appearance). Once the amount of cactus powder was determined, four cubes were fabricated to determine mechanical performance at 14 days of age.

**Mortar Testing**

For mortar characterization, workability and mechanical development were determined. To determine the amount of water needed to obtain mortars with the same fluidity (plastic consistency), and before cube fabrication, ASTM C-2309 and C-305 were followed for flow table and mortar fabrication respectively.

For mechanical characterization, the cubic specimens were evaluated for compressive strength. Cubes were tested up to failure under compression by a procedure similar to that which is detailed in ASTM C-109 (2005). Other mechanical characteristics evaluated were flexural and direct tensile strength. The flexural strength was tested in beams, which were tested up to failure under flexure (three-point bend test), and direct tensile strength was tested in briquettes, following ASTM C-307 (2012) procedure.

**RESULTS & DISCUSSION**

**Mortar Test Results**

Final proportions were selected based on the stability of the mortar. The chosen mortar proportions were 1%, 3%, 5%, and 9% cactus powder addition. Mortars with low consistency values (70%) did not perform as workable mixtures because they were too dry. On the other hand, mortars with consistency values greater than 100% lacked workability since the mixture became too liquid.

The specimens were tested after drying. Some of the mixtures showed cracking due to excessive shrinkage. These results corroborate the hypothesis that using cactus additives diminishes the amount of cracking of the lime mortar.

The compressive strength was used to determine the best percentage of additive (the results from three specimens per mixture are shown in Table 01). As the compressive strength results indicate, mixtures with 1% cactus powder addition achieved the highest values overall.

The mortar was tested at 7, 14, and 28 days and, to determine long-term performance, at approximately 500 days (Fig. 01).

![Fig. 01. Average mortar compressive strength of control and 1% cactus-added mixtures versus time.](image1)

![Fig. 02. Compressive stress and deformation of mortar C-A.](image2)

![Fig. 03. Compressive stress and deformation of mortar C-A with 1% nodal powder.](image3)
Flexure tests up to failure were performed to determine the modulus of rupture and shear presented in a mortar subjected to bending. The direct tensile strength tests were performed with control and 1% added cactus mixtures. For the masonry only, the axial load strength was examined in specimens of white lime mortar with 1% cactus powder added. The axial load determination was performed on fifteen samples of masonry. Table 02 shows the results with and without additives. Resistance to compressive stress was increased by 14% in the mortars with additives. Fig. 02 and Fig. 03 show the stress-strain graphs and variability that resulted with and without the additive.

CONCLUSIONS

The addition of 1% cactus powder increased the compressive strength at least twice as much as a control mortar, increased modulus of rupture by 30%, and increased tensile strength by 200% as compared with a control mortar without such addition.

The addition of 1% cactus powder increased by 14% the resistance to compressive strength of masonry and decreased the variability of resistance to compressive strength among the specimens.

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Sandra del C. Arguello-Hernández is a civil engineer specializing in the restoration of ancient monuments.

<table>
<thead>
<tr>
<th>Addition (%)</th>
<th>Weight (gr)</th>
<th>Width (cm)</th>
<th>High (cm)</th>
<th>Area (cm²)</th>
<th>Load (Kg)</th>
<th>f’c (Kg/cm²)</th>
<th>f’c averages</th>
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<tr>
<td>1</td>
<td>210.98</td>
<td>5.22</td>
<td>5.07</td>
<td>26.47</td>
<td>142.5</td>
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<td></td>
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<td></td>
<td>219.71</td>
<td>5.4</td>
<td>4.95</td>
<td>26.73</td>
<td>137.5</td>
<td>5.14</td>
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<td></td>
<td>216.93</td>
<td>5.18</td>
<td>5.02</td>
<td>26.00</td>
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<td>3</td>
<td>200.14</td>
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<td></td>
<td>208.62</td>
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<td>25.45</td>
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<td>2.25</td>
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<td>5.34</td>
<td>4.87</td>
<td>26.01</td>
<td>53</td>
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<td>175.17</td>
<td>5.06</td>
<td>4.89</td>
<td>24.74</td>
<td>62</td>
<td>2.51</td>
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Table 01. Compressive stress of masonry with mortar nopal powder addition

<table>
<thead>
<tr>
<th>Element</th>
<th>Compressive stress (MPa)</th>
<th>F*m (MPa)</th>
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</thead>
<tbody>
<tr>
<td>Piles of sand-lime mortar</td>
<td>1.274</td>
<td>0.927</td>
</tr>
<tr>
<td>Piles of sand-lime mortar with 1% added nopal</td>
<td>1.463</td>
<td>1.232</td>
</tr>
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</table>

Table 02. Single and average cube compressive strength with different cactus % addition at 14 days
Amirais Flores Ponce is a civil engineer specializing in the restoration of ancient monuments.

BIBLIOGRAPHY
Multi-analytic Approach to the Characterization of Lime Mortars from the Temple of Diana, Mérida (Spain)

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INTRODUCTION

The Roman city Emerita Augusta became an important center of Roman power in the Iberian Peninsula. The city, now called Mérida, was founded in 25 BCE by an order of Emperor Octavio Augusto. Intended for retired soldiers (veterans-emeritus), it was later converted into the capital of the Roman province Lusitania. The city has well-preserved important buildings, and this archaeological ensemble was declared a United Nations Educational, Scientific and Cultural Organization World Heritage Site in 1993. Among the buildings, the Temple of Diana stands out. Located in the center of the Roman forum, behind the decumanus maximus, the monument is a temple with rectangular plan (40.75 m long and 21.90 m wide) and northeast-southwest orientation. It includes a hexastyle porticus and an 11-column peripteros with 10 m columns with Corinthian capitals and bases.

The temple has a 3 m high podium with access via a staircase. An underground porticus (cryptoporticus) with two ponds and waterways borders the northern space of the forum.

Fig. 01. Temple of Diana. Photograph courtesy of D. Ergenç.
The temple is built with blocks of granite, facings of *opus quadratum*, and well-preserved architectural features that correspond to the Augustan period or early years of the Julio-Claudian dynasty. In the 16th century, the Renaissance-style Palace of the Counts of Corbos was constructed on the structure. In 1972, archaeological excavations began, from 1986 to 1992 restoration works were conducted, and an important intervention in the building environment was undertaken from 2009 to 2011.

Although studies of the temple have been completed, no information has been published on the composition of the original mortars used in this Roman monument. The aim of the present paper is to characterize these mortars and provide information for possible future actions in the building.

**METHODS & METHODOLOGY**

Five mortar samples were collected from the different areas of the temple. Two mortars were sampled from the temple itself, one was sampled from the water-related structure (fountain or water channel) in front of the temple, and two were extracted from two walls of the *cripsoporticus-temenos*:

- **M1**: Foundation above the granite ashlar;
- **M2**: Flooring;
- **M3**: Vault of fountain or channel;
- **M4**: Wall of *cripsoporticus-temenos*;
- **M5**: Interior wall in *cripsoporticus-temenos*;

The five Roman mortar samples collected from different parts of the Temple of Diana were characterized using several analytical techniques. Polarized light optical microscopy (POM) was conducted on an Olympus BX51 microscope fitted with an Olympus DP12 digital camera. Whole mortars were grinded to use in X-ray diffraction (XRD) analyses. A Bruker D8 Advance X-ray diffractometer fitted with a copper anode tube and PC-ADP diffraction software were utilized. XRD patterns were acquired by operating at 40 kV and 30 mA at 2h angles of 2–68° with a 0.020-step scan, a speed of 2°/min., CuKα radiation, and a graphite monochromator. For the interpretation of graphs, EVA X-ray diffraction analysis software was utilized. Thermal analysis (TG-DSC) was performed with a TA Instruments SDT-Q600, DSC Q-200, and General V4.1C DuPont 2000 thermogravimetric analyzer in a nitrogen atmosphere at a heating rate of 10°C/min. Colorimetric analysis were conducted through spectrophotometer CM 700d-Minolta and Chromatic parameters CIE Lab (L*a*b*), and Chroma (C*=√((a*)²+(b*)²)) color spaces were used.

**Fig. 02.** (1) Quartz, plagioclase, and 2 mm quartzite fragment in M1—crossed polarized light; (2) biotite and unaltered slaked lime with a shrinkage crack in M3—plain light; (3) 4 mm granitoid fragment embedded in a carbonated lime binder in M4—crossed polarized light; (4) under- and overburned lime lump 4 mm in size in M5—plain light. Photograph courtesy of D. Ergenç.
RESULTS & DISCUSSION

The first macroscopic analysis showed that the light brown-yellow mortar samples had a conglomeratic appearance (M1, M2, and M3) with coarse aggregates (1–4 cm) and sandy texture (M4 and M5) with smaller aggregates (0.5–5 mm).

Microscopic analysis revealed that all samples had a variety of rock fragments and quartz, calcite, feldspar, and biotite aggregates embedded in a porous lime binder. Other than the M3 sample, all binders showed a dark-brown carbonated appearance under the microscope. Observed rock fragments were quartzite, granitic rocks, marble, slate, schist, and limestone (Fig. 02). The aggregate percentage was estimated as 60–70% in the mortars. In addition, larger (1–5 cm) lime lumps were encountered in all samples except M2, which may have been caused by poor workmanship or by lack of water during slaking.

XRD analysis revealed that all mortar samples had quartz, calcite, albite, and anorthite. Only the M2 sample did not contain biotite. M1, M4, and M5 showed peaks of actinolite (Table 01).

Colorimetric studies proved that the samples had high luminosity, changing between 70 and 80 with saturation changes between 8 and 14. M2–M4 had the highest and M1–M5 had the lowest luminosity values. M4 had the lowest a* and b* values (Table 02).

All studied mortars had hydraulic features as determined by the correlation between the ratio of CO₂ (weight loss % between 600–800°C) and H₂O (weight loss % between 200–600°C) and CO₂. Two groups could be discerned (Table 02). The first group had structurally bound water to decomposition of calcium carbonates (CO₂/H₂O) ratio below 4, and decomposition of calcium carbonates (CO₂) was between 5 and 15% (MM1, MM3, and MM5). The second group had CO₂ percentages of 15–25 and a CO₂/H₂O ratio between 4 and 8 (M2 and M4).

Samples M2 and M4 could be classified as hydraulic and artificial pozzolanic mortars, while M1, M3, and M5 were in the highly hydraulic mortar class. Results were coherent with other studies.

Thermograms of the studied samples showed typical lime mortar trends with the main weight loss between 600 and 800°C. The M3 sample differed from others.
that showed well-marked weight loss between 200 and 400°C, indicating C-S-H formations and weight loss after 600°C, which implies the complete decomposition of calcareous components of mortar. The M4 and M5 samples showed a transformation peak of quartz at 573°C.

**CONCLUSIONS**

In this study, various analytical techniques were used to characterize mortars collected from the Temple of Diana in Mérida. Results showed that all samples were lime mortars. All mortars had angular to semi-angular aggregates and high amounts of rock fragments of quartzite, marble, slate, schist, limestone, and granite and lime lumps embedded in carbonated lime binders with locally different carbonation degrees. The use of similar raw materials, as well as similar composition and morphology, indicate a common origin for all the mortars. The petrographic and thermogravimetric analysis revealed that the workmanship and manufacturing of the mortars were variable. The mortar from the water channel/fountain vault had more hydraulic properties than others, and the flooring mortar included neither lumps nor biotite.

**ACKNOWLEDGMENTS**

This research was funded by the project CLIMORTEC (BIA2014-53911-R) and by the Program Geomateriales 2 (P2013/MIT2914) of the Community of Madrid. The authors are grateful to the Consortium of the Monumental City Mérida for the facility they provided during the sampling for this study.

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**BIBLIOGRAPHY**


(Endnotes)


The Hydration of Lime Using *Nopal* Mucilage to Optimize Hydrated Lime Mortars for Conservation of Built Heritage

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\textsuperscript{b} Universidad Autónoma Metropolitana, Mexico City, Mexico

INTRODUCTION

High-calcium hydrated lime is a material present in mortars and plasters in many historic buildings in Mexico. Therefore, its use in interventions for their conservation is essential.

Since ancient times, cultures that use lime have known that including additives in the formulation of mortars can improve the properties of the compound, optimizing its design, implementation, and material performance.\textsuperscript{1} One affordable additive in Mexico is mucilage or *baba* from the *Opuntia* cactus (*nopal*), which behaves well when used in the formulation of paste and restoration mixtures.\textsuperscript{2}

The conditions of lime hydration have a strong impact on the behavior of mortars that are manufactured with this binder.\textsuperscript{3} Therefore, the main objective of the research described in this article was to select a method of extracting *nopal* mucilage that could be used as an agent of hydration of quicklime (*CaO*) to improve the properties of this binder as hydrated lime putty (*Ca(OH)\textsubscript{2}*) from the time of its production and not only during mortar or mixture formulation.

METHODS & METHODOLOGY

Extraction methods described by various authors\textsuperscript{4} were reproduced with some adjustments based on experience.
In the first phase of experimentation, performed by students of the Faculty of Chemistry at Universidad Nacional Autónoma de México, nopal mucilage was observed to interact strongly with cations such as Ca\(^{2+}\). The chemical substance responsible for this bond is galacturonic acid. The authors hypothesized that this substance is the most important factor for the chemical interaction with lime and would produce the desired results in lime mortars.

The nopal mucilage extraction method that works best will be the one that results in the highest amount of galacturonic acid in the extract. The research also sought to increase the speed of the extraction method and the quantity of mucilage obtained and to facilitate, as much as possible, the extraction process to optimize the dynamics of the restoration work.

The mucilage containing the largest amount of galacturonic acid should perform better during lime hydration and produce hydrated or slaked lime putty (Ca(OH)\(_2\)) with better application and resistance properties.

The tested extraction methods were classified into two groups: those that use water to obtain the mucilage (constant ratio followed: 1:2, nopal: water by weight) (Fig. 01); and those that use water directly from the cladode.

### Methods of extraction of nopal mucilage

<table>
<thead>
<tr>
<th>Method No.</th>
<th>Species used</th>
<th>Elements removed</th>
<th>Cladodes cut</th>
<th>Proportion in weight nopal:water</th>
<th>Appliance used</th>
<th>Temperature (°C)</th>
<th>Stirring</th>
<th>Mesh aperture</th>
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<tbody>
<tr>
<td>1</td>
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<td>Cutin, epidermis and spines</td>
<td>Chopped in pieces (2cm)</td>
<td>1:2</td>
<td>liquefied</td>
<td>70–80</td>
<td>occasional</td>
<td>2mm–1mm-12–15μm</td>
</tr>
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<td>Cutin, epidermis and spines</td>
<td>Chopped in pieces (2cm)</td>
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<td>70–80</td>
<td>occasional</td>
<td>not meshed</td>
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<tr>
<td>3</td>
<td>Tlaxcalancingo Puebla</td>
<td>Cutin, epidermis and spines</td>
<td>Chopped in pieces (2cm)</td>
<td>1:2</td>
<td>/</td>
<td>/</td>
<td>/</td>
<td>2mm</td>
</tr>
<tr>
<td>4</td>
<td>Supermarket</td>
<td>Cutin, epidermis and spines</td>
<td>Chopped in pieces (2cm)</td>
<td>1:2</td>
<td>/</td>
<td>80</td>
<td>constantly for 30 minutes</td>
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</tr>
<tr>
<td>5</td>
<td>Tetla Tlaxcala</td>
<td>Cutin, epidermis and spines</td>
<td>Chopped in pieces (2cm)</td>
<td>1:2</td>
<td>/</td>
<td>80</td>
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<tr>
<td>6</td>
<td>Tlaxcalancingo Puebla</td>
<td>Spines one by one</td>
<td>Cut half lengthwise</td>
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<tr>
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<td>Tecali Puebla</td>
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<td>Spines one by one</td>
<td>Cut half lengthwise</td>
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<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>9</td>
<td>Tetla Tlaxcala</td>
<td>Spines one by one</td>
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<td>/</td>
<td>/</td>
<td>40–60</td>
<td>constantly for 30 minutes</td>
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</table>

Table 01. Title: Methods of extracting nopal mucilage. Image owner: Angélica Pérez Ramos
extract mucilage directly from the plant without using other substances (Fig. 02; Table 01).

The extraction methods were tested on *Opuntia ficus-indica* cultivated species indigenous to Tlaxcalancingo, Puebla; wild species from Tecali, Puebla, and Tetla, Tlaxcala; and species purchased in supermarkets in Puebla City.

In the first extraction methods tested, cladodes from Tlaxcalancingo were used. Cutin, epidermis, and spines were removed. The cladodes were then chopped, liquefied in a home appliance, poured into water, and then the mixture was heated to between 70°C and 80°C. One portion of the extract was passed through meshes of different apertures (method no. 1), while another portion was left unscreened (method no. 2).

Method no. 3 developed as a variant of the first two. *Nopal* from the same source was chopped without cutin, epidermis, and spines, poured into water, and left for 24 hours before its extract was passed through a mesh with 2 mm openings.

Extraction method no. 4 consisted of exposing some cladodes obtained in a convenience store (chopped and poured into water) to a temperature of 80°C with constant stirring for 30 minutes.

Extraction method no. 5 was developed as a variant of extraction method no. 4 and consisted of chopping *nopal* native to Tetla after it was determined that a larger amount of mucilage was obtained from each cladode. The extract was subjected to a temperature of 80°C and was constantly stirred for 30 minutes.

Extraction method no. 6 was developed using cladodes from Tlaxcalancingo. This method, which reproduces a traditional Otomi technique, consisted of cutting the cladode in half lengthwise and scraping the inner faces to remove the mucilage without using water as a solvent. This extraction technique was replicated using native cladodes from Tecali (method no. 7) and Tetla (method no. 8).

Method no. 9 was a variant of extraction method no. 8. After the product was obtained, it was constantly stirred for 30 minutes while the temperature was raised to between 40°C and 60°C.

Subsequently, acid-base titrations were performed on 25 ml of the extract obtained from each method by gradually adding 0.25–0.50 ml of sodium hydroxide $2 \times 10^{-2}$ M. A pH meter was used to reflect the results in titration curves, which led to partial conclusions about the presence of galacturonic acid.

RESULTS & DISCUSSION

Among the extraction methods that did not use water, method no. 8 produced the largest amount of product (19.8 kg of *nopal* produced 11 L of mucilage). This and method no. 6 yielded *nopal* that was too viscous to be strained through a mesh and contained the greatest amount of galacturonic acid (Fig. 03).

Overall, the methods in this group produced a greater amount of *nopal* mucilage than those in group one (where 4.95 kg of *nopal* produced 11 L of mucilage).
The mucilage extracted using method no. 4 contained a large amount of galacturonic acid but not as much as was obtained with method no. 8. The *nopal* indigenous to Tetla produced mucilage that was touch evaluated as having the best viscosity (when obtained by method no. 5).

Mucilage obtained by method no. 8 was selected for the quicklime hydration process. A too low reaction rate took place, oscillating between 10 and 15 minutes, and the reaction temperature did not exceed 40°C, which may have resulted in a decrease in the surface area of calcium hydroxide (Ca(OH)₂) crystals and therefore a significant decline in the rheological properties of the lime putty. The paste obtained presented a heterogeneous consistency to sight and touch.

CONCLUSIONS

The extraction methods that included water produced larger amounts of mucilaginous substance but required at least 24 hours.

Extraction methods that obtained mucilage directly from the cladode reduced production times and offered a greater amount of galacturonic acid in the resulting composition. However, the volume of mucilage (liters) obtained was lower compared to that obtained in the first group. During hydration of quicklime, the higher viscosity of the mucilage was a disadvantage.

The hydration process using mucilage was reproduced using mucilage extracted by method no. 4, and the results reflected the desired temperature and putty consistency.

In the next experimental phase, lime putties will be analyzed and hydrated lime mortars will be formulated to compare their chemical resistance and rheological properties by developing different techniques.

ACKNOWLEDGMENTS

The authors thank Consejo Nacional de Ciencia y Tecnología for granting a scholarship to the first author of the article.

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Microemulsions for Cleaning Hydrophobic Material from Spanish Wall Paintings

INTRODUCTION

Protective coatings—among them, waxes, oils, and natural resins—have been applied to mural paintings throughout history. In the 20th century, acrylic and vinyl resins were introduced as consolidants and coatings to protect wall paintings. While these coatings were applied with the best of intentions, they can cause problems by decreasing the natural transpiration of the wall and promoting saline efflorescence.

Traditional cleaning techniques have often used mechanical methods or organic solvents. Many of these materials are aggressive to the painting, toxic to the conservator, and bad for the environment. Treatments employing these materials are also often inefficient and cause problems in the porous structure of the paintings. For these reasons, suitable alternatives for cleaning have been considered. These may include nanostructured systems such as microemulsions or micellar solutions. These systems are believed to offer suitable properties for cleaning, while limiting interaction with the original artwork. Furthermore, many are nontoxic or exhibit a reduced toxicity.

The first application of microemulsions for the conservation of cultural heritage was performed in the late 20th century. During the restoration of the Brancacci Chapel (Florence, Italy), Emiliano Ferroni and Piero Baglioni removed wax with a microemulsion.1 These mixtures were subsequently used to remove synthetic polymers applied in previous restorations.2 Following the publication of successful interventions in Italy, microemulsions were tested on two Valencian murals, one in the Ducal Palace of Gandia and one in the Church of St. Nicholas in Valencia. In both cases, advantages and disadvantages were observed, and they serve as the impetus for the present research. In the Ducal Palace, a micellar solution was tested, and a reduction of the layer of polyvinyl acetate was observed. However, analytical methods detected significant amounts of sodium, which may be attributed to the presence of a surfactant. In the Church of St. Nicholas, a reduction of existing salts was observed after the application of a microemulsion. Nevertheless, organic material was still present after cleaning. This may indicate that the cleaning was not completely effective.

METHODS & METHODOLOGY

1. The Ducal Palace

The construction of the Ducal Palace of Gandia began in the first half of the 14th century. The building contains Gothic, Renaissance, Baroque, and neo-Gothic artistic styles. The present article focuses on the restoration of the Baroque paintings on the palace’s facade. The original painting technique employed a layered sequence of stucco and fresco. The facade of the courtyard showed losses, erosions, surface accretions, and numerous materials from previous interventions. The north and eastern walls were fully overpainted during a campaign to reproduce the original design. The balconies above the courtyard were covered with a layer of polyvinyl acetate (PVA), in addition to sulfate and oxalate salts (Fig. 01).
The condition issues of the Ducal Palace were similar to the exterior decorations of Santa Maria dei Battuti in the cathedral of Conegliano (Italy), both of which were treated with PVA. The polymer was reduced using PC22, a micellar solution composed of 69% water, 22% propylene carbonate, 5.1% 1-pentanol, and 3.9% sodium dodecyl sulfate (SDS). This treatment method was also employed for the Ducal Palace.

The PC22 was applied in a poultice of cellulose pulp and allowed to stand for two hours. After removal of the poultice, the surface was washed with 5% ammonium bicarbonate in water, followed by several rinses with deionized water. Days after the treatment, the surface exhibited residues that generated foam, so further clearance with deionized water was required.

2. Mural Paintings of St. Nicholas

The Church of St. Nicholas is a 15th-century Gothic structure with Baroque decoration. Inside the church, mural paintings were executed in lime above a calcium sulfate layer. The paintings were carried out at the end of the 17th century by Dionis Vidal, who followed the design of his master, Antonio Palomino.

Over the centuries, the paintings were obscured by soot and other particulates from candles and airborne pollutants. Generous overpaint and foreign materials from previous restoration campaigns (including wax, paraffin, fatty acids, grime, and salts) were also found. X-ray diffraction (XRD) confirmed the presence of potassium nitrate and calcium sulfate. A microemulsion composed of 0.4% xylene, 2.1% ammonium carbonate, 4.9% Triton X-100, and 92.6% deionized water was used to clean the surface. The microemulsion was delivered in a poultice of cellulose pulp and allowed to stand for two hours (Fig. 02). Following this period, the surface was rinsed with 5% ammonium bicarbonate in water followed by several applications of deionized water.

This microemulsion was similar to the one prepared for the restoration of the frescoes of the Oratory di San Nicola al Ceppo (Florence) that were damaged by water from the Arno River flood in 1966. Due to this, the painting was contaminated by organic deposits and sulfates. The microemulsion reportedly offered two types of restorative technology that would offer desulphation “according to the Ferroni-Dini method” and “detergency with an oil-in-water microemulsion.”

The treatment of these two artworks illustrates the need for more research into problems associated with aqueous cleaning systems containing surfactants.

RESULTS & DISCUSSION

Fourier transform infrared (FTIR) spectroscopy of a surface sample taken before treatment of the Ducal Palace suggested the presence of calcium oxalates and calcium sulfate. Bands in the FTIR spectra (2,933, 2,859, 1,725 cm⁻¹) indicated the existence of organic matter, which might be associated with a synthetic
resin, possibly one used as a consolidant. FTIR spectroscopy and scanning-electron microscopy–energy dispersive X-ray spectroscopy (SEM/EDS) executed after cleaning suggested the presence of residual SDS, despite numerous rinses with deionized water.

The use of excess water can cause surface precipitation and efflorescence, in addition to spalling of the lime support. While the cleaning system was effective in reducing the vinyl polymer, the presence of SDS residues suggests the material cannot be completely removed, causing problems for the long-term conservation of the mural.

In the case of the Church of Saint Nicholas, analysis by FTIR spectroscopy executed before cleaning suggested the presence of calcium sulfate in high proportion to calcium carbonate. The analysis also emphasized the presence of organic matter, possibly including paraffin and calcium oxalates. FTIR analysis conducted after cleaning suggested a drastic reduction of calcium sulfate. Organic material was still present after cleaning and suggested the presence of paraffin; however, the treatment successfully reduced the presence of sulfates (Fig. 03).

Analytical studies such as colorimetry, FTIR, SEM-EDS, or gas chromatography–mass spectrometry could be performed to verify the results obtained in the cleaning tests. The interaction of an interlayer of calcium sulfate in some Spanish frescos needs to be investigated further to find ways of achieving more-effective results.

CONCLUSIONS

The problems that emerged during restoration, such as surfactant residues, high contact times in paintings with gypsum plaster inside, and the evaluation of the cleaning results, suggest directions for future research.

The two cases illustrate the need for more research into problems associated with aqueous cleaning systems containing surfactants. A majority of published research discusses fresco paintings that contain only lime. However, many Spanish frescos were executed using a technique that includes interlayers of calcium sulfate. This addition can affect the condition, cleaning methodology, and efficacy of treatment.

Other methodologies are believed to offer suitable properties for cleaning these particular frescoes. At this moment we are investigating the testing of emulsions without surfactants, rigid gels, and other products marketed as chemical gels. These materials have been applied to mock-ups and samples of other mural paintings to determine their efficacy for cleaning, whether they leave residual products on the surface, and, ultimately, their safety as materials for use in the treatment of artworks.

ACKNOWLEDGEMENTS

The authors express their gratitude to the Universitat Politècnica de València and the Valencian community for supporting this doctoral research project through their programs for the formation of predoctoral personal investigators. We also thank Josh Summer for advice with translation.

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Multi-method Analysis of the 18th-Century Portrait of Count Andras Hadik de Futak

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†Pokrajinski Zavod za Zaštitu Spomenika Kulture, Petrovaradin, Serbia

INTRODUCTION

When examining works of art, especially historical ones, as little damage as possible should be inflicted. At the same time, data must be gathered for future conservation and restoration work. Therefore, noninvasive techniques such as Fourier transform infrared spectroscopy (FTIR) and X-ray fluorescence spectroscopy (XRF) are an excellent choice for examinations of cultural heritage,1 in addition to noninvasive X-ray radiography (RTG). These analytical techniques are complementary. XRF identifies inorganic pigments and ground layers, while FTIR identifies organic pigments and binding media and can also give information about some inorganic compounds.2 Scanning electron microscopy–energy dispersive spectroscopy (SEM-EDS) and light microscopy can be used as invasive techniques to examine the morphology and composition of painted layers and to determine whether a painting has multiple layers.

This article reports on the examination of a portrait of Count Andras Hadik de Futak created by an anonymous author in 1764. This oil painting was

Fig. 01. Selected ZOIs on the portrait of Count Hadik: (a) ZOIs on the initially visible outer painting analyzed before cleaning; (b) ZOIs analyzed on the original (inner) painting, discovered after the cleaning procedures. Source: author’s photograph.
done on a linen canvas, and linseed oil was used as a binding medium. Count Hadik, a Hungarian nobleman of Slovak origins and a friend of Empress Maria Theresa, was a prominent figure in the Habsburg Empire, where he was a Hussar cavalry general and a field marshal during the Seven Years' War.³

The investigation of the painting was done in two stages—before and after the cleaning procedure. The primary aim was to determine the techniques used in the painting, information that can inform decisions about future conservation treatments and help determine the painting’s historical authenticity. During the cleaning work, another painting was discovered beneath the investigated one. This newly discovered painting was presumed to be the original portrait of Count Hadik.

METHODS & METHODOLOGY

To identify all the pigments present, 36 zones of interest (ZOI) on the portrait were selected for analysis before cleaning and 23 ZOIs were selected after cleaning (Fig. 01). Additionally, five samples were collected for stratigraphic analysis of painted and ground layers and were prepared for SEM-EDS and optical microscopy analysis with polarized light. The RTG imaging analysis was done prior to cleaning using a standard medical X-ray scanner for projectional radiography.

FTIR analysis was done with a portable Bruker ALPHA FTIR spectrometer equipped with a DRIFT contactless external reflection module. Spectra were obtained using a beam with 4 mm diameter (12.25 mm² sampling zones) within a wavenumber range of 4,000–400 cm⁻¹ at a resolution of 4 cm⁻¹ over 24 scans. The collected spectra were analyzed using Bruker OPUS software for data acquisition and evaluation and compared with the spectra from available databases.

The XRF analysis was done with a Bruker ARTAX 200 μXRF spectrometer equipped with an Rh X-ray source and integrated video camera. The experiments were performed in air with each zone of interest measured for 100 seconds using tube voltage of 25 kV and current of 1500 μA.

Cross-section samples were prepared by vacuum impregnation in an epoxy resin with the exposed surface ground and polished using Struers line for sample preparation. The polished samples were observed through a Zeiss Axioscope A.1 polarized light microscope with 60° polarization angle. Afterward, the same samples were prepared for SEM-EDS investigation by surface deposition of gold (deposition time: 180 seconds, current: 30 mA, distance from the gold source: 50 mm). The SEM-EDS investigation was done with a JEOL JSM 6460LV SEM and Oxford Instruments INCA X-sight LN2 EDS.

RESULTS & DISCUSSION

Vast differences were observed between the original (inner) painting and the later (outer) painting, including damaged areas—removed paint layer (pink colored areas) as seen in Figure 01, and missing parts of canvas (left eye, eyebrow, and cheek, right shoulder, and other areas), which can be seen on RTG scans in Figure 02.
<table>
<thead>
<tr>
<th>PIGMENTS</th>
<th>X-ray emission lines</th>
<th>IR absorption bands</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Outer painting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>White Pigments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead white</td>
<td>Pb: Lα1, Lα2, Lβ1, Lβ2</td>
<td>N/A</td>
</tr>
<tr>
<td>Zinc white</td>
<td>Zn: Kα1, Kα2, Kβ1, Kγ1</td>
<td>N/A</td>
</tr>
<tr>
<td>Chalk white</td>
<td>Ca: Kα1, Kα2, Kβ1</td>
<td>1750, 1450, 690 cm⁻¹</td>
</tr>
<tr>
<td>Titanium white</td>
<td>Ti: Kα1, Kα2, Kβ1</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Yellow, Ochre and Red Pigments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vermilion</td>
<td>Hg: Lα1, Lα2, Lβ1, Lβ2</td>
<td>N/A</td>
</tr>
<tr>
<td>Chrome yellow</td>
<td>Cr: Kα1, Kα2, Kβ1</td>
<td>N/A</td>
</tr>
<tr>
<td>Molybdenum yellow/orange</td>
<td>Mo: Kα1, Kα2, Kβ1</td>
<td>N/A</td>
</tr>
<tr>
<td>Burnt sienna</td>
<td>Fe: Kα1, Kα2, Kβ1, Mn: Kα1, Kα2, Kβ1</td>
<td>N/A</td>
</tr>
<tr>
<td>Iron oxide red</td>
<td>Fe: Kα1, Kα2, Kβ1</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Blue and Green Pigments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cobalt blue</td>
<td>Co: Kα1, Kα2, Kβ1</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Black Pigments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon black</td>
<td>C: Kα1</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Inner (original) painting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>White Pigments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead white</td>
<td>Pb: Lα1, Lα2, Lβ1, Lβ2</td>
<td>N/A</td>
</tr>
<tr>
<td>Chalk white</td>
<td>Ca: Kα1, Kα2, Kβ1</td>
<td>1750, 1450, 690 cm⁻¹</td>
</tr>
<tr>
<td><strong>Yellow, Ochre and Red Pigments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vermilion</td>
<td>Hg: Lα1, Lα2, Lβ1, Lβ2</td>
<td>N/A</td>
</tr>
<tr>
<td>Iron oxide red</td>
<td>Fe: Kα1, Kα2, Kβ1</td>
<td>N/A</td>
</tr>
<tr>
<td>Molybdenum yellow/orange</td>
<td>Mo: Kα1, Kα2, Kβ1</td>
<td>N/A</td>
</tr>
<tr>
<td>Iron based earth ochre</td>
<td>Fe: Kα1, Kα2, Kβ1</td>
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<tr>
<td>Burnt sienna</td>
<td>Fe: Kα1, Kα2, Kβ1, Mn: Kα1, Kα2, Kβ1</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Blue and Green Pigments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(none)</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Black Pigments</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**ORGANIC MATERIAL**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Outer painting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binding media</td>
<td>Animal glue</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Linseed oil</td>
<td>N/A</td>
</tr>
<tr>
<td>Coating</td>
<td>Shellac</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Inner (original) painting</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binding media</td>
<td>Animal glue</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Linseed oil</td>
<td>N/A</td>
</tr>
<tr>
<td>Coating</td>
<td>(none)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 01. Identified pigment palette
Inorganic Material—Pigments and Ground Layers

The identified CaCO$_3$ was a part of the imprimatura (ground layer), forming the chalk ground layer (calcite and animal glue). Red bole was also identified as the ground layer of the original painting.

As a result of the examination of 36 zones before cleaning (i.e., of the outer portrait), the following pigments were identified: lead, zinc, chalk, and titanium whites; chrome and molybdenum yellows; vermilion; burnt sienna; iron oxide red; cobalt blue; and carbon black. The results obtained during the examination of 23 zones after the cleaning procedures identified the narrower pigment palette of the original layer of the painting: lead and chalk whites, vermilion, iron oxide red, molybdenum yellow/orange, iron-based earth ochre, and burnt sienna. The absence of “modern” pigments such as zinc and titanium whites on the inner (original) painting was consistent with conservationists’ findings about the origin of the painting (18th century). The lack of definitive identification of blue and green pigments on the original painting was most likely caused by their earth (aluminosilicate) origin (e.g., green earth) (Table 01).

The analysis of the cross-section samples showed the multilayered nature of the painting and provided the main evidence for the existence of the original painting beneath the initially visible one. The combination of techniques (light microscopy and SEM-EDS) enabled the determination of the number of layers present, their thickness, and their elemental composition. Three to five layers (painted and imprimatura) were noted, with thicknesses varying from 27 to 170 µm. EDS analysis showed characteristic chemical elements for the types of layers identified: C, Al, Si, K, and Ca corresponded to the red bole/chalk ground layer; Hg and S corresponded to the vermilion pigment layer; Pb, C, and O corresponded to the lead white pigment layer, and so on.

Organic Material—Binding Media and Coating

The FTIR analysis of all ZOIs confirmed the presence of linseed oil, which was used as a medium for pigments on both the outer and the inner (original) painting. Figure 03 (a) shows a comparison of the FTIR spectra of the scanned point in ZOI 1 (blue graph) and linseed oil (red graph) on the outer painting, while Figure 3 (b) shows a comparison of the FTIR spectra of the scanned point in ZOI 21 (blue graph) and linseed oil (red graph) (Fig. 03).

The animal glue found on the painting was likely used as a binder in the imprimatura.

Shellac was identified using FTIR in all nondegraded areas of the outer painting, but it was not identified on the original painting. This was expected, as shellac, being the outermost layer (protective coating), was removed mechanically in the damaged areas of the painting and during the cleaning procedure.

CONCLUSION

The work presented in this article—completed by a multidisciplinary team of material scientists/technologists and painter-conservationists—suggests a successful path for resolving complex problems in the cultural heritage field. XRF and FTIR proved to be excellent complementary methods for analyzing a complex artwork matrix. Additional techniques such as RTG scanning, light microscopy, and SEM-EDS were used to determine the structure, damage, and composition of the painting. The identified material composition of the canvas, ground layers, painted layers (pigments), and binders proved crucial for defining a methodology for the technical protection of the whole painting structure.

ACKNOWLEDGMENTS

Financial support from the Serbian Ministry of Education, Science and Technological Development (Contract No. III45008) is gratefully acknowledged.
Curriculum Vitae

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Vladimir Petrović is a painting conservator at the Provincial Institute for Protection of Cultural Monuments, Petrovaradin.

BIBLIOGRAPHY


(Endnotes)


Synthesis and Analysis of Verdigris Pigments of the 19th and 20th Centuries Using Three Modern Techniques

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Rocco Mazzeo b

a Universidad Complutense Madrid, Spain
b Università di Bologna, Ravenna, Italy

INTRODUCTION

Verdigris is a copper acetate salt of historical importance as a pigment used on easel paintings, mainly in Europe from the 15th to 17th centuries. During that time, it was used as an ingredient in the production of green-bluish tones. Nowadays it is used as an intermediate in the manufacture of Paris green, as a textile dye, as a pigment for ceramics, and as a catalyst. The Margarita San Andrés research group has performed an exhaustive historical review of verdigris recipes and their corresponding analytical information. The review made apparent the importance of the establishment of identification patterns for each variation of verdigris that is known in order to avoid inaccuracies in the interpretation of novel or known verdigris pigments.

Fig. 01. Flow chart of the final synthesis process for the Brumlen (A), Schneider (B), and Bearn (C) patents.
One observation that can be drawn from this review is that recipes from before the 19th century are the most thoroughly studied, even though new processes were patented after the Industrial Revolution.2

This work thus had two targets. The first was to test the feasibility of the synthetic processes developed during the 19th and 20th centuries; in particular, a method patented by Ludwig Brumlen3 in 1857 titled “Improvement in processes for manufacturing verdigris”; one patented by Georg Schneider4 in 1911 called “Process of producing verdigris”; and a modern chemical process described by J. Gauld Bearn5 in The Chemistry of Paints, Pigments and Varnishes in 1923. The second aim was to characterize the morphology, crystallinity, and chemical composition of the products of these synthetic processes by different analytical techniques—optical microscopy, scanning electron microscopy (secondary electron) (SEM(SE)), attenuated total reflectance Fourier transform infrared spectroscopy (ATR-FTIR), X-ray diffractometry (XRD)—in order to contribute to the spectra database of verdigris.

Finally, a comparison of the craft recipes and the new industrial production pathways considers the yield of the reaction, the quality (resistance to aging) of the pigments obtained, as well as the duration of the production processes.

METHODS & METHODOLOGY

The methodology followed for the synthesis of each of the verdigris pigments was based on their corresponding patent, as well as processes from the book The Chemistry of Paints, Pigments and Varnishes. Because key information about the manufacturing process is not always included in the patent documents, several experiments were needed to determine the optimal values for the different variables of the process. The final processes developed for each document are described in Figure 01.

The three pigments obtained were analyzed by optical microscopy, SEM(SE), ATR-FTIR, and XRD.

RESULTS & DISCUSSION

Yield

Each crystallization process consisted of two or three successive filtrations to extract the crystals of verdigris before the solvent completely evaporated (to avoid the inclusion of undesired products). The yields of the reactions for the first crystallization were:

- Brumlen: 71.86%
- Schneider: 76.68%
- Bearn: 37.08%

After the second crystallization, the yield of the Bearn reaction increased.

The Brumlen and Schneider reactions gave a good yield, above 70%, at the first crystallization. The Schneider reaction produced bigger and purer crystals.

Macroscopic Evaluation, Stereoscopic and Optical Microscopy, and SEM(SE)

Descriptions of the macroscopic and microscopic observations are given in Table 01. See also the pictures in Figure 02.

Analysis of the data presented in Table 01 suggests that the size of the crystal was related to the color of the particle: the bigger the size of the crystal the darker and greener the color; conversely, the smaller the size, the bluer and lighter the color.

<table>
<thead>
<tr>
<th>Name</th>
<th>Macroscopic observations</th>
<th>Optical Microscopy</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brumlen</td>
<td>Crystalline powder with a light green – bluish color. It is possible to observe groups of particles that are easy to break.</td>
<td>Small crystals with light green – bluish color. All the crystals are stick together making piles.</td>
<td>Tiny particles agglomerated forming a bigger particle.</td>
</tr>
<tr>
<td>Schneider</td>
<td>Big crystals with smooth surface and dark matt green color.</td>
<td>Rhomb crystals with tiny crystals that make darker zones in the surface of the crystal.</td>
<td>Define rhomb crystals with cracked surface</td>
</tr>
</tbody>
</table>

Table 01. Macroscopic and microscopic description of the verdigris crystals obtained by the three different methods
Under polarized light the three synthesized verdigris had a moderate to high birefringence behavior, with second- to third-order colors strongly masked by the body color. Anomalous colors (blue-green) were always produced. Extinction was straight and complete.

The size of the crystals obtained from each reaction varied considerably. Further experiments are needed to determine whether this is related to the presence of CO₂.

The SEM(SE) images showed that the particles produced by the Brumlen and Bearn reactions were similar; that is, they were formed by the agglomeration of many tiny particles. The image of the Bearn reaction showed that this grain formation had the disadvantage of being easily contaminated, since crystals of the second product, Na₂SO₄, were encrusted in the particle. On the other hand, the Schneider image showed a homogenous surface with some flakes and a definite rhombic geometry.

**ATR-FTIR**

Figure 03 shows the FTIR spectra obtained for each verdigris. The three spectra have the same pattern: bands in the region from 3,455 to 3,260 cm⁻¹ that correspond to the tension vibrations of the hydrated water (vH₂O); two peaks in the region from 3,000 to 2,860 cm⁻¹ that are due to the tension vibration of the methyl group (vCH₃); acetate group bands (vCOO) that appear in the region from 1,590 to 1,415 cm⁻¹; and bands from 950 to 940 cm⁻¹ due to the C–C bond. These spectra confirm the presence of the acetate group in the structure as well as hydration.

Additionally, the spectra labeled *verdigris vap* correspond to the verdigris obtained by the old vinegar vapor technique. The four spectra have the same behavior, showing the same bands regardless of the synthesis reaction used.

**XRD**

The results from the XRD technique suggest that all three patents produced hoganite (JCPDS pattern: 00-027-0145), a mineral with the chemical formula Cu(CH₃COO)₂·H₂O with a monoclinic prismatic system. Comparison of the patterns obtained for the three compounds is shown in Figure 04.

Comparison with results previously obtained by the San Andrés research group showed that the XRD results also corresponded with the compound obtained by the old vinegar vapor technique.

**CONCLUSIONS**

The processes examined in this study are highly sensitive to the order of addition of the solutions: the acetate solution must be added to the copper solution due to the availability of the Cu(II) ions to form a coordination compound; otherwise an undesired product will be obtained. Higher temperatures improve the solubilization of the reactants, and mixing time is a key factor for the yield of the verdigris.
When compared to the old vinegar vapor technique, the three reactions had a significantly shorter duration. However, the Bearn and Brumlen reactions demanded special attention (affecting the synthesis time) during the crystallization process. Therefore, the Schneider reaction presents the best time and yield production.

With respect to crystal sizes, further studies are needed to analyze the hypothesis that CO₂ bubbles were working as nucleation centers.

The XRD technique confirmed that the three verdigris compounds obtained were the same as the one obtained by the old vinegar vapor technique.

The analyzed 19th- and 20th-century patents are verdigris synthetization techniques that produce the same compound as the ancient recipe but offer the advantages of being more time-efficient, having a much more controlled process, and allowing the reuse of subproducts.

Lastly, the increased yield and reduced time of these synthetic processes is a recommendation for their use in cultural heritage research projects.

ACKNOWLEDGMENTS

This research was supported by Geomateriales 2 (S2013/MIT-2914) CAM and Structural Funds (Fondos Estructurales (FSE y FEDER)), CONACYT (Ref. 333318), and a Università di Bologna Fondazione Flaminia Scholarship awarded to María Elena Cruz Nuñez for support of her internship at Universidad Complutense Madrid.

The authors are also grateful to X-Ray Diffraction Center of the UCM and to Ana Albar of the Laboratory of Materials of the IPCE.

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Ruth Chércoles has a bachelor’s and master’s degree in chemistry and a PhD in fine arts. She is a professor of applied chemistry in the Faculty of Fine Arts of Universidad Complutense Madrid. She is a member of the Research Group UCM-930420.

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Rocco Mazzeo is a full professor and director of the international master’s degree course (Laurea Magistrale) for the SCORE program at the Università di Bologna. He is also head of the Microchemistry and Microscopy Art Diagnostic Laboratory at the Università di Bologna.
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(Endnotes)


4 Schneider, G. “Process of producing verdigris; and a modern chemical process.” Patent n. 440,991, USA, 1911.

Earth and Ochre Pigments: Different Compositions, Different Colors

INTRODUCTION

The colorimetric properties of pigments are related to their chemical composition and physical properties such as morphology, particle size, and refractive index. Natural earth and ochre pigments are categorized under a general terminology that includes a wide range of compositions and colors. They are widespread in nature and include yellow, red, and brown colors that have been used from the Paleolithic to the postmodern era. Evidence of their early use in art is extensive, and many classical and medieval authors describe them.1

Natural earth and ochre pigments contain both oxides and oxide-hydroxides of iron along with various aluminosilicates. In addition, fillers such as calcite and gypsum can be added by suppliers. The nature and percentage of these components can vary, and those variations can affect color, as can the binder used to apply the pigment.

In this article, several commercial pigments corresponding to the natural earth and ochre group of pigments were analyzed, and the relationship between their composition and color was established, taking into consideration morphological properties and particle size. These same pigments were also agglutinated with various binders—commonly used in traditional pictorial techniques—to prepare pictorial layers and carry out colorimetrical measurements.

METHODS & METHODOLOGY

The materials studied are used as artistic pigments and are manufactured by Agroquímica del Vellés.

The pigments selected were red ochre (OR), yellow ochre (OCA), natural sienna (SN), burnt sienna (ST), natural umber (UN), and burnt umber (UT). Each pigment was analyzed using a variety of techniques.

Composition and morphological properties, both size and shape of the particles, was studied with a JEOL JSM 6400 scanning electron microscope (SEM(SE)-EDS) with 20 kV accelerating voltage, incorporating a LINK eXL energy dispersion spectrometer with resolution of 138 eV–5.39 keV.

In addition, attenuated total reflectance–Fourier transform infrared spectroscopy (ATR-FTIR) analyses were carried out to study the infrared spectrum of absorption of each pigment. Spectra were obtained with a Thermo Nicolet spectrometer (model 380) with DTGS detector (4,000–400 cm⁻¹), using 64 scans and a nominal resolution of 4 cm⁻¹.

Molecular structures were studied by X-ray diffraction (XRD) using a Philips X'PERT diffractometer, voltage 45 kV and intensity 40 mA.

The colorimetrical measurements were achieved with a spectrophotometer Konica Minolta CM 2600d, measurement spot: 3 mm, SCE mode, CIELab space, range 400 nm to 700 nm, step size of 10 nm, light source D65, standard observer 10°. These measurements were taken of powder pigments and their corresponding pictorial layers.

The pictorial layers were prepared by mixing each pigment with three different binders: linseed oil, gum arabic, and rabbit skin glue. The purpose of
studying the pigment/binder relationship was to obtain homogenous pictorial layers on a white support previously prepared in the laboratory. All the pictorial layers were applied with a cylindrical hand applicator setting a thickness of 120 µm. Colorimetric measurements were taken after 15 days.

Pigments were also agglutinated with lime plaster. In this case, all were prepared by mixing 0.1 g of pigment with 16 g of lime plaster that had previously been prepared by mixing slaked lime and marble dust (1:4 ratio). The colored lime plaster was applied on limestone. Measurements were taken after seven days.

RESULTS & DISCUSSION

All pigments were analyzed to establish their composition. Table 01 summarizes the results obtained by SEM-EDS, XRD, and ATR-FTIR. A semiquantitative analysis was carried out by SEM-EDS, in which the composition was expressed in oxides. Some components of earth pigments, such as clays, were not detected by XRD due

<table>
<thead>
<tr>
<th>Pigment</th>
<th>MEB-EDS (% in weight)</th>
<th>XRD [JCPDS patterns]</th>
<th>ATR- FTIR (band wavenumbers cm⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Ochre (OR)</td>
<td>Fe₂O₃: 97; SiO₂: 3</td>
<td>Fe₂O₃ [Burnt ochre: 00-033-0664]</td>
<td>Fe₂O₃: 524, 449</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SiO₂: 1093</td>
</tr>
<tr>
<td>Yellow Ochre (OCA)</td>
<td>Fe₂O₃: 73; SiO₂: 11; Al₂O₃: 8; CaO: 2; K₂O: 1; MgO: 2; SO₃: 0.7</td>
<td>FeO(OH) [Goethite: 00-029-0713]; Fe₂O₃ [Iron(III) oxide] 01-085-0599</td>
<td>Fe₂O₃: 522, 447</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FeO(OH): 3105, 1790, 1661</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SiO₂: 1093; 97, 794, 667</td>
</tr>
<tr>
<td>Natural Sienna (SN)</td>
<td>Fe₂O₃: 53; SiO₂: 17; Al₂O₃: 11; CaO: 15; K₂O: 1.7; MgO: 2.5; SO₃: 0.7</td>
<td>CaCO₃ [Calcite: 01-083-1762]; FeO(OH) [Goethite: 00-081-0463]; CaAl₂Si₂O₈·4H₂O [Gismondine: 00-020-0452]</td>
<td>CaCO₃: 1417, 871, 712</td>
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<tr>
<td></td>
<td></td>
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<td>FeO(OH): 3121, 1796, 906, 797</td>
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<td></td>
<td>Aluminium silicate: 3627</td>
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<td></td>
<td></td>
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<td>1005, 669, 525, 461</td>
</tr>
<tr>
<td>Burnt Sienna (ST)</td>
<td>Fe₂O₃: 36; SiO₂: 3; Al₂O₃: 1; CaO: 60</td>
<td>CaCO₃ [Calcite: 01-083-1762]; Fe₂O₃ [Iron(III) oxide-α: 01-089-0596]; FeO(OH) [Goethite: 00-029-0713]</td>
<td>CaCO₃: 1795, 1393, 870, 712</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fe₂O₃: 531, 452</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SiO₂: 1063</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FeO(OH): 914, 800</td>
</tr>
<tr>
<td>Natural Umber (UN)</td>
<td>Fe₂O₃: 46; SiO₂: 7; Al₂O₃: 5.5; CaO: 40; K₂O: 0.6</td>
<td>CaCO₃ [Calcite: 01-086-2334]; FeO(OH) [Goethite: 00-029-0713]; SiO₂ [Silicon oxide-α: 01-078-1252]</td>
<td>CaCO₃: 1795, 1395, 871, 712</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SiO₂: 1029</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fe(OH): 908, 797</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hydroxy aluminosilicate: 3640</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3626, 3617, 3119, 669, 526</td>
</tr>
<tr>
<td>Burnt Umber (UT)</td>
<td>Fe₂O₃: 58; SiO₂: 9; Al₂O₃: 6; CaO: 27; K₂O: 1.3</td>
<td>CaCO₃ [Calcite: 01-081-2027]; Fe₂O₃ [Iron(III) oxide-α: 01-089-0598]; SiO₂ [Silicon oxide: 01-089-1961]; (Fe₂O₃·Al₂O₃)·(Al₂O₃·Fe₂O₃)·4 [Iron dialuminium oxide: 01-089-1681]</td>
<td>CaCO₃: 1796, 1392, 870, 712</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SiO₂: 1026</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Fe₂O₃: 526, 444</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hydrated aluminium silicate: 3120, 912, 801</td>
</tr>
</tbody>
</table>

Table 01. Pigment analysis (MEB-EDS, XRD, ATR-FTIR)
to low crystallinity or concentration. In these cases, their presence was determined from the FTIR-ATR spectrum.

Table 02 shows the basic properties of the pigments: color, particle shape, and particle size. According to Feller and Bayard, the pigments showed a fine (1.0–0.3 µm) or very fine (< 0.3 µm) particle size, excepting the natural umber (UN), whose particles had a medium size (3–13 µm).

Red ochre pigment (OR) was homogenous in composition, morphology, and particle size. A pure iron (III) oxide, its particles are rounded. These results suggest that it was a red ocher of synthetic origin.

The remaining pigments were heterogeneous. They were composed of iron (III) oxide or iron (III) (oxide hydroxide), along with such components as calcite, quartz, and aluminosilicates. Their morphology was also diverse. They were composed of a mixture of equant rounded, prismatic, and tabular particles as well as granular and laminar aggregates.

Analysis of the natural and burnt umber pigments did not identify the presence of manganese dioxide. According to the literature, however, this oxide is characteristic of such pigments.

Figures 01, 02, and 03 show the colorimetical properties of the powder pigments, as well as the pictorial layers prepared with the binders. Values obtained from colorimetric measurements were plotted in the CIELab diagram and the reflectance spectra. All were within the red-yellow area but presented significant differences in lightness (L*), chroma (C*), and hue angle (h'). These variations were determined by the composition of the pigments and the nature of the medium used to bind them. (A value of h' = 90° defines a yellow hue, and h' = 0° a red hue.)

The obtained results suggest that the powder pigment color was related to the iron content and how this element was found. If it was iron (III) oxide

<table>
<thead>
<tr>
<th>Pigment</th>
<th>Color (L,a,b)</th>
<th>Particle shape</th>
<th>Particle size* (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Ochre (OR)</td>
<td>L*: 35.05±0.33; a*: 30.89±0.05; b*: 28.35±0.22; C*: 41.93±0.18; h': 42.55±0.19</td>
<td>Anhedral and equant rounded particles; granular aggregates</td>
<td>0.13 (very fine)</td>
</tr>
<tr>
<td>Yellow Ochre (OCA)</td>
<td>L*: 60.42±0.07; a*: 14.04±0.04; b*: 52.46±0.11; C*: 54.31±0.11; h': 75.02±0.03</td>
<td>Equant rounded and tabular particles; tabular and granular aggregates</td>
<td>0.20 (very fine)</td>
</tr>
<tr>
<td>Natural Sienna (SN)</td>
<td>L*: 53.87±0.14; a*: 14.75±0.18; b*: 37.83±0.46; C*: 40.61±0.49; h': 68.70±0.03</td>
<td>Platy, prismatic and rounded particles; aggregates</td>
<td>0.31 (very fine)</td>
</tr>
<tr>
<td>Burnt Sienna (ST)</td>
<td>L*: 40.64±0.25; a*: 21.26±0.12; b*: 21.62±0.28; C*: 30.33±0.28; h': 45.49±0.23</td>
<td>Platy, acicular and prismatic irregular particles; aggregates</td>
<td>0.16 (very fine)</td>
</tr>
<tr>
<td>Natural Umber (UN)</td>
<td>L*: 45.36±0.13; a*: 2.11±0.07; b*: 24.09±0.26; C*: 24.19±0.27; h': 85.00±0.12</td>
<td>Equant rounded and prismatic particles; tabular aggregates</td>
<td>0.11 (very fine); 1.60 (medium)</td>
</tr>
<tr>
<td>Burnt Umber (UT)</td>
<td>L*: 31.15±0.37; a*: 6.42±0.10; b*: 14.37±0.35; C*: 15.74±0.36; h': 65.93±0.21</td>
<td>Equant rounded, platy and prismatic particles; tabular aggregates</td>
<td>0.55 Fine</td>
</tr>
</tbody>
</table>

*Classification according to Feller and Bayard (1986)
hue, it was reddish, and if it was iron (III) oxide hydroxide, it was yellowish. Other minerals present had a clear influence on chromatic attributes. For example, calcite promoted a decrease of chroma. As expected, natural sienna and natural umber pigments had a brown color that was darker in the burnt variety. The particle size of the iron oxides also influenced their color. For iron (III) oxide (hematite), particles of 0.1–0.2 µm appeared bright red. For goethite, particles in the 1 µm size range were yellow. Our results matched these data.

In general, the pigments studied showed a small particle size and contained equant rounded particles, characteristics that improved their hiding power.

Among the agglutinated pigments, the colorimetric measurements displayed in CIELab diagrams and reflectance curves showed the clear influence of the type of binder. Organic binders caused a decrease of lightness ($L^*$) that was more evident in pictorial layers obtained with linseed oil. However, lime plaster (inorganic binder) caused a significant increase of this chromatic attribute.

On the other hand, the hue angle ($h_{ab}$) is lower in the case of the bounded pigments in comparison to the powder pigments. Painting layers were therefore more reddish. An exception was the behavior of natural umber, where noticeable changes were minimal.

When the binder was aqueous (gum arabic and rabbit skin glue), chroma ($C^*_{ab}$) suffered a significant decrease in all the pigments studied. However, when the binder was linseed oil, this property did not change in some pigments (red ochre, yellow ochre, and natural and burnt sienna) but was significantly reduced in others.

**CONCLUSIONS**

The studied pigments had a complex composition that was determined using a variety of analytical techniques. The complementary use of these techniques allowed many relevant pigment components to be identified.

Earth and ochre pigments were heterogeneous in composition. They were composed of iron (III) oxide or iron (III) oxide hydroxide, as well as components such as calcite, quartz, and aluminosilicates.
The shape of pigment particles was also heterogeneous. Granular, prismatic, and tabular particles were detected, although laminar aggregates were also frequent. All the pigments studied showed a fine or very fine particle size, except natural umber, whose particles were of medium size.

Colorimetric properties of studied pigments were related to their composition; that is, to iron content (iron (III) oxide or iron (III) oxide hydroxide), aluminosilicates, calcite, and so on. Particle size also had an influence.

In every case, the colorimetric characteristics of the pigments (lightness, chroma, and hue angle) were modified when the pigments were bound. In general, these changes affected these three colorimetric characteristics. However, the appearance and intensity of these changes depended on the nature of both the binder and the pigment.

ACKNOWLEDGMENTS

This research was supported by Geomateriales 2 (S2013/MIT–2914) CAM and Fondos Estructurales (FSE y FEDER) and by a Collaboration Grant (2015–2016) awarded to Águeda Sáenz Martínez by MINECO (Spain). Thanks to the X-Ray Diffraction Center and the Microscopy Electronic Center of Universidad Complutense Madrid for providing analytical services. Thanks also to Fátima Marcos Fernández for her help.

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BIBLIOGRAPHY


(Endnotes)


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Characterization and Study of Light Stability of Contemporary Encaustic Paint Brands

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b Instituto de Restauración del Patrimonio, Valencia, Spain

INTRODUCTION

The composition of ancient encaustic paint has been a constant source of controversy. The term encaustic comes from the Greek words enkaio and kaustikos, meaning “to burn with fire,” referring to the process of fusing the paint. Encaustic was described by Roman writers such as Pliny the Elder1 (24–79 CE) and Vitruvius2 (ca. 80 BCE–15 CE) as a wax-based paint composed of raw beeswax and pigment, which was kept molten with heat in order to be applied. In addition, other wax-based techniques were described, such as the so called Punic wax, a cold encaustic based on an emulsion of beeswax treated with an alkali, which could be used alone or mixed with other binding media.

The restoration of encaustic paintings is a field little studied. Restorers specialized in this type of material have undertaken studies on specific artworks and their alterations, such as the Fayum mummy portraits or Roman wall paintings.3 Over the last few decades, researchers have attempted to chemically characterize these artworks, trying to unravel the mysteries surrounding encaustic technique and its definition.4

Fig. 01. FTIR spectra of R&F encaustic medium, sample before and after UV aging.
However, contemporary art entails other peculiarities. Artists use techniques that lie far from the old recipes for encaustic paint, opting instead for commercial products that are easier to acquire and simpler to use. Nevertheless, these paint brands, advertised as “traditional encaustic paint,” do not provide objective data about their products’ chemical composition, durability, or stability over time.

The present study concerns the results of the characterization of two encaustic paint brands by Fourier transform infrared spectroscopy (FTIR) and gas chromatography–mass spectrometry (GC-MS) and an evaluation by colorimetry and optical microscopy of changes resulting from exposure to ultraviolet (UV) light. The goal was to compare the chemical composition of the two products and their deterioration under extreme light conditions as prelude to a study of contemporary encaustic painting conservation.

METHODS & METHODOLOGY

Two of the most popular commercially available encaustic paint brands, R&F and Cuni, were selected for the study. These two paint brands were chosen to facilitate comparison with traditional application techniques. One is a water solvent cold encaustic (Cuni), and the other is an encaustic that requires the application of heat (R&F).

FTIR

The infrared spectra in the attenuated total reflectance (ATR) mode of the samples were obtained using a Vertex 70 FTIR spectrometer with a fast recovery deuterated triglycerine sulfate temperature-stabilized coated detector and an MKII Golden Gate ATR accessory. A total of 32 scans were collected at a resolution of 4 cm, and the spectra were processed using the OPUS/IR software.

GC-MS

An HP-5973 Network (Hewlett-Packard, USA) mass spectrometer coupled to an HP-6896N gas chromatograph (Agilent Instruments, USA) was used to identify the organic materials present in the samples. Agilent Chemstation software (MSD) G1701CA was used for the integration of peaks and for the mass spectra evaluation. GC separation was achieved in a chemically bonded fused-silica capillary column HP-5-MS (Agilent Instruments, USA) (stationary phase 5% phenyle 95% methylpolysiloxane, 30 m x 0.25 mm x 250 mm nominal).

Colorimetry

The color measurements were taken using a spectrophotometer Minolta CM-2600d, with conditions of CIE standard illuminant type D65 (daylight color temperature of 6,500°K and observer pattern of 10°), using an area measuring 8 mm in diameter (M) and 100% UV.

Optical Microscopy

A stereoscopic light microscope, Leica MZ AP0 (X8-X80), and a bilateral fiber-optic light microscope, Leica DFC 420 (Leica Microsystems, Germany), were used for selecting the samples to be analyzed.

Accelerated Aging Chamber by Exposure to UV Radiation

The samples were exposed to UV radiation for 100 hours in an accelerated aging chamber Q-Panel Series, Model QUV/Basic, with manufacturer Q-LAB lamps equipped with UVA-340 (0.68 W/m2).

RESULTS & DISCUSSION

FTIR and GCMS Characterization

After characterization by FTIR, the intensity of the absorption band in R&F encaustic was observed at ≈1,710 cm⁻¹, indicating that the stretching vibration of carbonyl groups of free fatty acids had increased and that the exposure to UV radiation favored the hydrolysis of glycerides present in the wax (Fig. 01). In the Cuni encaustic, in turn, the increase was observed in the intensity of the absorption bands at 1,641 and 1,578 cm⁻¹, associated with the formation of metal soaps and oxalates respectively.
After UV aging, a greater variation of the values $a^*$, $b^*$, and $L^*$ were observed in the samples of R&F encaustic than in the samples of Cuní. Titanium white pigment showed greater $\Delta E^*$ variation (over 3 CIELAB units) in both brands. In turn, the black pigment of both brands suffered the least color variation because of aging (Table 01).

### Optical Microscopy

Optical microscopy revealed a remarkable color change in the samples of the R&F encaustic. The attraction of dust by the surface was common to both types of encaustic, especially with black and white pigments. The phenomenon of blistering also occurred in both types of encaustic, although morphologies differed, having a rounded appearance on the Cuní brand and an amorphous appearance on the R&F. Significant dispersion between pigment and binder was observed in the samples of the R&F brand (Fig. 02).

### CONCLUSIONS

Analysis of the two paint brands confirmed that their chemical composition makes them significantly different. The first encaustic type (R&F) corresponds to what we might call “traditional academic encaustic paint”; that is, a combination of beeswax, dammar resin, and pigment. The second encaustic type (Cuní), defined as a “water-soluble encaustic” because of the presence of soaps, has great similarities to the ancient recipe of Punic wax mentioned by Pliny and Vitruvius.

Evaluation of the results revealed that one paint brand (R&F) was more sensitive to aging than the other (Cuní). This is probably due to the presence of dammar resin, which tends to yellow and harden over time.

All formulas of encaustic paint used over the centuries have a common compound: beeswax. However, this research indicates that present-day manufacturers of encaustic paint use different formulas, which suggests that their paints’ rates of deterioration over time will also differ.

### Acknowledgements

Financial support is gratefully acknowledged from Spanish “I+D+I MINECO” projects CTQ2011-28079-C03-01 and CTQ2014-53736-C3-1-P, supported by ERDEF funds.
The authors thank the Microscopy Service of the Universidad Politécnica de Valencia for providing their facilities to conduct tests. I (Ana María Bernabé García) am grateful to the Kunstkonserveringen team (Aarhus, Denmark) for sharing with me their wisdom about encaustic paintings during my internship in 2014. I am also grateful to Agneta Freccero (Istituto Svedese di Roma) for facilitating the acquisition of some of her publications, which have been a great help.

**CURRICULUM VITAE**

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Laura Osete Cortina holds a DPhil in chemistry. She is a technician in charge of the laboratory of analysis of artworks of the Instituto de Restauración del Patrimonio, Universitat Politècnica de València.

**BIBLIOGRAPHY**


(Endnotes)

INTRODUCTION

The “Textile Industrial Revolution” ushered in changes in dress and the consumption of fashion. To meet the public’s demand for new products and trends, the clothing industry required faster textile processing and an increase in raw materials at lower cost. These requirements led the chemical textile industry to experiment with alternatives to natural fibers, leading to the invention of new materials with trade names such as Tergal®, rayon, Meraklon®, and Lycra®.

The arrival of synthetic fibers caused a revolution in the fashion world, giving more consumers access to clothes that were once affordable only for the privileged classes. In addition, synthetic fibers became part of the creative process of many designers, who experimented and created new trends with these new materials.¹

Costumes and textiles first entered museums as objects of consumption with ethnographic, historical, or documentary value. Not until the end of 20th century did fashion begin to acquire aesthetic value, achieving the status of “masterpiece” (Fig. 01). Nowadays, some designers create entire collections to be exhibited in galleries and museums instead of on the runway. In this sense, fashion arrived at museums, regardless of materials, dating, or any other type of information commonly associated with museum objects. For example, in Spain some contemporary designers donate a costume from every collection to the Museo del Traje (Costume Museum) in order to increase its modern collection.²

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When museums catalog such acquisitions, the nature of the synthetic fibers is not usually specified. Fibers of natural origin are easily distinguished with an optical microscope, which allows the study of morphology. However, morphological study is not enough in the case of synthetic fibers.

During the first half of the 20th century, a specific extruder nozzle was used for each type of fiber, resulting in a specific cross-section. Cross-sectional shape is thus useful to identify some fibers, but unfortunately this characteristic is not a special feature of every type of fiber.

Synthetic and semisynthetic fibers are polymers with specific chemical characteristics. Different techniques of analysis are therefore required to identify their chemical composition. This information is essential for the complete documentation of garments in a museum collection. Fiber composition can help to date pieces and can even reveal previous restorations. In addition, this information is necessary to implement an appropriate preservation plan and, when necessary, direct conservation treatments based on the chemical composition of the fiber.

MATERIALS & METHODOLOGY

The aim of this project was to develop a methodology for determining the chemical composition of synthetic and semisynthetic fibers frequently used in the textile industry and in fashion design. The analytical techniques used were Fourier transform infrared spectroscopy with attenuated total reflectance (ATR-FTIR) and pyrolysis-gas chromatography/mass spectrometry (Py-GC/MS).

The ATR-FTIR technique is suitable for identifying synthetic polymers. By measuring the radiant energy associated with the vibrations of molecular bonds caused by infrared (IR) radiation and then studying the absorption bands on the resulting spectrum, researchers can identify a material’s chemical composition.

FTIR spectra were obtained with a Thermo Nicolet spectrometer (model 380) with DTGS detector (4,000–400 cm⁻¹), using 64 scans and a nominal resolution of 4 cm⁻¹. The spectrometer was equipped with an ATR diamond crystal accessory.

The Py-GC/MS technique has been successfully used in the conservation field to identify a wide range of synthetic polymers. This technique can provide additional information about the chemical composition of polymeric matrices and can identify minority components such as plasticizers.

The Py-GC/MS analyses were carried out with an integrated system comprising a Pyroprobe CDS 520 pyrolyzer, an Agilent 7890A gas chromatograph equipped with an HP-5MS 5% phenyl methyl siloxane capillary column (30m x 250 μm x 0.25 μm), and an Agilent 5975C mass spectrometer (MS) with a quadrupole mass analyzer. The pyrolyzer transfer line was set at 290°C and the injector at 280°C. The GC/
MS experiments were carried out by split injection and detected in the range m/z (29 to 550).

This paper presents results corresponding to two fabrics and three threads. According to the information provided by the suppliers, the fabrics were made of polypropylene and rayon, and the threads were polyester, nylon, and acrylic. The synthetic fibers exist under various trademarks; for example, polyacrylic fibres (Orlon®, Acrylan®, Crilenka®, Creslan®, Dolan®, Zefran®, and Crylon®); polyester (Tergal®, Terylene®, Terlenka®, Trevira®, Dralon®, and Terital®); polyamide (Perlon® and Enkalon®); and so on.

Images obtained via a stereoscopic light microscope (Table 01) show that the fabric made of rayon had a plain weave structure and that the polypropylene was a nonwoven fabric. We were unable to determine whether the latter had two sides or just one.

RESULTS & DISCUSSION

Results of the research are summarized in Table 02.

ATR-FTIR of the rayon fabric showed that it is a cellulosic semisynthetic fiber: cellulose acetate. Composition was confirmed by Py-GC/MS, the peak corresponding to acetic acid formed by the fragmentation of cellulose acetate.

The term rayon is sometimes associated with regenerated cellulose, but in this case the results confirmed that the fabric composition was cellulose acetate.

The ATR-FTIR bands for the polypropylene sample confirmed the fibers corresponded to this polyolefin. In the Py-GC/MS analysis, a peak linked to 1-propene was observed. This monomer is commonly used in the manufacture of polypropylene.

Analysis confirmed that composition was the same on both sides of the polypropylene fabric (Fig. 02).

The ATR-FTIR spectrum for the nylon threads revealed bands assigned to polyamide. The Py-GC/MS analysis complemented this result and indicated the type of polyamide: ε-caprolactam, a monomer used to produce nylon 6 (Fig. 03).

In the case of the polyester, the bands in the FTIR-ATR spectrum coincided with the aromatic ring, allowing us to conclude that it is a poly(ethylene terephthalate) (PET). The Py-GC/MS analysis identified fragments associated with PET.

The ATR-FTIR spectrum of the polyacrylic thread showed a defined band of C≡N group, assigned to acrylonitrile, the monomer used to produce polyacrylic fibers. Bands from a carbonyl group [C=O] and the functional group ester [C-C (O)-O] and [-O-C-] were also observed, showing that the polyacrylic fiber studied is a copolymer of an acrylonitrile and an acrylate. However, the Py-GC/MS analysis for polyacrylic thread failed to detect fragments associated with this copolymer.

![Fig. 02. ATR-FTIR spectra of both sides of polypropylene fabric. Image by LabMat®.](image-url)
<table>
<thead>
<tr>
<th>FIBRE</th>
<th>ATR-FTIR absorption bands (cm⁻¹)</th>
<th>PyCG/MS</th>
<th>IDENTIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial name</td>
<td>ATR-FTIR</td>
<td>m/z</td>
<td>Compound</td>
</tr>
<tr>
<td>Polyester (Thread)</td>
<td>-CH₂: 2962 and 2917 C=O (ester): 1708 [C-C(O)-O] (ester): 1256 [-O-C-] (ester): 1174 and 1092 Aromatic ring: C-H aromatic ring: 1016, 970, 871 and 720</td>
<td>32, 40, 44 29, 44</td>
<td>Acetaldehyde Dimethyl ether</td>
</tr>
<tr>
<td>Poly (propylene) (Fabric)</td>
<td>CH₃: 2949 and 2867 CH₂: 2915 and 2836 C-H (-CH₂-): 1455 and 1358 C-H (-CH₃-): 1375 -CH₂: 1166 and 972 -CH₃: 997, 898 and 840</td>
<td>41 29, 43, 57 29, 41, 56, 69, 84 29, 43, 55, 70, 83, 126</td>
<td>1-propene Pentane 2. methyl 1pentene 2.4-dimethyl heptene</td>
</tr>
<tr>
<td>Nylon (Thread)</td>
<td>-NH: 3295 cm⁻¹ Amide II overtones: 3067 CH₂: 2931 and 2860 Amide I: [C=O]: 1630 Amide II and Amide III (-NH and C-N): 1541 and 1262 C-H: 1460, 1415 and 1374 Amide IV [C(O)-N-H]: 681</td>
<td>30, 42, 55, 85, 113</td>
<td>ε-caprolactam</td>
</tr>
<tr>
<td>Polyacrylic (Thread)</td>
<td>-CH₂: 2919 and 2850 C-H: 1452 and 1367 Acrylonitrile: C N: 2241 Acrylates: C=O: 1735 [C-C(O)-O]: 1231 [-O-C-]: 1069</td>
<td>No results</td>
<td>No results</td>
</tr>
</tbody>
</table>

Table 02. FTIR-ATR absorption bands and m/z characteristic of Py-CG/MS present in the analyzed materials; materials identified
CONCLUSIONS

ATR-FTIR is a useful technique for analyzing fibers, threads, and fabrics that are part of cultural heritage. The main advantages of this method are that the samples do not need to be prepared and results are obtained simply by pressing the fiber or thread against the ATR diamond crystal.

The ATR-FTIR and Py-GC/MS techniques are complementary. In some cases, Py-GC/MS can provide the exact composition of a polymer, such as identifying ε-caprolactam, the monomer used in the production of nylon 6.

To differentiate among various trademarked synthetic fibers, conservators should perform analyses that will determine the fiber’s specific chemical composition.

ACKNOWLEDGMENTS

This research was supported by research project HAR2015-68680-P.

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BIBLIOGRAPHY


(Endnotes)

Artificial Patinas in Contemporary Weathering Steel Sculpture

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INTRODUCTION

Weathering steels were developed at the beginning of the twentieth century and first commercialized in 1933 under the name Cor-Ten (short for corrosion-tensile). They have a carbon content of less than 0.2%, and contain Cu, Cr, Ni, P, Si, and Mn as alloying elements in concentrations of 3–5%. Weathering steels were designed for structural purposes and have been used in civil engineering projects such as bridges, roads, high-voltage towers, facades, and roofs.

Under certain conditions, the surface corrodes, creating a natural patina that provides some protection against atmospheric corrosion. In addition to the protective properties of the patina, its various colors convey aesthetic properties to weathering steels. This led to weathering steels being used not only as a structural material but in works of art, mainly sculptures. Since the appearance of steel in sculpture in the mid-1960s, it has become one of the most commonly used metals.

The protective patina appears after wet and dry cycles, but achieving the rich color takes time. Some sculptors thus accelerate the patination process of the surface. This acceleration is artificial and does not correspond to the way the material was designed, so it might affect the protective capacity of the patina, thus compromising the long-term conservation of the artwork.

Many studies have been carried out on the long-term corrosion of weathering steels under different atmospheres and conditions, but all refer to the natural formation of the patina. No studies deal with the process of artificially
accelerating the creation of patinas and the impact of artificial patination on the conservation of the works of art, so a research project has been started by the authors to study these questions. Preliminary results published by the authors showed that artificial treatments do have an impact on the initial corrosion behavior of patinas, so deeper study of this topic is required. The main objective of this project was to analyze and evaluate the short- and long-term corrosion behavior of representative artificial patinas on weathering steels used by contemporary sculptors. The present communication reports on results from the first stage of this project: identifying and completing an initial characterization of the patination methods used in contemporary sculpture.

METHODS & METHODOLOGY

We interviewed 17 Spanish sculptors, blacksmiths, and foundry workers. We asked them about the methods and techniques they use to accelerate the patination process of weathering steels, problems they had encountered when working with this material, and their personal impressions.

The data obtained will be used to design an experimental setup to reproduce in a laboratory setting the conditions created by artists and blacksmiths. Artificially patinated weathering steel coupons will be exposed to an urban atmosphere, and the composition, structure, and protective properties of the patinas will be monitored. Laboratory results will be compared with in situ measurements on actual weathering steel sculptures.

A preliminary test involved two patinas produced using HCl at 10% and H2O2 at 30%. Solutions were brushed on the surface, and the surface was sprayed with distilled water twice a day for five days. Initial characterization was carried out by scanning electron microscopy (SEM), optical microscopy, and electrochemical impedance spectroscopy (EIS, 100 kHz–10 mHz frequency swept, 10 mV RMS amplitude, and 10 points/decade), using a G-PE cell specifically developed for measurements on metallic cultural heritage.

RESULTS & DISCUSSION

Working directly with sculptors and blacksmiths proved to be not only interesting but necessary. The procedures for artificial patination of weathering steels are not documented in technical or scientific literature. Furthermore, gathering information directly from artists ensures the representativeness of the patination methods selected for the research project. Sculptors have investigated and tested methods to achieve different colors and textures. As a consequence of their investigation and experience, each of the interviewed sculptors had developed his or her own method based on the aesthetic results he or she wanted to obtain.

The compounds in use were typically nitrates, chlorides, sulfates, and hydroxides, anions that are aggressive to weathering steel. The sculptors prepared the concentration of their solutions by intuition, but all consulted sources agreed with the following concentrations in water solutions:

- FeCl3·6H2O (15–40%);
- Fe(NO3)3 (40–60%);
- H2O2 applied directly as a commercial product (30%);

![Fig. 02. (a) Optical microscope image of HCl artificial patina; (b) Optical microscope image of H2O2 artificial patina.](image-url)
H2SO4 (10–20%);
• HCl diluted at 10% from the commercial product (37%);
• HNO3 (We could not find an exact solution used, but, considering the strong acid solutions, it is probably used at about 10%).

After the application of the solutions, the surface of the weathering steel was washed several times or left outdoors if the weather was rainy.

SEM cross-sections of patinas produced using HCl at 10% and H2O2 at 30% (Fig. 01) showed that the thickness of the patina was bigger for the HCl method than for the H2O2. This difference was probably due to the aggressive action of the HCl. Macrophotographs (Fig. 02) show the different colors and textures that the two conditions created. The HCl patina was brownish, while the H2O2 patina was yellowish. This result confirmed the information provided by some of the sculptors.

Based on the results of the interviews and the preliminary tests, six conditions were selected for preparation and full characterization of artificial patinas (Table 01).

The artists permitted measurements to be taken of several real objects they had produced using their own patination methods. Figure 03 shows EIS results for an 11-year-old artificial patina prepared by Carlos Albert with an HNO3 solution, compared with a natural five-year-old patina. The shapes of the spectra are similar (two depressed capacitive loops, one associated with the patina layer and the other with the faradaic process, followed by a diffusion tail at low frequencies), indicating that the processes taking place are similar. However, the natural patina has a higher total impedance; that is, it is more protective, even when compared with an older artificial patina.

CONCLUSIONS

Most artists use artificial patination methods when sculpting with weathering steel. These consist in the application of salt or acid aqueous solutions followed by wetting and drying cycles. Preliminary results confirm that the artificial patination procedures influence patina formation, thickness, color, and texture, suggesting that artificial patinas are less protective than natural ones. A more in-depth study is necessary to understand the effects of artificial patinas on the conservation of contemporary sculpture in weathering steel. The authors have identified six products as most representative and will be subjecting them to a detailed, long-term evaluation.

ACKNOWLEDGMENTS

This project was supported by MNECO grants HAR2014-54893-R, BES-2012-052716, and BES-2015-071472. The authors thank the Museo de Escultura de Leganés and the Museo Reina Sofía, as well as the following sculptors and artistic foundries for their invaluable collaboration: Carlos Albert Andrés, Joan Barrantes, Arturo Berned, Rafael Canogar, Martín Chirino, Carlos Ciriza, Víctor Delgado, Salvador Fernández-Oliva, Antonio Ferragut, Manuel Mateo Cuenca, Daniel Perona Luna, Josep Plandiura, Carlos Purroy, Ricardo Ugarte, and Carles Valverde; Fundición Codina, Fundición Esfinge, Fundición Magisa, and Petra Restauración.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Type of compound</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeCl3·6H2O</td>
<td>Salt</td>
<td>40%</td>
</tr>
<tr>
<td>Fe(NO3)3·9H2O</td>
<td>Salt</td>
<td>40%</td>
</tr>
<tr>
<td>H2SO4</td>
<td>Acid</td>
<td>10%</td>
</tr>
<tr>
<td>HCl</td>
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<tr>
<td>H2O2</td>
<td>Oxidant</td>
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</table>

Table 01. Conditions chosen for the experimental design
**CURRICULUM VITAE**

Ana Crespo has a bachelor’s degree in chemistry from Universidad Complutense Madrid and a master’s degree in materials science and engineering from Universidad Carlos III de Madrid. She is completing her PhD with a dissertation on “characterization and evaluation of the protective capacity of artificial patinas in contemporary weathering steel sculpture.”

Blanca Ramírez-Barat has a bachelor’s degree in chemistry and fine arts from Universidad Complutense Madrid and a master’s degree in materials science and engineering from Universidad Carlos III de Madrid. She is working on the development of an electrochemical cell for in situ diagnoses of metallic cultural heritage.

Emilio Cano is a tenured scientist at the Centro Nacional de Investigaciones Metalúrgicas, CSIC. He completed his PhD in fine arts from Universidad Complutense Madrid in 2001. His fields of expertise include corrosion and protection of metallic cultural heritage, indoor corrosion, and electrochemical techniques for conservation science.

**BIBLIOGRAPHY**


(Endnotes)


INTRODUCTION

Plastic has been used in the artistic field since the beginning of the 20th century. But after barely half a century of life, plastics started to show symptoms of instability. This created a need to research ways of addressing these problems.

The conservation of artworks that incorporate plastic is thus a growing challenge. As time goes by, the materials are increasingly threatened; however, reliable data on how to maintain these artworks in pristine condition are lacking. A set of rules that will guide preservation is urgently needed.

The presence of “malignant plastics”—that is, those emitting volatile organic compounds (VOCs) as they degrade—is a serious problem for the preservation of plastic in art collections, because such plastics are a danger both to themselves and to nearby materials. Studies addressing this problem from a general point of view are lacking.

METHODS & METHODOLOGY

A review was undertaken of published research concerning plastics that emit gaseous pollutants. In addition, a survey was carried out in museums and institutions whose collections hold plastic objects and pieces of art. The study was carried out at an international level to allow broader comparisons.

RESULTS & DISCUSSION

The danger posed by plastics in contemporary art collections is one we have only basic notions about, essentially based on experience. Some research mention it, but most research in this area is just beginning. Nevertheless, seven studies warn of risks associated with specific types of plastic that, as they deteriorate, emit gaseous pollutants that can damage art that is exhibited or stored nearby. All seven studies identify cellulose acetate, cellulose nitrate, and poly(vinyl chloride) (PVC) as dangerous. Five of the studies also add polyurethane, and two add rubber.

What Are VOCs Emissions?

When plastics are exposed to extrinsic sources of deterioration, chemical reactions may occur to modify the attributes of the plastic. The release of degraded products by the object is a common side effect. Degradation products are typically derived from compounds added during production (e.g., fillers and plasticizers) and can be found in three states: solid, liquid, and gaseous. When they are gaseous, they may have characteristic odors, an indication of the presence of gaseous pollutants.

Because emissions can start or accelerate the degradation process in other works, some plastics are potentially dangerous for nearby works.

The most common gases released by cellulose acetate, cellulose nitrate, PVC, polyurethane, and rubber are acetic acid, sulfur-containing gases, and NO\textsubscript{X}.

How Are They Identified?

Once a problem is known, museums must determine whether it is present in their collection. Early research in
this area has focused on the different of odors released by affected objects. This identification may also be done by scientific analysis, but Condition Reports indicate they use the empirical analytic method.

Potential Casualties

Research⁶ has also identified materials that are vulnerable to these kinds of emissions. Materials sensitive to damage from gaseous pollutants emissions from malignant plastics include metals and organic materials (Fig. 01).

Plastic Preservation in Museums

To determine the state of preservation measures, an inquiry was carried out among museums whose collections include plastic objects and pieces.

After the initial contact with museums in both Europe and America,⁷ it became evident that there is an empty space to be filled regarding this issue.

Following the initial inquiry, several questions⁸ were developed to help understand the specific measures museums were taking to conserve plastic works and items and whether they were differentiating works in good condition from those showing signs of deterioration. Responses were analyzed in two large sections: Spanish scope and European scope (other than Spain).

Results indicate that storage facilities are a crucial area of concern because of how they limit preservation strategies. Funding problems were cited as a common reason for not performing routine scientific analysis.

Concerns about material conservation were more widespread internationally than among Spanish-only museums. In contrast, Spanish museums were generally more sensitive to rules of procedure.

Protocol-Devising Proposal

No preservation protocols exist for plastic materials, an oversight that needs to be addressed given the long-term risks plastic artworks and items pose not only to themselves but to other works stored or exhibited in the same place. Protocols should be based on two main pillars: material preservation and intervention guidelines.

CONCLUSIONS

Most of the reviewed studies focus on specific aspects of plastics conservation but often do not take into account the context in which materials are stored. Only a few studies address the issue from a more practical and realistic perspective. No studies have jointly evaluated preservation guidelines and action criteria.

Survey responses from museums and institutions indicate that, along with a lack of specific protocols, theoretical research and practical implementation go different ways.

Pollutant emissions from plastics have not been extensively studied by the preservation-restoration field. Because of the lack of research on malignant plastics, preservationists could turn to scientific studies to bring about a significant improvement in the field.

As for the differences identified at the national and international levels, no research on the problem is taking place in Spanish institutions, nor are any Spanish institutions involved in the international research efforts, which is why they follow the international guidelines.

Fig. 01. Originally the work presented transparent plastic elements; it now shows plastic decomposition signs, which cause deterioration processes on metallic parts. Portrait of Marcel Duchamp, Antoine Pevsner, 1926, cellulose nitrate on copper with iron. Yale University Art Gallery Gift of Collection Société Anonyme.
More research is needed in this area. Once completed, it should be aligned with existing protocols to develop specific models for plastics, including identification of the emissions risks of gaseous pollutants and measures to mitigate them.

Acknowledgments

I am grateful to my doctoral supervisor Maria Pilar Bustinduy for her patience and good advice. I also appreciate the financial support I have received from Euskal Herriko Unibertsitatea / Universidad del País Vasco.

Curriculum Vitae

Sara Liébana Molina has a bachelor’s degree in fine arts with a specialization in conservation and restoration of cultural heritage. She also has a master’s degree in conservation and exhibition of contemporary art and is a predoctoral fellow at Euskal Herriko Unibertsitatea / Universidad del País Vasco. She has completed internships at the Guggenheim Museum Bilbao and Bilbao Fine Arts Museum, among others.

Bibliography


(Endnotes)


Calcium Silicate Hydrate Characterization by Spectroscopic Techniques

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INTRODUCTION

Calcium silicate is present in the binder of many mortars used in cultural heritage, such as lime-pozzolan mortars or hydraulic mortars. After hydration the calcium silicate gives rise to an amorphous hydrated calcium silicate (called C-S-H gel)1 whose structure resembles that of tobermorite and jennite. However, while the C-S-H gel has no well-defined stoichiometry, the other two minerals are crystalline with well-established chemical formulas: Ca₅Si₆O₁₆(OH)₂·₄H₂O for tobermorite and Ca₉Si₆O₁₈(OH)₆·₈H₂O for jennite. The two minerals have a Ca/Si ratio of 0.83 and 1.5 respectively, while the C-S-H gel has a variable stoichiometry, presenting Ca/Si relations ranging from 0.5 to 2.1.

C-S-H gel can be prepared in several ways, including by (1) hydrothermal reaction² of CaO and SiO₂, (2) aqueous reaction of CaO and SiO₂, (3) aqueous reaction of Ca(NO₃)₂·₄H₂O and Na₂SiO₃·₅H₂O (double decomposition method),³ and (4) mechanochemical reaction⁴ of CaO and SiO₂. Different preparation methods lead to variations in the structure of C-S-H.

Hydrothermal and mechanochemical synthesis present some disadvantages since a long time is needed to assess the complete reaction of the SiO₂ and CaO compounds; furthermore, portlandite is formed as a secondary reaction product.

Due to the low crystallinity of C-S-H gel, spectroscopic techniques such as micro-Raman, Fourier transform infrared (FTIR) and nuclear magnetic resonance (NMR) are the most suitable methods to characterize the structure of the compound.

The C-S-H gel was synthesized in two ways: sample (1) by double decomposition; and sample (2) hydrothermally, using aqueous solutions of Ca(NO₃)₂·₄H₂O and Na₂SiO₃·₅H₂O. The formation of the amorphous compound was monitored by Raman and infrared spectroscopy. X-ray diffraction (XRD) analysis was done to follow the crystalline calcium silicate phases formed under hydrothermal synthesis.

METHODS & METHODOLOGY

Sample (1) of the C-S-H gel was prepared using stoichiometric mixtures of Na₂SiO₃·₅H₂O and Ca(NO₃)₂·₄H₂O dissolved in CO₂-free deionized water to obtain a C-S-H gel with an atomic Ca/Si ratio of 2.0. The amounts of the starting materials were 0.5 mol and 1 mol respectively; thus, the water/solid ratio was 52 (by weight).

Ca(NO₃)₂·₄H₂O was slowly added to the Na₂SiO₃·₅H₂O solution, and a jellied precipitate immediately formed. A solution of NaOH was then added to bring the pH to 12.0–12.5. The reaction was stirred for one day at room temperature.

The same steps were followed in preparing sample (2) (hydrothermal method), but the reaction was left in a Teflon container for 30 minutes at 100°C.
The solutions were correctly filtered, and the precipitates were washed three times with CO₂-free deionized water followed by ethanol. Finally, the samples were stored in vials inside a desiccator.

Each sample was analyzed using three techniques. Micro-Raman and FTIR were used to monitor the formation of the amorphous compound and to obtain a mineralogical characterization. XRD was crucial to follow the crystalline calcium silicate phases formed under hydrothermal synthesis.

Micro-Raman analysis was performed with an iNvA confocal Raman microscope (Renishaw) equipped with a Leica microscope and an electrically refrigerated CCD camera. Laser excitation line was provided by a diode laser (785 nm wavelength, 25 mW power). The spectra were obtained using a 50x magnification objective, a spectral resolution of 4 cm⁻¹, a 10-second exposure time and 20 accumulations per spectra in the range of 1,200–100 cm⁻¹ to increase signal/noise ratio. The frequencies were calibrated with silicon.

Infrared spectra were recorded in the range of 4,000–400 cm⁻¹ using a Bruker IFS66 FTIR spectrometer, a Globar source, and a DTGS detector. The samples were mixed with KBr with a sample/KBr ratio of 1/200 and compressed to create pellets.

Raman and FTIR spectra were normalized to the most intense bands of the C-S-H gel, which were 670 and 690 cm⁻¹ respectively.

The XRD patterns for the samples were recorded on a Bruker AXS D8 Advance diffractometer fitted with a Lynxeye super-speed RX detector, a 2.2-kW Cu anode (Kα 1.54056 Å), without monochromator. The scanning range, from 5 to 60°, was covered in a 24-minute period.

RESULTS & DISCUSSION

The Raman spectra (Fig. 01) of both samples revealed the presence of an amorphous compound that was identified as C-S-H gel due to a strong band at 669 cm⁻¹ (SB Si-O-Si). Furthermore, other broad bands proved the formation of the compound, such as 1,011 (ν₁ SiO₄ SS of Q₂), 838 (ν₁ SiO₄ SS of Q¹), 490 (ν₄ SiO₄), 447 (ν₂ SiO₄ Onon-Si-Onon), and 315 cm⁻¹ (lattice vibrations Ca-O). Nevertheless, the presence of amorphous and crystalline calcium carbonate were detected in the samples, with the main bands at 1,076 cm⁻¹ and 1,080 cm⁻¹ respectively. Additionally, for the hydrothermally synthetized sample, small sharp bands at 411, 840, and 865 cm⁻¹ might have been caused by a crystalline calcium silicate formed under heating conditions.

The mid-IR spectra (Fig. 02) showed a complex group of bands centered at 970 cm⁻¹, which is related to the symmetric and asymmetric stretching vibrations (Si-O) of Q² tetrahedra in tobermorite (T) and jennite (J). Thereby, bands at 1,047 (T, J), 996 (?), 983 (T), and 954 cm⁻¹ (J) were assigned to the minerals. Other bands were associated with C-S-H gel, such as 664 (bending Si-O-Si), 514, 463, and 451 cm⁻¹ (internal deformations SiO₄).

Moreover, two other compounds were identified as calcium carbonates. The main bands at 1,484 and 1,420 cm⁻¹ allowed us to identify amorphous calcium carbonate and calcite respectively, which was in line with the Raman results. The band at 1,637 (bending H-O-H) and the broad
bands at 3,442 and 3,241 cm⁻¹ (stretching H-O) corresponded to water and hydroxyl groups in the C-S-H gel structure.

The X-ray diffraction (Fig. 03) exhibited very broad bands due to the low crystallinity of the sample. Tobermorite is the only compound that could be identified, and doubts exist about the identification of calcite and other crystalline calcium silicate phases because the quantity of these compounds was below the detection limit.

CONCLUSIONS

Calcium silicate hydrate gel was synthetized under hydrothermal conditions using calcium nitrate and sodium metasilicate as starting materials. Both tobermorite and jennite were identified by FTIR; however, by XRD only tobermorite was detected. No other crystalline phases, such as carbonate and/or anhydrous calcium silicate, were distinguished in the diffractogram due to the low quantity present in the sample, considering that both phases were identified by Raman and FTIR. Spectroscopic techniques can be used to identify calcium silicate hydrate with different compositions and to determine whether these compounds came from pozzolanic or cement reaction.

ACKNOWLEDGMENTS

This research was supported by the Comunidad de Madrid and European Social Fund under the Programa GEOMATERIALES-2-2013/MIT-2914.
TECHNIQUES FOR CHARACTERIZATION, DIAGNOSIS AND CONSERVATION ASSESSMENT
Advances in SERS: Devising Contemporary Art Materials Investigation Tools

INTRODUCTION

Preserving contemporary artworks with an adequate set of advanced tools is a cutting-edge theme for the scientific community, as well as for private and public art galleries, chemical manufacturers, and conservation practitioners. Due to the fast degradation and perishability of the materials used, many contemporary artworks might not be accessible to visitors in the future. The Universidade de Santiago de Compostela is among the 27 partners of the NanoRestArt project, which focuses on the synthesis of novel nanomaterials and on the development of innovative methods to address the conservation of a wide variety of materials used by contemporary artists.

This article presents the preliminary results of surface-enhanced Raman scattering (SERS) applications for the detection of early degradation products on plastic art materials. Previous research has shown that organic pigments and dyes (e.g., red lakes), as well as binder media (e.g., ovalbumin), varnishes, and resins can be identified by SERS.\(^2\) This information allows for more refined authentication and dating of paintings, textiles, or paper collections and helps explain fabrication processes in archaeometry. However, given the high potential of the technique and the lack of published data on SERS applications for contemporary art conservation, we are attempting to devise high-performance SERS-active substrates. Our challenge is to develop substrates suitable for in situ and nondestructive sampling of plastics used by contemporary artists. This will expand the versatility of SERS applications already in use for heritage science research.

In principle, an electromagnetic field generated by plasma excitations enhances the signal through appropriate nanoparticles or nanostructured metals. Concurrently on the surface, chemical interactions between the metal particles and the target molecules occur.\(^3\) Compared to traditional Raman spectroscopy, SERS allows low-intensity signals to be amplified locally and reduces the strong interfering fluorescence background signal produced by organic materials. Therefore, smaller amounts of molecules can be detected.

The overall aim of the research is to detect low-molecular-weight, oxygen-containing, and nonvolatile compounds from oxidized polymeric surfaces, such as the plastics used in contemporary art. To do this, we are optimizing the parameters that affect the sensitivity and reproducibility of SERS activity.

METHODS & METHODOLOGY

Two sampling methodologies were investigated, both focusing on early, nonvolatile, oxidation products. The first was the direct sampling of weathering products with SERS-substrates, previously coated with thin metal layers, by placing the structured surface in contact with the plastic artifact. The second methodology was to place an elastomeric silicone sampling strip in contact with the plastic surface. To determine whether the strip released soluble species, it was tested beforehand using gas chromatography–mass spectroscopy (GC-MS). Subsequently, analyte molecules were transferred to the nanostructured
SERS substrate by rinsing the surface of the strip with a small amount of appropriate solvent (e.g., THF).

Previous research has reported the successful fabrication of fluorinated elastomeric SERS substrates using ultraviolet nanoimprint lithography (UV-NIL) followed by metal coating. In our case Al, Ag, and Cu were applied to the polymeric structure by physical vapor deposition (PVD). Micro- and nanostructured squared arrays with inverted pyramids and hexagonal arrays with cylindrical holes were used. For replication polymers, home-synthesized tetra-functional urethane methacrylate perfluoropolyether (PFPE) was used, along with commercial off-the-shelf hybrid organically modified ceramics (Ormocers®).

Aging tests, based on thermal and photo-oxidation were run to validate the efficiency of the SERS-active substrates in the detection of well-known degradation products. To achieve this, we analyzed more than twenty samples, including linseed oil, commercial polyisoprene, and historic synthetic rubber from museum collections. In addition, nonaged reference linseed oil and rhodamine were spread over the metalized surface, and Raman spectra were collected. Both sampling methods were nondestructive, did not leave residues on the surfaces under analysis, and the amount of sample was low (< 1 µg). Additionally, the sample could be directly analyzed without further preparation, which expands the potential of the technique for in situ applications. The SERS-substrates enabled us to reduce considerably the amount of material to be sampled, a significant factor in conservation practice. The integrity of artifacts is a priority in collections management, and heritage scientists can respect this principle and expand its intrinsic limitations by, for example, lowering the detection limits of the analytical instrumentation.

We expected to identify the characteristic Raman signals generated by, for example, hydroxyl and carbonyl groups. Further morphological and chemical characterizations of the substrates and the weathered samples were carried out through SEM-EDX, Fourier transform infrared spectrometry, and GC-MS.

RESULTS & DISCUSSION

Because our experimental set of SERS-active substrates is still being developed, this article reports only preliminary results. The focus was on commercial polymers usually affected by auto-accelerated oxidation processes of hydrocarbons, schematized as follows (Fig. 1): the initial step consists of the abstraction of some labile hydrogen from the polymer backbone, followed by oxygen addition and formation of hydroperoxide intermediates, where the initial radical species are formed by phototransformation or thermal decomposition of photochromic or other unstable impurities or structural defects. Unstable hydroperoxides easily decompose to form new oxygen-containing groups responsible for color changes. Concurrently, a series of secondary processes results in different molecular changes, such as cross-linking and fragmentation, macroscopically reflected in the emission of volatile organic compounds, in the formation of low-molecular-weight, nonvolatile compounds, and in changes to the mechanical properties of the polymer.

The direct deposition of typical SERS-active molecules (e.g., rhodamine 6G/5, unsaturated acids) onto the nanostructured SERS substrates showed consistent
results with different metal coatings, reaching very low levels of detection. On the other hand, preliminary tests of the direct sampling procedure on aged linseed oil and other samples suggest further refinements of the sampling protocol should be considered.

The second sampling methodology tested uses an elastomeric silicone strip placed in contact with the artwork and allows sampling of the surface by adsorbing nonvolatile oxidation products. Through microextraction, the analyte molecules were transferred to the SERS-active substrate. Results indicated that very low amounts of oxidation products were detectable (< 1 µg), on all types of samples. The best results were achieved with aged linseed oil and polyisoprene sampled with the silicone strip and transferred to nanostructured substrates coated with aluminum (Fig. 2). Further study of the transferring procedure, identification of the degradation products, and modeling of the adsorption mechanisms are currently under way. Additional metal-coating strategies are being investigated to improve control over thickness, geometry, and local signal amplification of the substrates (Fig. 3).

CONCLUSIONS

By using SERS Raman (validated through GC-MS, which is usually considered reliable and highly sensitive), evidence was obtained of early degradation products on plastics. The preliminary results of this investigation showed that further work is necessary to optimize the sensitivity and reproducibility of the SERS-active Raman substrates to detect early degradation products. Additional accelerated aging tests are planned for plastic-based artworks to strengthen the methodology. Finally, the geometry of the nanostructures and the thickness of the coated films used to research the plasmonic properties of different metals are being refined. Our contribution to the NanoRestArt project has shown that viable, if complex, developments of SERS substrates for contemporary art conservation are possible.

ACKNOWLEDGMENTS

This research is funded within the EU-Horizon 2020 project “Nanomaterials for the Restoration of Works of Art” (see http://www.nanorestart.eu/).

CURRICULUM VITAE

Daniela Reggio graduated in conservation science from Sapienza Università di Roma and in archaeometry from University College London. She is currently enrolled in the PhD program of materials science at the Universidade de Santiago de Compostela.

Manuel Gómez is a PhD candidate in materials science Universidade de Santiago de Compostela. He is currently working on the application of fluorinated polymers to the fabrication of nanostructured materials.

Massimo Lazzari has a PhD in chemistry and is an associate professor of chemical physics at the Universidade de Santiago de Compostela.
BIBLIOGRAPHY


(Endnotes)


5 A medium accelerated photo-aging device equipped with a xenon light source filtered for \( \lambda \leq 295 \) nm and isothermal treatment in a forced-air circulation oven were used (SUNTEST CPS+).

6 Renishaw InVia Reflex Raman spectrometer equipped with two excitation lasers, at 514 nm and 785 nm.

Nanodispersions for Deacidification of Painting Canvases

INTRODUCTION

In the past 15 years, alkaline nanoparticle dispersions have proved to be extremely effective as deacidifying agents for the preservation of paper artifacts, protecting them against cellulose aging.\(^1\)

New studies involving the use of nanoparticles in the deacidification of cellulose-based objects have increased over the last few years. Dispersions of calcium hydroxide nanoparticles were also proposed as a deacidifying treatment for canvas. These nanoparticles, due to their high reactivity, provide a stable neutral environment by rapidly forming a mild alkaline species, calcium carbonate.\(^2\)

Previous research has investigated deacidification treatments for the protection of canvas from acid-catalyzed cellulose depolymerization. The deacidification technique most commonly used to treat canvas, the Wei T’o method, was a mass deacidification technique developed for use in paper conservation. This procedure uses ethyl ethoxy magnesium carbonate in ethanol further diluted with volatile fluorocarbon solvents. It was later abandoned due to the environmental impact and toxicity of chlorofluorocarbon solvents.\(^3\)

The canvas is one of the most important components of an easel painting. Upon aging, the canvas loses its firmness and elasticity and is no longer able to function as a support for the paint layers. Several factors (e.g., materials used in the ground layer, light, pollutants, pH, temperature, relative humidity [RH], and previous conservation treatment) may also affect the physicochemical state of the canvas and induce hydrolysis of β-(1,4)-glycosidic bonds of cellulose. This results in the decrease of pH, depolymerization of cellulose, and the weakening of the canvas.

The aim of this work was to extend a commonly accepted practice used in the conservation of paper: the application of calcium hydroxide nanoparticles to canvas-supported paintings. This research is an extension

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Fig. 01. Nineteenth-century loose lining canvas from the Tate Conservation Department. (A) Canvas before application of alkaline nanoparticle dispersed in 2-propanol 3 g/L; (B) Canvas after the application Ca(OH)\(_2\) NPs.
of previous work within the European Union–funded NANOFORART project focused on the deacidification of original 19th-century linings with nanomaterials.\textsuperscript{4}

**METHODS & METHODOLOGY**

An original loose lining canvas (19th century) from the Tate Conservation Department (London, UK) was provided for the study. The linen canvas is sized with rabbit-skin glue and has a double ground layer consisting of a layer of linseed oil pigmented with chalk and some white lead and a second layer of linseed oil pigmented with white lead and a little bit of chalk. The primary canvas was therefore in contact with the sized layer of the lining and protected by the ground on the outside.\textsuperscript{5}

Calcium hydroxide nanoparticles in 2-propanol 3g/L (Ca(OH)\textsubscript{2}NPs) were prepared at CSGI and used for the deacidification treatments.\textsuperscript{6} Ca(OH)\textsubscript{2}NPs were applied on the sized layer of a series of samples by spraying until saturation was achieved. The operation was repeated four times with a 15-minute gap between applications to allow evaporation of the solvent. Samples were left to dry for 21 days at 20°C and 55% RH to allow carbonation and the deacidification process to occur (Fig. 01).

All samples were artificially aged using a hydrothermal environment to accelerate the degradation of cellulose and evaluate the efficacy of the nanoparticles as an alkaline reserve. The temperature was set at 80°C, and samples were kept at a humidity of 75\% using sodium chloride–saturated aqueous solutions.\textsuperscript{5} Before aging, two series (untreated samples and deacidified samples) were also treated with Plexisol\textsuperscript{®}P550 and BevaO.F.\textsuperscript{371} to evaluate the impact of the deacidification treatment during a standard conservation protocol. These two products were brushed onto the sized layer. Samples were then dried for three days before being treated with the same protocol used with the other samples.

Scanning electron microscopy (SEM) was performed using a Philips XL30 FEG-SEM (FEI, Eindhoven, Netherlands) on the sized layer before and after treatment and after aging. The system operated at 5 kV acceleration voltage and spot size 3. The samples (3 x 5 mm) were mounted on aluminum stubs (Agar Scientific, Essex, UK) and coated in an Au/Pd sputter coating system (Poralon E5000 sputter coater).

For the pH measurements, the ground was completely removed with a scalpel to measure the contribution of the canvas only. For each sample, 600–650 μg were weighed and placed inside 1.5 mL vials, to each of which was added 210 μL of deionized water (17.3 MΩcm). Measurements were performed on the extract after 24 hours with a digital pH meter.\textsuperscript{7}

**RESULTS & DISCUSSION**

SEM analysis was performed on the sized layer before and after the application of Ca(OH)\textsubscript{2}NPs (Fig. 02, A, B) and showed homogenous stratification of the nanoparticles on the fibers. As Giorgi et al. found,\textsuperscript{8} electrostatic forces closely bind the nanoparticles to the surface of the threads. After aging (Fig. 02, C), layers of carbonated nanoparticles NPs can still be detected.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>St. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tate canvas untreated</td>
<td>4.60</td>
<td>0.14</td>
</tr>
<tr>
<td>Tate canvas untreated aged</td>
<td>4.20</td>
<td>0.09</td>
</tr>
<tr>
<td>Tate canvas + NPs</td>
<td>6.70</td>
<td>0.01</td>
</tr>
<tr>
<td>Tate canvas + NPs aged</td>
<td>6.50</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Table 01. pH measurement on Tate canvases before and after the application of Ca(OH)\textsubscript{2} NPs and the aging treatment.
The pH measurements (Table 01) demonstrated the efficacy of the deacidification. The pH before treatment was 4.60, a consequence of the natural aging of the loose lining due to environmental factors. After 21 days, the pH reached 6.70. Deacidification produced an increase in pH (up to 2 pH units). After hydrothermal aging, the untreated samples showed a slight decrease up to 4.20. Treated samples maintained a value of 6.50, which indicates the efficacy of the deacidification.

Table 02 shows the pH measurements of the samples, both untreated and deacidified, after consolidation with Plexisol® P550 and BevaO.F.® 371, followed by aging. An increase of pH after consolidation of approximately 1 pH unit was observed for the untreated series and of approximately 0.30 pH units for the deacidified series. After aging, pH of untreated samples decreased due to the absence of an alkaline reserve. The pH of deacidified and aged samples showed a decrease, higher when compared to nonconsolidated samples (Table 01). This could be due to the aging of the consolidants, which may acidify the canvas and reduce the alkaline reserve on the support. To overcome this, a second treatment of nanoparticles could be applied during the deacidification process.

CONCLUSIONS

Nanomaterials provide an important contribution to the development of innovative protocols for the deacidification of cellulose-based artifacts. The deacidification of canvas using this new scientific conservative approach could become extremely important in the traditional conservation protocols.

CURRICULUM VITAE

Chiara Chillè is a conservator of easel paintings and a PhD student at Northumbria University. She has a master’s degree in conservation of paintings from the Università degli Studi di Palermo.

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BIBLIOGRAPHY


(Endnotes)


4 See http://www.nanoforart.eu/ [29-07-2016].


Analyzing the Microorganisms Biochemical Alteration Capability in Verdigris Paint Specimens Using VIMP

Annette S. Ortiz-Miranda, a Antonio Doménech-Carbó, b María Teresa Doménech-Carbó, a Laura Osete-Cortina, a Fernando Bolívar-Galiano, c Inés Martín-Sánchez c

INTRODUCTION

The growth of microorganisms in paintings and artworks, in general, is a major concern for museums worldwide due to the aesthetic and structural damage such growth can cause. Several analytical strategies based on spectroscopic and chromatographic techniques have been developed that enable the study of changes undergone by the binders and finishers after microbial attack. Nevertheless, the study of the minimal modifications occurring in both the binder and the pigment is difficult, and more selective and sensitive analytical techniques are required.

The present article describes the application of voltammetry of immobilized particles (VIMP),1 a solid-state electrochemical technique, for analyzing compositional changes experienced by a series of synthetic pictorial specimens. The specimens contained an electroactive pigment mixed with various binding media, which were submitted to biodeterioration by a series of fungi and bacteria recognized as biodeterioration agents of pictorial materials. Verdigris, a widely used copper pigment, was selected as a pigment probe and combined with egg and egg-oil emulsion binders. Using methods previously described for analyzing pictorial samples2 VIMP was used to monitor the biodeterioration caused by the attack of a series of microbial genera.

METHODS & METHODOLOGY

Microorganisms

The microorganisms studied were recognized biodeterioration agents, selected after an extensive literature review.3 Fungi and bacteria that could originate biodeterioration processes in paints were chosen. All of the species studied are ubiquitous saprophytes, commonly found in the air, and they came from stock collections belonging to the Spanish Type Culture Collection (CECT, Universitat de València, Spain).

The following microorganisms were used:

Fungi

• Aspergillus niger (An) (CECT-2008)
• Acremonium chrysogenum (Ac) (CECT-2723)
• Penicillium chrysogenum (Pc) (CECT-2306)
• Mucor rouxii (Mr) (CECT-2655)
• Trichoderma pseudokoningii (Tp) (CECT-2937)

Bacteria

• Bacillus amyloliquefaciens (Ba) (CECT-493)
• Arthrobacter oxydans (Ao) (CECT-386)
• Streptomyces cellulofans (Sc) (CECT-3242)

Test Specimen Preparation

Verdigris (Kremer) was used to prepare specimens with egg (EG@Cu) and egg-linseed oil emulsion (EO@Cu) binders. The paints, prepared following traditional recipes,4 were spread to form a thin film on glass slides and dried for 90 days.
Incubation and Inoculation of Specimens

Lyophilized collection stocks were hydrated in Czapek malt medium (CM) (fungus) and triptych soy broth (TSB) (bacterium) and incubated for 18 hours in a culture chamber (28°C). Afterward, they were inoculated onto solid CM medium (fungus) and triptych soy agar medium (TSA) (bacterium). After 48 hours, these cultures were used to prepare dense microbial suspensions on 0.9% NaCl aqueous solution. The suspensions were then inoculated onto specimens containing the studied paints after performing centrifugation to eliminate remaining culture media. Several drops (20 μL) of the suspension containing the microorganism were applied onto the support using a micropipette so that they covered a defined area (~20 mm²/drop) of the solidified model paint, and then the inoculated test specimen was placed in the incubator. After inoculation, each paint film was placed in the center of a Petri dish and incubated in darkness for 40 days at 28°C, 80% relative humidity.

Instrumentation

Electrochemical experiments were performed at 298K in a three-electrode cell under argon atmosphere using a CH 1660C device (IJ Cambria Scientific). A platinum wire counter electrode and an Ag/AgCl (3 M NaCl) reference electrode completed the three-electrode arrangement. Commercial paraffin-impregnated graphite bars (Staedler 200 HB type, 68% graphite by weight content, diameter 2 mm) were used, and a 0.25 M aqueous acetate buffer (Panreac) at pH 4.75 was used as the supporting electrolyte.

RESULTS & DISCUSSION

Figure 01 shows the cyclic voltammogram for microparticle deposits of verdigris on graphite electrode immersed into 0.25 M sodium acetate buffer, at pH 4.75. For the pure pigment, a cathodic wave at ca. –0.25 V vs. Ag/AgCl (C₁) appears in the initial cathodic scan, followed by a shoulder at ca. –0.45 V (C₂), which precedes the rising current for solvent discharge. In the subsequent anodic scan, anodic stripping peaks at 0.15–0.25 V (A₂) and 0.00–0.05 V (A₁) appear. The peak C₁ can be attributed to the reduction of pigment grains exposed to the graphite surface to Cu metal, whereas the process C₂ could be attributed to the reduction of Cu(II) ions that were reduced at the Cu-plated electrode surface giving rise to peak C₃. During the positive-going potential scan, the deposit of copper metal was oxidized to Cu²⁺(aq), which explains the stripping peaks process (A₁, A₂).

The voltammetry becomes significantly modified for samples of the pigment-binder specimens. In the first scan (Fig. 02), three reduction processes can be observed (C₁, C₂, C₃) at the same potentials, accompanied by two more or less overlapping anodic stripping peaks (A₁, A₂). The above voltammetry resulted from the superposition of different electrochemical process, assuming the Binder@Cu specimens were constituted by a more or less homogeneous
distribution of pigment particles partially embedded by a hydrophilic layer where different copper deposits existed.

In the case of the inoculated model paint specimens, an additional peak (C₄) in the second scan was observed. These features suggest that the biodeterioration process involves the partial release of compounds responsible for peak C₄ from the external layer of pigment grains. The most significant changes were observed for the egg-oil model paint specimens inoculated with bacteria. Two extreme behaviors were observed. *Arthrobacter oxydans* (Fig. 03b) appeared to eliminate the binding medium around the pigment particles (low C₄), whereas *Streptomyces cellulofans* (Fig. 03a) did not produce an equivalent effect.

The voltammograms obtained for the egg paint specimens inoculated with *Acremonium chrysogenum* (Fig. 03c) and *Bacillus amyloliquefaciens* (Fig. 03d) varied significantly from bacteria to fungi. A diminution on the signal C₄ associated with the reduction of verdigris-binding complexes is indicative of an aggressive biological attack. These differences observed in the voltammograms of the fungi- and bacteria-inoculated verdigris-based paints can be attributed to the different biochemical action of each type of microorganism in the binder-pigment boundary region. On the other hand, a simpler composition of the ionomeric layer seemed to be present in grain boundaries after bacterial attack, and fungal attack resulted in a more complex effect on the ionomeric layer, as suggested by the decrease in the C₂ region that could be ascribed to a reduction of the verdigris-binding-complex species.

**CONCLUSIONS**

The application of VIMP resulted in the observation of characteristic voltammetric features for verdigris pigment associated with egg and egg-oil emulsion binders. In the presence of the binder, the voltammetric signals for verdigris were modified by the signals that resulted from the pigment-binder association. Depending on the binder, such signals became more or less modified after biodeterioration.

These results support the idea that biodeterioration of pictorial specimens is significantly sensitive to the nature of the pigment and can be electrochemically monitored using solid-state methodologies. Thus, the proposed methodology has potential applications for microbiological attack characterization.

**Acknowledgments**

This work was performed by members of the microcluster Grupo de análisis científico de bienes culturales y patrimoniales y estudios de ciencia de la conservación (Ref. 1362) belonging to the Valencia International Campus of Excellence. We gratefully acknowledge the financial support provided by the Spanish
“I+D+I MICINN” projects CTQ2011-28079-C03-01 and -02 and CTQ2014–53736-C3-1-P and -2-P, as well as by the European Regional Development Fund.

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**Bibliography**


(Endnotes)


Investigation of Surface Active Materials for Paper Cleaning

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INTRODUCTION

The deterioration of paper in books and archival materials due to the degradation of the cellulosic substrate has been recognized since the turn of the century. The principal causes of the structure alterations are biodegradation, photo degradation, acid hydrolysis, and oxidation. Washing is a fundamental treatment that can improve document appearance while reducing acidity and thus stabilizing paper chemically. Cleaning paper with solutions of surfactants is better than washing only with water.1 During washing, soluble acids and dirt are moved from paper along with the chromophores that contains the organic compounds responsible for the yellow color of the paper.

Fig. 01. (a) Change in pH after heat aging the samples for 500 hours; (b) mechanical features of the paper after heat aging the paper samples for 500 hours; (c) Fourier transform infrared spectroscopy spectra of the paper samples.
Given the importance of preserving paper, the objective of this study was to adapt the surfactants in the washing process and to investigate their effect on paper’s properties.

**METHODS & METHODOLOGY**

The study examined changes to the mechanical, thermo-resistance, acid, and optical properties of paper samples after treatment with surfactant aqueous solutions (Amytis, Tinuvetin JUN HC, Tween 20, Triton X-100, P3-Triquart, Bromosept 50—used in medicine and food industry). The most suitable surfactant material for cleaning grease stains from paper was proposed. To conduct the research, a filter paper was chosen, made of 100% cellulose. Paper samples were washed in surfactant aqueous solutions, dried at room temperature, and thermally aged for 500 hours in a drying oven. Infrared (IR) and UV/Vis spectroscopy, mass spectroscopy (MS), tensile test, contact angle, polymerization degree (PD), and acidity measurements were used to characterize the samples.

**RESULTS & DISCUSSION**

When included as part of the paper-washing procedure, none of the tested surfactants and disinfectants had a significant impact on the acidity of the paper. The results presented in Figure 01 (a) reveal that the biggest change in pH after heat aging the samples for 500 hours occurred in samples that had not been washed or treated with the SAM (Δ pH = 0.71) but had been washed in the 2% P3-Triquart aqueous solution (Δ pH = 0.62). The lowest pH value was found in samples treated with 0.7% and 1.0% Bromosept 50 aqueous solutions (Δ pH values 0.35 for each).

The degree of polymerization was measured with a viscometer by measuring the viscosity of the solutions. The degree of polymerization was determined in accordance with the ISO 5351/04 methodology (viscometer: type, 53013; constant K, 0.03; Cat. No. 9.268313) in assessing the limiting viscosity number (η) of cellulose solution. The data (see Table 01) show the highest degree of polymerization before (1153.9 r. u.) and after (1126.4 r. u) thermal aging. Paper samples treated with 1% Amytis aqueous solutions had a similar degree of polymerization as the filter paper. The lowest degree of polymerization before (1060.2 r. u.) and after (1047.7 r. u.) heat aging was detected in samples treated with 0.7% Bromosept 50.

The contact angle and adsorption measurements of the paper samples were carried out on a flat surface using a contact angle measurement (CAM) system (KSV Instruments CAM 100). Measurement of contact angle and absorption were determined using the international standard T 458 cm-04 (TAPPI: 2004). Paper samples treated with SAM absorbed water faster than samples treated only with water.

Mechanical features of the paper tensile strength and tensile strength limit were measured by a dynamometer. Measurements were performed for paper samples treated with SAM before and after heat aging. Figure 01 (b) shows that after paper fibers swell their strength slightly decreases and that, at the time of washing, the introduction of a surfactant reduces tensile strength by ~ 5 N compared to the standard.

<table>
<thead>
<tr>
<th>Degree of polymerization (r. u.)</th>
<th>Before the samples heat aging</th>
<th>After the samples heat aging for 500h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter paper (FP)</td>
<td>1153.9</td>
<td>1126.4</td>
</tr>
<tr>
<td>FP was washed in water</td>
<td>1124.8</td>
<td>1115.9</td>
</tr>
<tr>
<td>FP + 1% Tinuvetin HC JUN</td>
<td>1138.6</td>
<td>1096.5</td>
</tr>
<tr>
<td>FP + 1% Amytis</td>
<td>1147.5</td>
<td>1128.1</td>
</tr>
<tr>
<td>FP + 1% Triton X-100</td>
<td>1105.4</td>
<td>1086.0</td>
</tr>
<tr>
<td>FP + 1% Tween</td>
<td>1145.9</td>
<td>1114.3</td>
</tr>
<tr>
<td>FP + 0.7% Bromosept 50</td>
<td>1060.2</td>
<td>1047.7</td>
</tr>
<tr>
<td>FP + 1% Bromosept 50</td>
<td>1071.5</td>
<td>1053.0</td>
</tr>
<tr>
<td>FP + 1% P3 – Triquart</td>
<td>1086.0</td>
<td>1074.7</td>
</tr>
<tr>
<td>FP + 2% P3 – Triquart</td>
<td>1071.5</td>
<td>1060.2</td>
</tr>
</tbody>
</table>

Table 01. The value of the degree of polymerization of paper samples

![Fig. 02. UV/Vis spectra of the paper samples.](image-url)
The paper samples were examined with UV/Vis spectroscopy to evaluate changes in absorption intensity and sample color after treatment with SAM. The data confirm (Fig. 02) that in the non-aged samples bands were observed at 228 and 282 nm. In the UV region, maximum absorption was observed in the samples treated with 1% and 2% P3 Triquart solutions (0.53 and 0.47 r.u. respectively). In the samples washed only with water, the intensities were higher: 0.13 and 0.07 r.u.

The IR spectrum (Fig. 01 (c)) results show that all samples had broad absorption peaks at 3,500–3,300 cm⁻¹, corresponding to OH group vibrations. The peaks at 2,900–2,800 cm⁻¹ correspond to -CH, -CH₂ groups. In the range of 1,730–1,617 cm⁻¹, low-intensity absorption peaks are visible, corresponding to keto-, diketo-, aldehyde, and carboxy groups. The peaks at 1,440 and 1,250 cm⁻¹ indicate C-O bond vibrations, and the band at 1,000 cm⁻¹ is attributed to C-O (by OH). The peaks of the samples treated with SAM correspond to the filter paper IR absorption spectrum. The intensity of the absorption bands was not notably different among the samples, and the same peak distribution remained even after 500 hours of thermal aging.

Mass spectrometric analysis of the paper samples was performed, and the paper samples were treated with 1% SAM (Triton X-100, Tween 20, Bromosept 50, P3-Triquart). The mass spectrum data (Fig. 03) reveal that material was fully washed after rinsing for 30 minutes in baths filled with distilled water that was changed every 10 minutes. However, the quantity of SAM material was much larger in samples that were not rinsed with water.

CONCLUSIONS

The use of surfactant and disinfectant materials in paper washing procedures had no significant impact on the acidity of the paper or degree of polymerization and only minimally changed the paper’s absorption properties and thermal stability. During the washing process, fiber swelling was unavoidable, and changes to the average dimensions were irreversible, but no signs of destruction were observed even after heat aging for 500 hours.

CURRICULUM VITAE

Justė Kupčiūnaitė is studying for a master’s degree in chemistry at Vilniaus Universitetas.

Milda Liubinienė is a PhD student in chemistry at Vilniaus Universitetas.

Aldona Beganskienė holds a doctorate in physical sciences. She is the dean of the chemistry faculty at Vilniaus Universitetas.

BIBLIOGRAPHY


(Endnotes)


5 T 458 cm-04: 200 TAPPI, Surface wettability of paper.
Development of Nanostructured Coatings for the Protection of Textiles and Paper

INTRODUCTION

High humidity or direct contact with water are the main causes of deterioration for cellulosic materials such as textiles and paper and may also contribute to the breakdown of glycosidic bonds and the growth of microorganisms. The use of hydrophobic coatings such as carboxylate-alumoxanes sol-gel, titanium dioxide nanoparticles, and modified copolymer lattices has been proposed to protect textiles and paper. This article reports on four promising formulations that were developed based on commercially available water-repellent products. The aim was to investigate their suitability for paper and textile conservation; in particular, whether they met the high physicochemical and aesthetic compatibility mandatory for cultural heritage applications. Three of the formulations were based on fluoroacrylic copolymer in ethanol, eventually functionalized with hydrophobic silica nanoparticles; the fourth product was based on polydimethylsiloxane in ethyl-acetate.

METHODS & METHODOLOGY

The cellulosic substrates used for this research included three types of paper and four textiles:

C1: Printed book paper, 1876; bulk: 84.56 gsm;
C2: Printed book paper, 1923; bulk: 93.6 gsm;
C3: Common white printing paper, 2015; bulk: 76.12 gsm;
T3: Cellulosic row canvas; threads/cm: 9;
T4: Painting canvas covered with red handmade preparation layer; threads/cm: 9;
T5: Painting canvas covered with white industrial preparation layer; threads/cm: 21;
T7: Blue cotton textile; threads/cm: 27.

Four formulations, diluted in one of two solvents, were used to treat the samples:

F1: Fluoroacrylic copolymer at 5.00%w in ethanol;
F2: Fluoroacrylic copolymer at 4.87%w mixed with 0.12%w of hydrophobic fumed silica nanoparticles (Aerosil R812—BET surface area: 260 ± 30 m²/g), in ethanol;
F3: Fluoroacrylic copolymer at 4.75%w mixed with 0.25%w of hydrophobic fumed silica nanoparticles (Aerosil R812—BET surface area: 260 ± 30 m²/g), in ethanol;
F4: Polydimethylsiloxane (PDMS—Sylgard 184 silicone elastomer) at 5.00%w in ethyl-acetate.

Ethanol and ethyl-acetate were selected as low-toxicity solvents likely to have the fewest negative environmental and health impacts. The products were applied both by spray (with an airbrush) and by immersion to compare methodologies already used for textile and book conservation. A total of 8 ml of each product was sprayed...
on three replicates of every sample (5 x 5 cm²), half on the front and half on the back. Samples T4 and T5 were treated only on the back side, as the front was a preparation layer. The immersion treatment called for a deep immersion of each specimen for 30 seconds. The solution was replaced every six samples. The four treatments also included a two-hour curing phase at 60°C.

A set of treated samples was artificially aged under solar lamps (500 hours at ca. 8,500 lux, 280–400 nm) to observe possible polymer decay.

To evaluate treatment effectiveness, the specimens were investigated through visual observation, optical and electron microscopy (DINO-Light Digital microscope; SEM JEOL JSM-6490LA), colorimetric analysis (Konika Minolta CM-2600d), and spectroscopic analysis (Thermo Nicolet Nexus Smart Orbit, 4 cm⁻¹ resolution, and spectroscopic analysis (ATR Nicolet FTIR with Yococu formulations). Samples (U), samples treated by spray (S), and samples treated by immersion (I). Data are reported for C1, C2, and C3 papers, treated with F1, F2, F3, and F4 formulations.

Table 01. Color change (ΔE), contact angle (°), vapor permeability (g/(s·m²)), Young’s modulus (MPa), and maximum load (N) values recorded for untreated samples (U), samples treated by spray (S), and samples treated by immersion (I). Data are reported for C1, C2, and C3 papers, treated with F1, F2, F3, and F4 formulations.

RESULTS & DISCUSSION

Selected data are reported in Tables 01 and 02. In general, all the products modified the visual aspect and changed the color of the samples independently of the application methods selected. Products F2 and F3, functionalized with hydrophobic fumed silica nanoparticles (0.12% and 0.25% respectively) formed white deposition due to the accumulation of nanoparticles, as confirmed by digital microscope observations (Fig. 01).
of nanosilica was higher with treatment F3. F1 gave the lowest variation of ΔE. In applications of F2 and F3, the higher the percentage of nanoparticles, the greater the specimen whitening was. In general, a significant ΔE variation resulted from F4 treatments, mainly due to changes in color lightness (−15.41 < ΔL < −0.41).

Independently of the application methods used, SEM images highlighted the ability of the products to homogeneously coat each fiber without creating a rigid and continuous film (Fig. 02).

Fourier transform infrared, attenuated total reflectance (FTIR-ATR) analysis showed the typical absorption peaks of the substrates and products. No other additional peaks related to chemical interaction of the substrates with the products were observed: this may suggest chemical compatibility of the products (Fig. 03).

As for wettability, the high values collected (contact angles from 115° to 147°) prove that all formulations provided excellent hydrophobic properties; moreover, the addition of nanoparticles amplified surface water-repellence, exemplifying the “lotus effect.”

<table>
<thead>
<tr>
<th>Samples</th>
<th>Colour change</th>
<th>Contact angle [°]</th>
<th>Vapour permeability [g/(s·m²)]</th>
<th>Young’s Modulus [MPa]</th>
<th>Maximum Load [N]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>I</td>
<td>U</td>
<td>S</td>
<td>I</td>
</tr>
<tr>
<td>T3</td>
<td>F1</td>
<td>2.57</td>
<td>5.95</td>
<td>0 ± 0</td>
<td>143 ± 9</td>
</tr>
<tr>
<td></td>
<td>F2</td>
<td>2.65</td>
<td>5.02</td>
<td>140 ± 4</td>
<td>140 ± 7</td>
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<tr>
<td></td>
<td>F3</td>
<td>3.80</td>
<td>7.03</td>
<td>139 ± 6</td>
<td>140 ± 5</td>
</tr>
<tr>
<td></td>
<td>F4</td>
<td>5.75</td>
<td>3.87</td>
<td>136 ± 6</td>
<td>142 ± 6</td>
</tr>
<tr>
<td>T4</td>
<td>F1</td>
<td>2.83</td>
<td>4.00</td>
<td>131 ± 8</td>
<td>132 ± 5</td>
</tr>
<tr>
<td></td>
<td>F2</td>
<td>3.49</td>
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Table 02. Color change (ΔE), contact angle (°), vapor permeability (g/(s·m²)), Young’s modulus (MPa), and maximum load (N) values recorded for untreated samples (U), samples treated by spray (S), and samples treated by immersion (I). Data are reported for T3, T4, T5, and T7 textiles, treated with F1, F2, F3, and F4 formulations.
Immersion and spray applications did not considerably affect the water vapor permeability (WVP) of treated textiles, while paper immersion treatments guaranteed a WVP close to the untreated specimens in comparison to spray-treated specimens. Acceptable variations of WVP (around 15–20% for textiles and 20–30% for papers) were measured, with the exception of spray treatments F1, F2 and F3 of C2 (relevant WVP decrease). Values close to the original WVP prove a homogeneous distribution of the products on each fiber, with the formation of a thin and flexible coating structure.

Hygroscopic tests on the treated paper and textiles, conducted at 60% and 80% relative humidity, showed that weight growth did not differ significantly from the untreated samples, maintaining water retention properties close to the initial ones and assuring product compatibility.

In general, for paper samples, tensile strength analysis gave similar results for all products with higher values of Young’s modulus and slightly higher maximum load values, obtaining a more resistant but stiff material. Instead, treated textiles always presented a decrease of Young’s modulus values in comparison with untreated samples, obtaining in this way a slight negative variation in stiffness and presumably a more flexible material (the maximum load remained similar). High standard deviations were measured due to intrinsic structural differences of the substrates replicates.

After artificial aging (500 hours at circa 8,500 lux), the treated samples did not show significant variation in wettability and chemical composition, as testified by FTIR-ATR analysis. Comparison of the ΔE values between treated and untreated samples underline the products’ stability under solar radiation.

CONCLUSIONS

Cultural heritage conservation products must adhere to specific requirements for chemical and physical compatibility with the substrates. Compatibility can be evaluated by measuring variations in color, WVP,
hygroscopy, mechanical strength, and through aging tests. Our results indicate that all treatments applied to paper and textile led to water-repellent surfaces, both with spray and immersion application methods.

In general, among the tested products, the F1 and F2 formulations performed best, reaching a compromise between the requirements previously mentioned. The F3 treatment also assured positive values of WVP, mechanical strength, and wettability, but the high percentage of nanoparticles considerably whitened the samples’ surfaces. The F4 formulation was the least effective due to its wide color changes and unfavorable variations in WVP. The performance of the products was not influenced by the structure or the physicochemical characteristics of the supports, assuring their versatility and potential application for the conservation of paper and textile.

Immersion applications are recommended because of they showed the best performance, but spray applications would be preferable for fragile documents and canvases with preparation layers.

**Curriculum Vitae**

Giulia Mazzon is a conservation scientist and a chemist. She has a master’s degree in chemical sciences for conservation and restoration from Università Ca’ Foscari.

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Muhammad Zahid is a PhD student. He is also an employee in the Smart Materials Group, Nanophysics Department, Istituto Italiano di Tecnologia, Genoa.

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*(Endnotes)*


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An Overview of Nanolime as a Consolidant for Calcareous Substrates

Jorge Otero, a A. Elena Charola, b Carol Grissom, b Vincenzo Starinieri a

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b Smithsonian Institution, Washington, DC, United States of America.

INTRODUCTION

Nanolime consists of nanoscale particles of calcium hydroxide \((\text{Ca(OH)}_2)\) that are applied in alcohol-based dispersions to wall paintings, limestones, lime mortars, and renders; in particular, as a preconsolidation treatment to improve surface cohesion. For decades, organic and inorganic consolidants have been used for the consolidation of these substrates. The use of organic consolidants such as acrylic, epoxy, or vinyl resins has been common in restoration treatments since 1960. However, the low compatibility with the substrate and the poor durability of the materials may cause degradation processes and interfere with future treatments. In contrast, inorganic-based consolidants such as barium hydroxide and limewater have a high physicochemical compatibility with the substrate and good durability. The nanolime treatment is similar to the traditional limewater technique, where a saturated solution of \(\text{Ca(OH)}_2\) in water is used to impregnate the treated surface. Following evaporation of water and the reaction of \(\text{Ca(OH)}_2\) with atmospheric \(\text{CO}_2\), calcium carbonate precipitates into the pores of the treated substrate. However, the traditional technique has some limitations, such as the low solubility of \(\text{Ca(OH)}_2\) in water and the deterioration of the treated substrate associated with application of large amounts of limewater solution. The use of nanolime in alcohol allows incorporation of larger amounts of lime into the treated substrate with far less water, yielding better penetration and faster carbonation. Nanolime began to be tested for application to the conservation of wall painting in 2001, 1 and this article reviews the considerable literature that has been produced.

NANOLIME SYNTHESIS

In most cases the synthesis of \(\text{Ca(OH)}_2\) nanoparticles follows a bottom-up process involving chemical precipitation from a liquid phase. Before nanolime was first synthesized, Giorgi et al. 2 obtained colloidal alcohol dispersions of \(\text{Ca(OH)}_2\) particles with higher stability and particle content than water-based solutions. Later, Salvadori et al. 3 developed a method for synthesizing \(\text{Ca(OH)}_2\) nanoparticles in diols. The synthesis pathway developed by University of Florence was adopted by several authors, who also tested the use of different precursors and surfactants. 4 Taglieri et al. 5 synthesized nanolime using an anion exchange resin (\(\text{OH}^-\) group). They obtained nanoparticles with better features (size, morphology, and reactivity) and by means of a shorter process.

NANOLIME APPLICATIONS AND CONSOLIDATION MECHANISM

Nanolimes have been tested as conservation treatments for various types of substrates. They have been shown to be effective for the deacidification of paper, wood, bones, and canvas and for a superficial consolidation treatment on wall painting, limestones, lime mortars, and plasters. 6 However, when a deep consolidation is needed, as in the case of large portions of weathered porous substrates, the results vary significantly among materials. 7

The degree of consolidation achieved in limestone and mortar depends on the characteristics of the consolidant...
(type of solvent, nanolime concentration and particle size, morphology, and specific surface area), physical and mechanical characteristics of the substrate, extrinsic factors (relative humidity [RH], exposure time, available CO₂), and application method. The residual water content in the alcohol medium (1:10 W/A ratio) has been shown to enhance the carbonation process. Lopez Arce et al. studied the influence of RH on carbonation kinetics and found that the optimum carbonation rate was achieved at 75% RH. Baglioni et al. measured the time required for the carbonation to occur at room temperature at high RH values (75%) and showed that full carbonation was achieved in 9–10 days. Slizkova et al. studied the influence of repeated applications and found that the optimum amount of consolidant varied with stone porosity. Borsoi et al. investigated the performance of different solvents on stones of different porosity and found that solvents with slower evaporation rates may improve the deep deposition of nanolime in large porous stones. Recently, Rodriguez-Navarro et al. studied the kinetics of Ca(OH)₂ (lime putty and commercial nanolime) conversion into calcium alkoxides in alcohol during storage, showing that freshly prepared alcohol dispersions provide faster and more-effective consolidation.

CONCLUSIONS

Nanolime is a promising consolidation treatment for calcareous substrates. However, further research is required to address its limitations. In particular, study is needed of the incomplete carbonation of the lime, especially at depth, which reduces the effectiveness of the method when a deeper consolidation of the substrate is required.

ACKNOWLEDGMENTS

This work was funded through the Cantor Global Mobility Scheme and a Vice-Chancellor Scholarship within the Doctoral Program at the Materials and Engineering Research Institute, Sheffield Hallam University, UK.

CURRICULUM VITAE

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BIBLIOGRAPHY


The Mosaic Panel from Orvieto in the Victoria and Albert Museum: pXRF and SEM-EDX as Tools of Assessment

INTRODUCTION

The mosaic panel representing The Nativity of the Virgin (1365) is the last fragment from the facade of the gothic cathedral of Orvieto, in central Italy. Since 1891, the panel has been part of the collection of the Victoria and Albert Museum (V&A) in London. The focus of the present study was to address late medieval and Renaissance mosaic technology in Italy. A further aim was to assess the extent to which portable X-ray fluorescence spectrometry (pXRF) can provide useful information on glass mosaics.

The majority of the tesserae result from the remelting and recycling of different glasses. High potash and relatively high lead oxide levels link the Orvieto evidence to coeval examples of Tuscan mosaics and to later productions from Rome. However, the lack of archaeological evidence for mosaic making does not allow further conclusions about the local production of glass in Orvieto.

METHODS & METHODOLOGY

Sixteen loose tesserae and one mortar fragment were analyzed using SEM-EDX, optical microscopy, and pXRF. Subsequently, 121 samples were analyzed through pXRF. The accuracies were preliminarily calculated by correlating the results of pXRF against the results from scanning-electron microscopy–energy dispersive X-ray spectroscopy (SEM-EDX) and referring to the certified recommended compositions. The comparison of SEM-EDX and pXRF allowed quantitative evaluations of errors.

The color grouping was achieved using the Munsell Book of Color. Green, red, blue, gold, “black,” and flesh tones were researched as separate groups (Fig. 01). Mean values and standard deviations were collected for each measurement.

Ex Situ Analyses

Three essential glass components were addressed: glass paste, opacifiers, and pigments, each further determined by looking at major, minor, and trace elements. Lengthwise and cross-sectional samples of the glass tesserae were obtained with a diamond saw and then embedded in resin blocks.

In Situ Analyses

Based on the high variety of colors and shades, panel 6 (Fig. 01) was chosen for the pXRF measurements. The instrument was an Innovix Systems Delta Premium XRF Analyzer equipped with a camera and a 3 mm collimator that works in energy mode (1–40 kV) with a thermoelectrically cooled detector. Generally, this type of instrument provides reliable analytical response for layer thicknesses ≤ 300 µm and surfaces ≥ 10 mm².

RESULTS & DISCUSSION

Preliminary attributions of historical versus modern tesserae are summarized in Table 1 so as to reconstruct the conservation-restoration history of the object over time (e.g., mortars, repairs). A synthesis of the
Fig. 01. The mosaic, named panel 6, is laid out horizontally in the sculpture conservation studio. The image is an overview of the tesserae analyzed and the color groups studied separately. The drawing represents the approximate location of the 121 tesserae analyzed by using the pXRF (Innovix Delta). The in situ and nondestructive analytical campaign lasted three days, even though several preliminary investigations were conducted in the laboratory to optimize the analytical parameters. Source: Original image of the panel © Victoria and Albert Museum, London, 2006. Graphic adaptations, Daniela Reggio, 2014.
Micromorphological features of the samples and their chemical composition is presented in Table 1, including interpretations of the production technology.6

Opaque green and green-blue translucent tesserae were analyzed. The overall texture of this type of glass appeared inhomogeneous and bubbly. The opacifying effect was provided by the air in the bubbles and by white inclusions identified as mineral phases dispersed within the amorphous glass matrix. Pieces of crushed rock were used to opacify the glass, as confirmed by imaging and microanalysis. However, the lack of a standardized production method was reflected in the scattered chemical composition. Remelting of different tesserae is likely. The pXRF analyses confirmed that the coloring agents were based on Cu and Fe and the opacifiers on Sn and Sb.

Translucent and opaque red glasses presented a homogenous matrix. Compared to the other tesserae, the red ones were usually bright and their distinctive intensity did not fade over time. Further, copper sulfide prills were detected with SEM-EDX, showing the addition of bronze scraps. This was also confirmed by the linear correlation between Sn and Cu, as determined through pXRF.

Crystalline phases dispersed in an amorphous glass matrix were recorded in all five shades of blue tesserae. Randomly distributed white and yellow inclusions were observed through optical and electron scanning microscope and might have been constituted by cassiterite and lead stannate. As for the glass paste, mixed alkali sources were confirmed by the copresence of high contents of Na2O and K2O. The pXRF measurements confirmed the positive correlation between color intensity and concentration of cobalt (Fig. 02).

Further, narrow “black” tesserae, characterized only by pXRF, presented a scattered chemical composition. Mn and Fe were constantly detected in these tesserae as part of the coloring process. Sb and Sn were not constantly associated, and this might be a clue to spotting earlier tesserae opacified only with Sb. Unusual concentrations of As and Co were also detected, demonstrating that more than one technological tradition was involved in the production of these glass mosaics.

Finally, the gilded tesserae were multilayered, with a transparent top layer (cartellina), metal leaf, and a support layer. The support layers were opaque black, transparent light green, and yellowish-colorless. The glass texture was uniform, although some bubbly features were detected. White inclusions were dispersed in the tesserae, and Cu was detected. The pXRF analysis revealed pure Au and its alloys, indicating at least two technological traditions.
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<tr>
<td></td>
<td>9.09</td>
<td>2.03</td>
<td>3.77</td>
<td>51.84</td>
<td>0.29</td>
<td>bdl</td>
<td>0.61</td>
<td>4.94</td>
<td>1.43</td>
<td>0.11</td>
<td>1.78</td>
<td>1.22</td>
<td>0.77</td>
<td>3.44</td>
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<td>12.71</td>
</tr>
<tr>
<td>SAMPLE 3 - Blue</td>
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<tr>
<td></td>
<td>10.37</td>
<td>2.44</td>
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<td>60.92</td>
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<td>6.09</td>
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<td>1.87</td>
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<td>4.81</td>
</tr>
<tr>
<td>SAMPLE 1 - Gilded (Cartellina, or top layer)</td>
<td></td>
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<tr>
<td></td>
<td>11.83</td>
<td>2.68</td>
<td>1.67</td>
<td>65.29</td>
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<td>0.24</td>
<td>0.83</td>
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<td>10.34</td>
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<td>SAMPLE 2- Gilded (Cartellina, or top layer)</td>
<td></td>
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<td>SAMPLE 2 – Gilded (Bottom layer)</td>
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<td>0.31</td>
<td></td>
<td></td>
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<td>2.17</td>
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<td>0.79</td>
<td>0.09</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 01. Results of the SEM-EDX analyses (reported in weight percent); bdl is below detection limit. Mean values are reported, and the associated standard deviations are in italic. The number below the measured values. The total concentration for each sample is 100%. The color groups are indicated in the left-side column and the samples highlighted in bold are attributed to nonoriginal production technologies. Green: sample 1 has very high Pb and Sb, resulting from remelting. Not reported in the table is the presence of Co in quantities at the limit of detection for samples 2, 3, and 4, also confirming remelting practices. Red: K levels in sample 4 are lower compared to the other samples, and Sb and Pb are not detected. Blue: in sample 3, not reported in the table, it has 1.64% by weight of As. This shows that modern decoloring agents are being used. Accordingly, in samples 1 and 2, Co is present in low concentrations (0.26 and 0.17% by weight respectively), and sample 3 does not have any. Gilded: these samples are 3 and the composition of the cartellina layer are reported for the first 2, as they differ substantially from the support layers. In sample 3, top and bottom glasses have the same composition. Pb, Sb, and impurities bearing S and Cl compounds are missing too. The tesserae in bold are attributed to nonoriginal production technology.
RESULTS & CONCLUSIONS

The glass composition of the tesserae determined using SEM-EDX was extended through pXRF. Preliminary tests with certified reference glass (Corning A, B, C, D) have shown that the pXRF enables relative concentrations of several elements (e.g., Cu, Mn, Sb) to be evaluated. Remelting of raw glass was reflected in the scattered composition of the tesserae. Mixed alkali sources were being used, probably combining ashes from different plants and geographical areas. Finally, the interpretation of the technological processes based on the chemical composition and the microscopic analyses confirmed that the Orvieto panel provides evidence of transitional glass-making traditions in central Italy during the late medieval and Renaissance period.

ACKNOWLEDGMENTS

This research was conducted under the supervision of Ian Freestone, head of the Wolfson Archaeological Science Laboratories, University College London. Thanks also to Charlotte Hubbard, head of the V&A sculpture conservation studio, and Victor Borges, senior sculpture conservator. Peta Motture, senior curator of the Medieval and Renaissance Galleries at the V&A, kindly granted the permission for sampling.

CURRICULUM VITAE

Daniela Reggio was trained at the Sapienza Università di Roma and at University College London. She is currently at the Universidade de Santiago de Compostela within the H2020 EU project NanoRestArt.

BIBLIOGRAPHY


(Endnotes)


Academic Nude Paintings (Late 19th and Early 20th Century) from the Lisbon Fine Arts Faculty Collection—Initial Insights from a Preliminary Multi-analytical Study

Ana Mafalda Cardeira, a,b Ana Margarida Cardoso, b António Candeias b

a Universidade de Lisboa, Portugal
b Universidade de Évora, Portugal

INTRODUCTION

The collection of the Faculty of Fine Arts of the Universidade de Lisboa (FBAUL) includes academic nude paintings created by students at the end of the 19th century and beginning of the 20th, a time when the influence of naturalism on teaching methods was starting to give way to the influence of modernism. By undertaking a technical and material study of some of these paintings, we sought to improve our understanding of that transition, as well as the fundamentals of painting methodology at the old Lisbon Academy of Fine Arts. For this initial attempt to characterize how the academy taught the oil-on-canvas technique at the turn of the 20th century, 20 nude paintings created by students in Lisbon and during their time in Paris as student borders were selected for study.

METHODS & METHODOLOGY

Sample Description
The study sample comprised 20 19th- and 20th-century academic nude paintings from the Universidade de Lisboa’s fine arts collection. In situ analyses were made using portable infrared reflectography, radiography, and energy dispersive X-ray fluorescence (EDXRF). All microsamples were mounted in EpoFix™ epoxy resin, observed with a DM 2500 microscope and Leica® DFC 290HD camera using 10x magnification and analyzed by Raman spectroscopy, Fourier transform infrared spectroscopy (FTIR), and scanning-electron microscopy–energy dispersive X-ray spectroscopy (SEM-EDS).

Infrared Reflectography

Infrared reflectography was performed in situ with an OSIRIS infrared camera operating at wavelengths from 900 to 1,700 nm. This camera has an InGaAs array sensor with a 0.05 mm resolution. Made by Rodenstock®, it has a focal length of 150 mm and aperture of f/5.6–f/45. Reflectograms were recorded at a working distance of 170 cm, with a focus of 20 cm, f/11 aperture, and diffused illumination at 1,000 lux reflectors with 2 Å–1,000 W tungsten halogen Quartz Light VC-1000Q.

Radiography

Digital radiographs were obtained using a GE XR 200, with a pulsed beam operating at 150 Kyp, with 25 pulses of 60 ns. Digital image capture devices were reusable medium-size photostimulable phosphor plates (37 cm Å– 43 cm) that, after being radiated, were scanned using a Dürr HD-CR 35 NDT scanner for analysis by computer imaging software.

Portable EDXRF

All specimens in the collection were analyzed by a handheld X-ray fluorescence analyzer. XRF spectroscopy was performed using a Bruker Tracer III-SD spectrometer with a silicon-drift (SDD) detector (XFlash®). Analyses were made with the following conditions: tube voltage of 40 kV, tube current at 30 μA, without filter, and with a measuring time of 100 s (lifetime). Spectra were acquired using S1PXRF software (Bruker).

Micro-Raman Spectroscopy Analysis

Raman analyses were undertaken with a HORIBA Jobin Yvon XploRA confocal spectrometer, using a 785 nm excitation wavelength, with maximum incident power of 0.2 mW and performed in a range of 3,200–100 cm\(^{-1}\). Spectra deconvolution was achieved by LabSpec (V5.78). The identification of pigments was made in agreement with literature, Spectral ID, and Kremer references spectra.

Micro-FTIR Analysis

The identification of binders was performed by \(\mu\)-FTIR using a Bruker Hyperion 3000 microspectrometer equipped with a medium-chain triglyceride detector and an objective of 15 Å– in transmission mode using a compression diamond cell from ST Japan. Spectra were acquired with 4 cm\(^{-1}\) spectral resolution, taking the average of 64 scans, within the infrared region of 4,000–600 cm\(^{-1}\).

RESULTS & DISCUSSION

Because of the infrared radiation reflectance of carbon-based materials, infrared reflectography revealed a distinct underlayer applied by the painters. In most of the paintings, reflectograms revealed outlines, contours, guide lines, and painters’ pentimenti. Because of the high absorption of X-ray radiation by Pb, radiographic imaging

<table>
<thead>
<tr>
<th>ID Painting Number</th>
<th>Separate layer</th>
<th>Mixed layer</th>
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</thead>
<tbody>
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<td>4102</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>3635</td>
<td>X</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>4103</td>
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<td>4076</td>
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<tr>
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<td>X</td>
</tr>
<tr>
<td>3673</td>
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<td>X</td>
</tr>
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</table>

Table 01. Preparation layers found on the 20 paintings under study
revealed the distribution of lead-based inks. In the case of painting 4105, infrared reflectography and radiography revealed an underpainting (upturned) (Fig. 01).

EDXRF was used for a first attempt to characterize materials in situ, and pigments were characterized by means of FTIR and Raman spectroscopy. EDXRF spectra revealed the constant presence of S, Ca, and Pb, related to the use of calcium- and lead-based compounds. FTIR and Raman spectroscopy confirmed the presence of gypsum, calcite, and white lead. Furthermore, FTIR analyses revealed how these compounds were used on the preparation layer. Microscope imaging was used as a first approach to distinguish two types of preparation layers, and SEM-EDS provided better insight and confirmation of where the compounds were applied separately or intermixed (Table 01).

In most paintings, the constant presence of Pb suggests that lead-based pigments were applied to both the preparation layer and light shades. However, in paintings 4076 and 4077, lead-based pigments were applied only to the preparation layer, and zinc-based pigments were used to achieve light shades. Skin tones were achieved with a complex mixture of white, yellow, blue, brown, and black pigments. Light shades used more white and yellow compounds, and dark tones were obtained with more blue and brown pigments. Background coloring was produced by intermixing all pigments. In paintings 4077 and 4099, made by the same artist between 1910 and 1918, chrome yellow (PbCrO$_4$) was applied instead of yellow ochre (FeOOH). Furthermore, zinc yellow was found in paintings made in 1910 by another artist. Zinc yellow (ZnCrO$_4$) is artificial, nontoxic, and does not darken with time, thus making it a suitable alternative for chrome yellow. Table 02 summarizes pigments characterized by coloring area.

The FTIR analyses provided insights into the media used by the painters, confirming that oil was applied in all paintings and that in most cases resin was used as a protective layer.

CONCLUSIONS

EDXRF, SEM-EDS, FTIR, and Raman spectroscopy techniques proved to be suitable to characterize the

<table>
<thead>
<tr>
<th>Color area</th>
<th>Pigment</th>
<th>Formula</th>
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</thead>
<tbody>
<tr>
<td>White</td>
<td>Lead white</td>
<td>$2\text{PbCO}_3 \cdot \text{Pb(OH)}_2$</td>
</tr>
<tr>
<td></td>
<td>Titanium white</td>
<td>TiO$_2$</td>
</tr>
<tr>
<td></td>
<td>Barium white</td>
<td>BaSO$_4$</td>
</tr>
<tr>
<td></td>
<td>Zinc white</td>
<td>ZnO</td>
</tr>
<tr>
<td>Yellow</td>
<td>Yellow ochre</td>
<td>FeOOH</td>
</tr>
<tr>
<td></td>
<td>Chrome yellow</td>
<td>PbCrO$_4$</td>
</tr>
<tr>
<td></td>
<td>Zinc yellow</td>
<td>ZnCrO$_4$</td>
</tr>
<tr>
<td>Red</td>
<td>Red ochre</td>
<td>Fe$_3$O$_5$</td>
</tr>
<tr>
<td></td>
<td>Vermilion</td>
<td>HgS</td>
</tr>
<tr>
<td>Blue</td>
<td>Ultramarine</td>
<td>Na$_{8-10}$Al$<em>6$Si$<em>6$O$</em>{24}$S$</em>{2-4}$</td>
</tr>
<tr>
<td></td>
<td>Prussian blue</td>
<td>Fe$_2$$[\text{Fe(CN)}_6]_3$</td>
</tr>
<tr>
<td>Green</td>
<td>Viridian</td>
<td>Cr$_2$O$_3 \cdot 2\text{H}_2\text{O}$</td>
</tr>
<tr>
<td>Brown</td>
<td>Raw Sienna</td>
<td>Fe$_3$O$_5$</td>
</tr>
<tr>
<td></td>
<td>Burnt Sienna</td>
<td>SiO$_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$</td>
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<tr>
<td></td>
<td>Hematite</td>
<td>Fe$_3$O$_5$</td>
</tr>
<tr>
<td>Black</td>
<td>Lamp black</td>
<td>C</td>
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</table>

Table 02. Pigments characterized by color area
priming layer and the palette used in these academic nude paintings. These analyses allowed a first characterization of materials used by students at the Lisbon Fine Arts Academy, including the nature of pigments and mixtures used to obtain different skin tones.

Further research with this group of paintings will examine how those produced in a Portuguese master class differ from those produced in a French master class in order to provide information about differences in training methodology and possible technical exchanges between the Portuguese and French academies of fine art.

**ACKNOWLEDGMENTS**

We thank the Faculty of Fine Arts of the Universidade de Lisboa for lending these artworks for investigation. Ana Mafalda Cardeira acknowledges the support of Fundação para a Ciência e Tecnologia, PhD program HERITAS grant PD/BI/113816/2015.

**CURRICULUM VITAE**

Ana Mafalda Cardeira is a PhD student in fine arts, sciences of art, at the Faculty of Fine Arts of the Universidade de Lisboa. Her research focuses on modernist influences in the academic nude paintings of the FBAUL collection.

Ana Cardoso is a PhD student in art history at the Universidade de Évora.

António Candeias is a chemistry professor at the Universidade de Évora specializing in surface chemistry and applications of chemistry to cultural heritage. He is director of the Laboratório Hercules.

**BIBLIOGRAPHY**


(Endnotes)


INTRODUCTION

Infrared thermography is a non-destructive and contactless technique based on the distribution of the radiant infrared energy emitted from a target which, in general, is represented in form of apparent surface temperature images. There are two different thermographic methods in function of the heat source: passive thermography in which a single image of an object is taken, and interpreted qualitatively, looking for anomalies in the distribution of apparent surface temperatures; while in active thermography, several images are taken in sequence while exciting thermally the object with an external heat source, as lamps and ovens. Thermal excitation may reveal subjacent defects by contrasting thermal responses. In both types of analyses, heat transfers between different materials or between the material and the environment are characterized. The principal advantage of this technique is that the heterogeneities in the near surface region (fissures, cracks, humidity, etc.), even in the initial stages of the degradation process, can induce measurable differences of temperature; however, the most significant inconvenient of this technique is that low emissivity materials, such as metallic materials can reflect the irradiation which could induce experimental errors.

In recent years, infrared thermography has been successfully applied to characterize the state of conservation of historical buildings, mural paintings and, to a lesser extent, archaeological and historical objects like mosaics, sculptures, paintings and jewelry. However, studies on glassy materials are scarce and they are focused on the evaluation of windows for industrial purposes.

Stained glass windows are complex artworks composed by glasses, which can be painted with grisailles and enamels, mounted on lead cames to form window panels. These cames are usually soldered to each other using a melted tin–lead alloy. The characterization of the materials of the stained glass windows is commonly carried out during their restoration, since the panels are dismounted and transported to the workshop.

In this study we present the results of the in-situ characterization of two different stained glass windows by infrared thermography. The studied artworks are the contemporary stained glass window entitled “Saint George and the dragon”, and a 20th century stained glass window from the CSIC headquarters in Madrid representing the allegories of Sciences, which was elaborated by the Mauméjean Frères workshop.

METHODS & METHODOLOGY

The characterization of glasses, enamels, grisailles, lead cames and tin–lead welds was carried out by infrared thermography. The thermographic analysis of the stained glass window entitled “Saint George and the dragon” was carried out with a FLIR ThermaCAM B4 (7.5 to 13 μm wavelength range, -20 to +130 °C temperature range and 0.08 °C of temperature accuracy) in transmission and reflection modes, and the 20th century stained glass window from the CSIC headquarters just in reflection mode. The studies were carried out by active thermography illuminating the stained glass windows during 10 min. The light source was a 500 Watts halogen lamp, because it resembles a black-body emission.
RESULTS & DISCUSSION

Each material has a different response to the infrared radiation of the spotlight, which was detected by infrared thermography.

In reflection mode, glasses showed an increase of the surface apparent temperature due to the reflection of the infrared radiation and the warming of their surface. The spotlight was switched off after 10 minutes of irradiation and the glasses experienced a progressively cooling (Fig.01). In transmission mode, glasses presented a significant increase of the surface apparent temperature due to the radiation transmission through them. This surface apparent temperature abruptly decreased after turn the spotlight off (Fig.01).

In reflection mode, glasses painted with enamels experienced a higher increase of their surface apparent temperature due to the warming of this layer. It was observed that thicker layers of enamel increased more the surface apparent temperature of the glass fragment than thinner ones (Fig.02 a). This effect was more intense in transmission mode in which the difference of the surface apparent temperature between the transparent glass and the glasses with enamels was over 2 °C. A similar effect was observed in the glasses painted with grisaille. The areas with thick lines showed the most important increase of surface apparent temperature (Fig.02 a). This temperature difference between the surface layers and the supporting glasses can induce the formation of thermal stress, and could originate fissures and cracks on enamels and grisailles.

In contrast to the thermal variations of glasses, enamels and grisailles, metallic materials presented an almost constant surface apparent temperature in transmission mode because of their low heat capacity. In reflection mode, lead cames showed an almost constant surface apparent temperature during the analysis and metallic tin–lead welds presented an important increase of the surface apparent temperature due to the energy reflected on its surface (Fig.02 b).

Similar results were observed in the stained glass window from the CSIC headquarters in reflection mode (Fig.03 a). Glasses, enamels and grisailles experienced the increase
of the surface apparent temperature followed by the progressive cooling after switched the spotlight off (Fig.03 b). As in previous results, thicker layers of enamels and thicker lines of grisailles presented the highest increases of surface apparent temperature, even the different enamels could be distinguished in the thermographic map (Fig.03 c).

CONCLUSIONS

Two stained glass windows have been successfully characterized with infrared thermography. Each material showed a different behavior. Glass, enamels and grisailles presented an increase of the surface apparent temperature followed by a progressive decrease due to the warming of the surface; lead cames maintained an almost constant surface apparent temperature, except those painted that behave in a similar way than enamels. Metallic tin–lead welds experienced the most important variation of surface apparent temperature due to the energy reflected by the surface of the weld.

Acknowledgements

The authors are deeply indebted to the Subdirección General de Obras e Infraestructuras (CSIC, María del Carmen González Peñalver) and the Servicio de Patrimonio (CSIC, José Antonio Ocaña Martínez), for providing official permissions, access, and kind cooperation to carry out this scientific research. They also acknowledge the partial funding of the Fundação do Ministério de Ciência e Tecnologia de Portugal (Ref. SFRH/BPD/108403/2015) and the research program GEOMATERIALES 2-CM Program Ref. S2013/MIT-2914 from the Community of Madrid. Finally, the authors wish to mention the professional support of the Spanish TechnoHeritage network.

CURRICULUM VITAE

Teresa Palomar, postdoctoral scientist at the New University of Lisbon, has focused her research career in archaeometry and conservation of inorganic materials, mainly glass. Fernando Agua, technician in the Department of Art History and Heritage in the Institute of History (CSIC). He is specialized in materials science and characterization, mainly glasses and ceramics.

María-Ángeles Villegas, is senior scientist at the institute of History (CSIC). Her research interests are about Cultural Heritage conservation, and the application of chemicalphysical techniques for archaeometric characterization of materials.

Miguel Gomez-Heras is scientist at the Geosciences Institute (CSIC, UCM) where he works on non-destructive testing of heritage materials. He holds the ITC Level II thermography certification.

BIBLIOGRAPHY


(Endnotes)

INTRODUCTION

The San Giovanni Addolorata Hospital in Rome, Italy, covers an area of exceptional archaeological interest, with features dating from the Roman Republic and Empire to the late Middle Ages. One of the most recent discoveries from this archaeological area is the Domus Valeriorum. This article presents the results of micro-Raman spectroscopy and energy dispersive X-ray microanalysis (EDX) studies of two second-century CE stucco fragments from the Domus Valeriorum obtained through COBRA, a project of the Agenzia Nazionale per le Nuove Tecnologie, l’Energia e lo Sviluppo Economico Sostenibile (ENEA) focusing on cultural heritage, availability, and perspectives for technology transfer. The samples were analyzed in laboratory to determine their component materials and the identities of the pigments used thereon. Cinnabar, malachite, and Egyptian blue were detected as pigments by the synergistic use of the two techniques, whereas chalk and calcite were detected as materials for the bas-relief figures. This nondestructive analysis was the first to be carried out on the Domus Valeriorum finds.

METHODS & METHODOLOGY

Raman Spectroscopy

A portable i-Raman spectrometer (B&W TEK Inc., USA) provided with a 785 nm excitation laser source and a CCD detector thermoelectrically cooled to 10°C was used. The spectrometer, having a resolution of 3 cm⁻¹, covers the spectral range 789–1048 nm, corresponding to Raman shifts of 75–3200 cm⁻¹. The excitation source is a GaAlAs solid-state diode laser with scalable power in the 3–300 mW range. During the measurements, the laser’s power was set to a few milliwatts to prevent pigment photodecomposition. Typical integration times were 1–10 seconds, with an average of 3–10, giving rise to a total exposure time of 3–100 seconds for each measurement.

Energy Dispersive X-ray Analysis (EDX)

A SEM-EDX “INCA” (Oxford Instruments) was used. The microanalysis was performed with an electron beam of 200 pA and 10 KeV and an acquisition time of 60 seconds in an area of the samples where crystals appeared to be distributed homogeneously. The main atomic constituents of the crystals (both malachite and Egyptian blue) were determined by observing the emission of their K-alpha lines, specifically at 277 eV for C, 524.9 eV for O, 1740 eV for Si, 3691.7 eV for Ca, and 8047.8 eV for Cu.

Samples

Two second-century stucco fragments from Domus Valeriorum (Fig. 01), “Sample 1” and “Sample 2,” were examined. Each fragment was approximately a few tens of cm2 with a thickness of about 5 cm. Sample 1 showed a white figure in relief on a granulated background of green color. Sample 2 showed a white figure in relief, apparently of the same material as the first, on a granulated background of green-blue shades. On Sample 2, two whitish edges were slightly raised (1–2 mm), and a red area was present on the edge. The samples’
background was stucco. With Raman spectroscopy, we attempted to find the composition (in terms of pigment) of the various colored zones and figures in relief.

RESULTS & DISCUSSION

The Raman spectra of the bas-reliefs from the two samples presented a strong fluorescence signal and some Raman peaks. After eliminating the fluorescence contribution, we obtained the elaborated Raman spectra, which showed the same result for both samples (Fig. 02a). The observed peaks were located at 153 cm$^{-1}$, 283 cm$^{-1}$, and 1084 cm$^{-1}$ in the case of calcite (CaCO$_3$). After the elaboration of the Raman spectrum of the white rim of Sample 2 (Fig. 02b), we were able to identify peaks that can be attributed to calcite (1084 cm$^{-1}$) and gypsum (1005 cm$^{-1}$). The red edge of Sample 2 gave a Raman spectrum identical to cinnabar (HgS) (Fig. 02c).

Observing Sample 1 under the optical microscope revealed that the green color was due to green microcrystals on a composite base where dark or reddish particles on a white background also appear. The blue pigmentation of Sample 2 had a similar structure to that of the green area of Sample 1; however, the source of the background color was observed to be blue rather than green microcrystals. The Raman spectra in this case (Fig. 02d) were affected by a wide fluorescence band and have not yet been assigned to a specific material. To clarify and test hypotheses about the nature of the unidentified pigments, an EDX survey was carried out on two small fragments of green and blue pigment. Compositional analysis revealed the presence of Cu, C, and O in the green microcrystal belonging to the green area of Sample 1, as would be expected from pigment malachite (Cu$_2$CO$_3$(OH)$_2$), as well as traces of Ca, probably as an impurity of the substrate in which the crystal was immersed. The EDX does not detect hydrogen, so the atomic percentages of the various elements were in line with the stoichiometry of malachite (without considering hydrogen): Cu, 2 atoms of 8 = 2/8 ~ 25%, O 5/8 ~ 62.5%, C 1/8 ~ 12.5%). Thus, the presence of the crystalline malachite green pigment was confirmed by the EDX compositional analysis.

Fig. 01. IInd-century stucco fragments from Domus Valerium: Sample 1 (A) and Sample 2 (B).
The compositional analysis of a blue microcrystal belonging to the blue area of Sample 2 revealed the presence of Cu, Ca, Si, and O, as would be expected from pigment cuprorivaite (Egyptian blue) \((\text{CaCuSi}_4\text{O}_{10})\). C was also found, probably as an impurity. The atomic percentages of the various elements were in line with the stoichiometry of cuprorivaite \((\text{Cu}, 1 \text{ atom of } 16 = 1/16 \approx 6\%, \text{Ca} 1/16 \approx 6\%, \text{Si} 4/16 \approx 25\%, \text{O} 10/16 \approx 62\%)\). The scaled measured percentages were due to the quantitative not negligible C. Impurities of calcite \((\text{CaCO}_3)\) or other compounds might have slightly altered the measured stoichiometry. Nevertheless, the identification of Egyptian blue pigment on the blue area of Sample 2 was supported by the EDX compositional analysis.

CONCLUSIONS

Within the frame of the COBRA project, Roman fresco pigments from Domus Valerium samples were characterized by applying Raman spectroscopy as a rapid, nondestructive, accurate, and applicable in situ analysis. The pigments were identified by comparing their Raman spectrum results with the Raman spectra of reference pigments/materials.

In some cases, due to the fluorescence background in the Raman spectra of some areas of the samples and due to their composite nature, the identification of the pigments was not possible and a further characterization by EDX was required. EDX compositional analysis provided evidence for the presence of malachite and cuprorivaite on the analyzed samples.

Acknowledgements

We acknowledge the financial support of the COBRA project. The samples were analyzed in return for the concessions and for the interest of G. Bandini and S. Morretta (Superintendence for the Colosseum, Museo Nazionale Romano, and the Archaeological Area of Rome).

Curriculum Vitae

Adriana Puiu is a physicist with a PhD in quantum electronics, a researcher at ENEA, and an expert in molecular spectroscopy and data analysis. She is involved in the development and application of laser techniques for cultural heritage.

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Luisa Caneve has a degree in physics and is a senior researcher at ENEA with experience in the application of laser spectroscopic techniques (LIBS and LIF) in areas such as environmental monitoring, cultural heritage, security, and energy.

Stefano Lecci has an MS in biological sciences and is a technical expert at ENEA. He has expertise in scanning electron microscopy, EDX, and electron backscattering diffraction.
Valeria Spizzichino has a PhD in chemical science and is a researcher at ENEA. She is an expert in Raman, LIF, and atomic spectroscopy and is skilled in prototypal laser apparatus and data analysis procedures.

Giacomo Casaril is a conservator restorer with 30 years of experience. He works as a private firm on behalf of superintendencies carrying out the conservation of paintings, stone, mosaics, stuccos, and ceramics.

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INTRODUCTION

Lime mortar is characterized by high porosity, low mechanical strength, good workability, and so on. Such properties make the mortar vulnerable to physical, chemical, and biological attack. In all cases of deterioration, water plays an important role due to the mortar’s high porosity.

Pozzolanic substances may be added to reduce porosity and lower the possibility of weathering due to chemical attack. Where mortar porosity cannot be reduced, surface coatings are applied to repel water. Since such products are applied to the outermost surface, they are the components most liable to deteriorate. Due to the small amounts involved, however, determining when they have deteriorated and should be replaced can be difficult. This issue is seldom addressed in the literature, however.²

<table>
<thead>
<tr>
<th>Recording condition</th>
<th>$^{29}\text{Si}$</th>
<th>$^1\text{H}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resonance frequency (MHz)</td>
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<td>40.13</td>
</tr>
<tr>
<td>Pulse duration (µs)</td>
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<td>4.5</td>
</tr>
<tr>
<td>Pulse delay (s)</td>
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<td>10</td>
</tr>
<tr>
<td>No. of scans accumulated</td>
<td>1000</td>
<td>100</td>
</tr>
<tr>
<td>Spinning speed (cycles/s)</td>
<td>4000</td>
<td>10000</td>
</tr>
<tr>
<td>Contact time (s)</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Table 01. Recording conditions for NMR spectra

Spectroscopic techniques can be used to study coatings. The reactivity of siliceous consolidants used to conserve porous cultural heritage materials was studied by Zenndri et al.³ using $^{29}\text{Si}$ NMR, indicating that ethyl silicate exhibited greater reactivity than colloidal silica. Carmona-Quiroga et al.⁴ studied the interaction between antitraffiti and cement mortar using $^{29}\text{Si}$ NMR and revealed that antitraffiti products reacted with C-S-H gel, raising the relative proportion of Si in Q² positions. Domingo et al.⁵ established the best conditions for Raman and Fourier transform infrared spectroscopy (FTIR) to study consolidants and water-repellent treatments.

In the present study, $^{29}\text{Si}$ and $^1\text{H}$ NMR were used to characterize different waterproof coatings before and after their application into lime mortars. Polymerization reactions were studied after curing of the waterproof products in open air over an evaporating dish, without interaction with the substrate. Interaction and polymerization of the coating over the lime mortar was also studied by the same spectroscopic technique.

METHODS AND METHODOLOGY

The lime mortars were made with a 1:1 lime to sand ratio and a water to lime ratio of 0.82. The fresh mortar was poured into 1 x 1 x 0.5 cm molds, demolded after 24 hours, and then stored in a carbonation chamber (21°C and 50% relative humidity [RH]) for one month.

Two noncommercial waterproofing materials were used. Thirty ml of product were placed on an evaporating
dish, and the solvent was allowed to evaporate (40ºC, 30% RH) to obtain reticulated waterproofing materials.\(^4\)

The initial and reticulated waterproofing materials and the lime mortar fully immersed in the waterproofing product were characterized using \(^{29}\)Si, \(^1\)H, and nuclear magnetic resonance (NMR) with magic-angle spinning (MAS). The \(^{29}\)Si and \(^1\)H single-pulse MAS spectra were obtained with a Bruker MSL-400 analyzer. The recording conditions for each of the nuclei are given in Table 01.

**RESULTS AND DISCUSSION**

The two initial waterproofing substances were characterized by \(^{29}\)Si NMR (Table 02).

The results confirmed the presence of ethyl silicate in both coatings, an indication that both products were slightly hydrolyzed. The presence of \(\text{RSi(OMe)}_3\) in the first product makes it an alkylmethoxy-silane, whereas the second is a polymethyl siloxane, with \((\text{CH}_3)_3\text{Si(O-)}\) groups. The alkyl group in the first product is a terbutyl (Table 02).

Two clearly differentiated areas can be distinguished on the spectrum of the first product reticulated on the evaporating dish (Fig. 01), at –49 to –70 and –90 to –110 ppm. The former contains signals for tert-butyltrimethoxysilane with one (–49.0 ppm), two (–57.2 ppm), and three (–66.7 ppm) degrees of polymerization. The four signals in the second zone differ in intensity and correspond to ethyl silicate, nonpolymerized and in different stages of hydrolysis and polymerization. The most intense signals were found for ethyl silicate with three (–101.5 ppm) and four (–110.0 ppm) degrees of polymerization (Fig 01).

Deconvolution of the \(^{29}\)Si NMR spectra (Fig. 02) showed that 10% of the tertbutyltrimethoxysilane formed dimers, 47% formed linear chains, and the remaining 43% reached the highest degree of polymerization. Nineteen percent of the ethyl silicate, in turn, polymerized to degree two, 48% formed branched chains, and 33% formed a three-dimensional silicate. Neither of the two active compounds underwent total polymerization.

Table 02. \(^{29}\)Si MAS NMR spectrum signals and assignment for the initial waterproofing coatings and reticulated

<table>
<thead>
<tr>
<th>Product 1</th>
<th>Product 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial</strong></td>
<td><strong>Reticulated</strong></td>
</tr>
<tr>
<td>-46.9</td>
<td>-49.0</td>
</tr>
<tr>
<td>-53.1</td>
<td>-57.2</td>
</tr>
<tr>
<td>-59.5</td>
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<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>-110.0</td>
</tr>
</tbody>
</table>
at 3.8 ppm (the ethoxy group proton in the ethyl silicate) (Fig. 03). Similarly, the $^{29}$Si MASNMR spectrum for reticulated product 2 (Fig. 01) showed a widening of bands in the –90 to –110 ppm zone, (ethyl silicate polymerization region). The $^1$H MAS NMR spectrum for the second product showed an intense band at 0.3 ppm (Fig. 03), attributed to the proton in the CH$_3$ group attached to the Si. The two small bands (1.0 and 1.4 ppm) were generated by the proton in the CH$_2$ group in -OCH$_2$CH$_3$. Finally, two other bands at 4.5 ppm (narrow) and 7.1 ppm (wide) were attributed to silanol-group hydrogen bonds.

Deconvolution of the $^{29}$Si NMR spectra of product 1 showed two components, centered over –66 and –78 ppm (Fig. 02). The first was assigned to terbutyltrimethoxysilane with three degrees of polymerization (RSi(O-)$_3$), an indication that total polymerization was reached, whereas the second corresponded to ethyl silicate with one degree of polymerization (Si(OEt)$_3$(O-) and Si(OEt)$_2$(OH)(O-)), signifying that total polymerization was not reached. These findings agree with Zendri et al.,$^7$ who observed that ethyl silicate underwent greater polymerization in the presence of CaCO$_3$.

The $^1$H NMR-MAS spectra for the mortars treated with different waterproofing products showed two new signals at 4.8 and 6.2 ppm in product 1 (Fig. 03) from hydrogen bonds between silanol groups. In product 2 (Fig. 03), the broadness of the signal in the 3–8 ppm interval could be due to the hydrogen bonds formed between silanol groups.

The $^{28}$Si cross polarization (CP) MAS NMR spectra for product 2 applied to mortar showed two signal zones, one in the 0–30 ppm range and a higher-intensity envelope in the –46 to –116 ppm interval (Fig. 02). The deconvolution of these two zones yielded signals centered over 10 ppm and –86 ppm, corresponding to polymethylsiloxane in dimer form and ethyl silicate with one degree of polymerization.

CONCLUSIONS

$^{28}$Si and $^1$H NMR is a suitable technique to characterize different waterproof coatings before and after their application into lime mortars as well as to study their degree of polymerization. Product 1 was a mixture...
of terbutyltrimethoxysilane and ethyl silicate that was polymerized to a higher degree applied over the lime mortar (60%) than on the evaporating dish (43%). In the case of product 2, a mixture of polymethylsiloxane and ethyl silicate, 0% polymerized into the evaporating disc, but after application into the lime mortar 20% polymerized, forming dimers.

$^1$H NMR is more suitable than $^{29}$Si NMR for in situ identification of the studied waterproofing compounds.

**Curriculum Vitae**

Carlos Fortes-Revilla has a PhD in chemistry and is a quality assurance manager at Sika. His main research focus is the development of new admixtures.

Maria Teresa Blanco-Varela is a research professor at the Instituto de Ciencias de la Construcción Eduardo Torroja (IETCC-CSIC). Her research focuses on the synthesis, characterization, and durability of artificial building materials.

Sagrario Martínez-Ramírez has a PhD in chemistry. His research is focused on the synthesis and durability of artificial building materials.

**BIBLIOGRAPHY**


(Endnotes)


The Impact of Acid Exposure on Building Stones Studied by X-ray Computed Microtomography

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INTRODUCTION

On buildings, acid rain and dry deposition of gaseous pollutants are major factors in stone alteration processes. Sulfur dioxide (SO$_2$) has been the main pollutant involved in building stone decay, giving rise to crust formation, blackening, yellowing, and carbonate dissolution. Nitrogen oxides (NO$_x$) are better known as catalysts for SO$_2$ oxidation.

In recent decades, the ratios of pollutant emissions have changed, with a decrease of SO$_2$ and an increase in NO$_x$. Some studies indicate nitrate salts might crystallize in depth within stone during exposure to a pure NO$_2$ and a mixed HNO$_3$/H$_2$SO$_3$ atmosphere. One study demonstrated that alterations appeared faster after mixed-acid attacks on stone, compared to attacks by a single acid component.

However, no study has yet highlighted the effects of the alteration processes of a shifted pollutant ratio on internal stone microstructure, different salt location, or crystallization phases over time.

The aim of the research described in this article was to assess the weathering kinetics and the reactivity of two building stones submitted to different acid attacks following the present-day emissions ratio of NO$_x$/SO$_2$. Aging tests based on the UNE-EN 13919 standard and on some studies were performed on two stones with different composition and porosity. Stone changes were assessed over time by X-ray computed microtomography (µCT), a nondestructive 3D imaging technique.

METHODS & METHODOLOGY

The Savonnières limestone (S) and a reconstituted stone (RS) used in this study came from historic buildings. They are still commonly used in the north of France and the south of Belgium.

S is an oolitic vacuolar and calcitic limestone. RS is an artificial stone rich in silicium and was used during the last restoration of Orval Abbey. This heterogeneous material is mainly composed of limestone debris and sand, bonded by a Portland-like cement (Ca- and Si-rich).

Cylindrical samples, 4 mm in diameter and 2 cm high, of each stone were submitted to two types of aging tests, with one sample by stone type and by test:

Dry deposition was simulated by acid atmosphere tests based on the UNE-EN 13919 standard. After saturation of the samples, one sample of each stone was put in a hermetic box above a mixed-acid solution ([H$_2$SO$_3$] = 0.2 mol.l$^{-1}$ and [HNO$_3$] = 0.6 mol.l$^{-1}$), with no contact between the samples and the solution.

Dissolution processes induced by acid rain were simulated by immersing other samples of each stone type in 500 ml of a mixed-acid solution at pH 5 ([H$_2$SO$_4$] = 5.10$^{-6}$ mol.l$^{-1}$ and [HNO$_3$] = 1.10$^{-5}$ mol.l$^{-1}$).

The test duration was 28 days. Samples were fixed on the top of a carbon stem to facilitate the µCT
scanning. Samples were dried in an oven for 60 hours at 40°C and then scanned in μCT. This procedure was repeated after the 1st, 10th, and 28th days of the test.10

On the black-and-white images from the μCT scans, the gray scale depended on the chemical density of the sample, thus the higher the density the lighter the color appears.

RESULTS & DISCUSSION

Acid Atmosphere Test

On S, after one day of exposure, the substitution of carbonates by sulfates led to a receding surface (in red in Fig. 01 a–c) and to an in-depth crystallization that remained stable until the end of the test. The acids reacted with the ooliths and the cement without noteworthy distinction (e.g., the areas circled in white in Fig. 01 a–c).

On RS, a loss of a part of the initial surface was observed (the red areas in Fig. 01 d–f), and a needle-shape crystallization was seen after the first day of the test. The heterogeneity of RS composition made it difficult to distinguish the salts from some of the stone components on the grayscale images (Fig. 01 e, f).

Acid Immersion Test

The progressive dissolution of both stones over time was induced by immersion in a mixed-acid solution simulating acid rain (Figs. 02 and 03).

For S, μCT images revealed that the dissolution of ooliths and matrices was progressive and of similar intensity (Fig. 02 a–c; Fig. 03 a, b). The surface and open porosity were affected (Fig. 02 c; Fig. 03 b). Crystallization of possible nitrates (slightly lighter gray tone than calcite gray tone in the images) was also observed inside some ooliths (e.g., the area circled in yellow in Fig. 02).

For RS, the observations of 2D slices (Fig. 02 d–f) and 3D rendering highlighted an initial dissolution of the matrix followed later by the attack of the calcitic clasts leading to granular disaggregation (Fig. 03 d).

The dissolution was progressive but more significant during the first day of immersion (Fig. 02).

CONCLUSIONS

The two tests led to different alterations. Atmospheric exposure caused mainly salt crystallization, and acid immersion caused dissolution.

During the acid-stone interaction, the dissolution phase that occurs before the crystallization phase is well known and named the “acidity effect.”11 When an acid, for example sulfuric (1) and nitric acid (2), reaches the limestone surface, it is neutralized via the following anionic replacement reactions:

1. \[ \text{CaCO}_3 + \text{H}_2\text{SO}_4 \rightleftharpoons \text{Ca}^{2+} + \text{SO}_4^{2-} + \text{H}_2\text{O} + \text{CO}_2 \]

2. \[ \text{CaCO}_3 + 2\text{HNO}_3 \rightleftharpoons \text{Ca}^{2+} + 2\text{NO}_3^- + \text{H}_2\text{O} + \text{CO}_2 + \text{Ca(NO}_3)_2 \]
Gypsum tends to remain on the stone surface during this substitution reaction, while nitrates are soluble salts prone to movement inside the stone.\textsuperscript{12}

Exposure to mixed-acid gas led to salt crystallization, preferentially on sample surfaces, for both types of stone. This crystallization occurred after one day and remained stable until the end of the test. For S, the crystallization penetrated progressively in depth (Fig. 01 a–c). Meanwhile, for RS the salts grew in efflorescence (Fig. 01 d–f). However, the dissolution phase due to the acidity effect was highlighted by a surface recession on S and a new porosity between crust and stone in RS.

The immersion test produced a major dissolution phase on the surface and open porosity of both stones throughout the test but was more evident during the first day. No equilibrium was reached until the end of the test due to the small size of the samples. In addition, the acid rain simulation test revealed different dissolution steps depending on the stones. The dissolution process was homogeneous for S due to its pure calcitic composition and affected ooliths and matrix similarly. Moreover, nitrate crystallization was highlighted by the advent of compounds darker than gypsum but lighter than calcite inside some ooliths. In RS, the dissolution was differential and focused on carbonate.
fragments. Silicate compounds were not affected. RS thereby showed a clear granular disaggregation after 28 days of the test, with a higher dissolution of the matrix than grains with variable composition.

The main changes occurred during the first 24 hours for both types of stone and in both types of test. Acid atmosphere tests led mainly to a crystallization phase, while acid immersion led to dissolution of stones. The X-ray computed microtomography proved to be an innovative, nondestructive technique that allowed the observation of the changes within the stone microstructure during the early weathering stages in high spatial resolution.

**Curriculum Vitae**

Soizic Gibeaux is a PhD student working on the effects of environmental agents and atmospheric pollution on restored cultural heritage in the GEGENAA Laboratory at the Université de Reims Champagne-Ardenne.

Patricia Vazquez has a PhD in geology from the Universidad de Oviedo and is an associate professor at the Université de Reims Champagne-Ardenne. Her research interests include weathering processes at meso- and microscales.

Tim De Kock is a postdoctoral fellow of the Flemish Fund for Scientific Research at Universiteit Gent and is cofounder of Inspect bvba, specialized in building stones and the study of low-temperature and -pressure pore-scale processes.

Veerle Cnudde is the coordinator of the Pore-Scale Processes in Geomaterials Research group and co-coordinator of the Centre for X-ray Tomography at Universiteit Gent.

Vincent Barbin is a full professor of geosciences at the Université de Reims. He has a PhD in geology from the Université Pierre-et-Marie-Curie, Paris. His research focuses on using SEM and cathodoluminescence microscopy to study geomaterials.

Céline Thomachot-Schneider is associate professor at the Université de Reims. She specializes in petrophysics applied to the understanding of weathering processes, especially frost action and salt crystallization.

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Evaluation of Nanostructured Coatings for the Protection of Stones

Silvia Germinario, a Giovanni Baldi, b Valentina Dami, b Andrea Cioni, b Federica Fernandez, c Patrizia Livreria a

INTRODUCTION

The aim of this study was to evaluate the effectiveness of the treatment of Apuan marble with nanostructured products.

The focus of the work was on methods of accelerated aging used to simulate the types of natural aging to which marble in historical buildings can be exposed.

Rock samples were examined after being exposed to high temperature cycles in a muffle furnace, treatments in saline solution, cycles of thermal shock, and aging by SO2 action in the presence of humidity (UNI EN 13919, 2004).

After every artificial aging cycle, changes in appearance were noted, and chemical-physical properties were measured so that differences between fresh and treated samples could be compared.

After evaluating the effects of the accelerated aging and applying nanostructured products to the samples, the protective qualities of the coatings were measured using the following tests: contact angle; evaluation of the photocatalytic properties by methylene blue degradation tests; photodegradation kinetics of pollutants under UVA irradiation.

Before and after each application, scanning electron microscopy (SEM) was performed to evaluate changes in the surface morphology of the samples.

METHODS & METHODOLOGY

In this work, a series of accelerated aging tests was performed, and changes in sample color and weight were analyzed via spectrophotometer analysis and analytical balance respectively. In addition, variations in chemical composition were evaluated by X-ray diffraction using an X’Pert PRO X-ray diffractometer (Philips) and by X-ray fluorescence analysis using a sequential X-ray Spectrometer PW 1480 (PANalytical). After aging each sample, a series of nanostructured products was applied by brush to the sample’s surface.

The first set of aging tests consisted of thermal treatments at two temperatures, 100°C and 400°C. These tests were conducted for a total of 192 hours, divided into seven 24-hour periods. Depending on the color changes and weight loss results, different products were applied. For samples aged at 100°C, the following products with protective properties were applied: HP-15-02 polydimethylsiloxane, an alcoholic solution containing hydrophobic component and titanium dioxide; and PARNASOS® PH000026, a nanoparticle titanium dioxide aqueous suspension.

The following products with consolidant and protective features were applied to samples aged at 400°C: PARNASOS® ZG12-16, a suspension of water and alcohol, at pH 8, of silicon dioxide nanoparticles; PARNASOS® PH000026; and KVP000004, a liquid polymer glass solution with consolidant features.
The second series of aging tests used saline solution (UNI-EN 12370, 2001). Samples were subjected to 15 cycles, starting from an immersion phase in 14% Na₂SO₄ ·10H₂O solution for four hours followed by a drying phase in an oven at 105°C (± 5°C) for 15 hours. PARNASOS® PH000026, which has a protective function, was applied to all the specimens because the aging test did not provoke any decohesion of material.

The third series of tests involved thermal shock treatments (UNI EN 14066, 2013), which allowed for the evaluation of potential modifications within the stone after sudden changes in temperature. The specimens underwent 21 thermal cycles of eight hours each in an oven at 105°C, and 16 hours of water immersion, for a total time of 21 days. After the aging process, products HP-15-02 and PH000026 were applied.

The fourth and last series of tests was performed to better understand and evaluate the resistance to aging by SO₂ action in the presence of humidity (UNI EN 13919, 2004). The tests were performed first on untreated marble samples and then on nine previously treated specimens: three with PARNASOS® PH000026; three with HP-15-02; and three with KMR1008, which is Fluoroalkylsilane, in alcoholic solution that confers only hydrophobic properties.

RESULTS & DISCUSSION

Thermal treatment results showed that the samples heated at 100°C suffered a slight change in color, with a total color difference ΔE of 1.93. For the samples treated at 400°C, the change was remarkable, with a ΔE of 14.25.

Aged samples did not show clear signs of undergoing deterioration processes. In both samples, weight loss was less than 1%.

For samples aged at 100°C, the protective properties conferred by PARNASOS® PH000026 were also evaluated through methylene blue degradation. The product showed good activity: 91.6% depletion after four hours of UVA irradiation. Specimens treated with HP-15-02 showed a contact angle of 81.24°.

For samples aged at 400°C, SEM images on samples treated with ZG12-2016 and KVP000004 showed low product penetration (Fig. 01).

PARNASOS® PH000026 photocatalytic activity was evaluated by methylene blue degradation. The product showed good activity: 91.6% of total color degradation after four hours of UVA irradiation.

Samples treated with saline solution showing a gradual increase in ΔE values. After the first two cycles of treatment, the ΔE value was 3.34, while after the 16th cycle the total color difference ΔE value was 8.25. The specimens did not show significant weight loss, usually under 1%.

The capacity of the protective treatments to remove air pollutants was tested by NOx (mono-nitrogen oxides) photocatalytic degradation measurements (UNI EN 11247, 2007). The tests compared samples of marble treated with the solutions to marble that had not been treated. The analysis showed good photocatalytic activity.

Specimens aged through thermal shocks showed significant color changes after 21 cycles, with a ΔE value of 9.71.

These specimens did not have significant changes in their weight, with total loss below 1%.

PARNASOS® PH000026-treated samples were tested by methylene blue degradation, showing

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**Fig. 01. SEM images (BSE): (A) sample treated with ZG12-2016; (B) sample treated with KVP000004 (Colorobbia Research, Ce.Ri.Col., Vinci, Italy).**
good activity, with a percentage of degradation of 94.4% after four hours of UVA irradiation.

HP-15-02–treated samples showed good hydrophobicity, as the contact angle was 94.23°.

Specimens aged by SO₂ action in the presence of humidity showed a progressive increase in decay throughout entire test, with the formation of gypsum patinas, deformations, and superficial pitting.

After the treatment, specimens showed color changes, with a total color difference ΔE value of 0.4771 and with a loss in weight of over 1%.

Backscattered SEM images showed PARNASOS® PH000026 had the ability to halve SO₂ penetration (Fig. 02).

CONCLUSIONS

The main goal of the aging tests conducted on Apuan marble was to replicate as closely as possible the natural aging that occurs in the marble’s original environment. The samples showed signs of degradation due to aging after each test.

Moreover, all the products applied to the samples showed the effectiveness of their characteristics. In some cases, they reduced corrosion effects over time, and in some they stopped other forms of degradation.

ACKNOWLEDGMENTS

The research was carried out as part of the “Distretto di Alta Tecnologia per i Beni Culturali della Sicilia” Progetto di Formazione TECLA PON03PE-00214-1/F7 “Ricerchatori ed Esperti di Alta Tecnologia e Innovazione Tecnologica Applicata al Settore dei Beni Culturali” OF1, Master “Esperto di Nanotecnologie e Nanomateriali per i Beni Culturali”—CUP B79G14001460007, with the collaboration of Colorobbia Research Center, CE.RI.COL.

CURRICULUM VITAE

Silvia Germinario is a graduate in science and technology for the conservation of cultural heritage from the Università degli Studi di Bari Aldo Moro and holds a master’s degree in nanotechnology for cultural heritage from the Università degli Studi di Palermo.

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Valentina Dami has a master’s degree in chemistry and works at Colorobbia Italy. She has researched surface functionalization with nanoparticles and on nanomaterials characterization. She also has skills in analytical procedures.
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BIBLIOGRAPHY


(Endnotes)


Biocide Treatments on Limestones Based on Silver Nanocomposites

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INTRODUCTION

Biopatina formation on stones contributes to the deterioration of historic buildings, and current chemical treatments used to avoid biodeterioration usually have a low durability, a high toxicity, and/or incompatibility with stone substrates.1 Advances in nanotechnology are enabling us to develop new treatments to avoid biopatina effects; for example, application of silver nanoparticles (AgNPs) that have antibacterial properties2 or titanium oxide nanoparticles (TiO2NPs) that have a high photocatalytic activity under ultraviolet light.3 The mixture of these two types of nanoparticles allows for nanocomposites with both properties, increasing the reactivity of TiO2NPs across the visible spectrum.4 This article presents the results of efforts to synthesize and analyze nanocomposites containing silver and titanium in order to evaluate their biocide properties and potential use in stone conservation.

METHODS & METHODOLOGY

Two silver-based nanocomposites were synthesized in this study. The first contained citrate-capped silver (Ag@cit),5 and the second contained silver, titanium dioxide, and activated carbon (Ag/TiO2/AC).6 Several modifications of the synthesizing protocols were carried out to obtain six types of nanocomposites. Table 01 shows the composition and concentration of the synthesized nanocomposites.

Raman spectroscopy using a Bruker Senterra confocal Raman microscope was carried out to control the composition of the six synthesized nanocomposites.

The physiochemical characterization of nanocomposites was carried out by ultraviolet-visible spectroscopy (using an Ocean Optics spectrometer equipped with an HR4000 detector), and hydrodynamic diameter and zeta potential measurements were made using a Dynamic Light Scattering Zetatrac Analyzer. Measuring these properties allowed the stability of the product to be checked.

Antibacterial activity was first tested in liquid cultures using a growth curve. This assay consisted in determining the absorbance at 600 nm of the Escherichia coli (E. coli) culture without (control) and with varying amounts of nanocomposites. Absorbance was measured using a POLARstar Omega microplate reader spectrophotometer in mixtures of 200 μL of E. coli inoculum at an optical density of 0.3 and various aliquots (4, 10, 20, and 40 μL) of the tested nanocomposites. Table 01 shows the nanocomposite concentration employed in the assays.

Limestone slabs from Utrera’s quarry (Seville, Spain) were employed for the assays of biopatina inhibition. This limestone had a high content of quartz and fossils (2–5%) and a high porosity (9.6%) with a porous size between 0.1–1 μm.9 Each slab was 1.5 x 1.5 x 0.5 cm. The slabs were treated with 200 μL of nanocomposites at the concentrations specified in Table 01. In calculating these concentrations, the amount of AgNPs was equalized.
Chlorophytes and cyanophytes collected from the biopatinas of several stone facades of different churches sited in Seville were cultivated in a rich phosphate medium. Limestone slabs were immersed in this medium, and the trials were maintained at room temperature and lit with an incandescent lamp. Biopatina formations on the slabs were evaluated after 28 days of immersion and five days of drying at room temperature.

Biopatina formation inhibition (BFI) was analyzed with a Colorimeter X-Rite SP20. Inhibition was quantified in terms of total color difference ($\Delta E^* = (\Delta L^* + \Delta a^* + \Delta b^*)^{1/2}$), using the method described by Ortiz et al.\textsuperscript{10} An optimal value of $\Delta E^* < 10$ was used as reference.

**RESULTS & DISCUSSION**

**Nanocomposites Characterization**

Raman spectra allowed us to corroborate the chemical composition of the different nanocomposites. A silver band was identified at 200 cm\textsuperscript{-1}. TiO\textsubscript{2} showed bands at 200, 400, 500, and 600 cm\textsuperscript{-1} and AC at 1,300 and 1,600 cm\textsuperscript{-1}, while citrate showed a band only at 250 cm\textsuperscript{-1} (Fig. 01).

Surface plasmon resonance is a special property of AgNPs. Citrate-capped nanocomposites showed a narrow bandwidth centered at 400 nm, a result of their high colloidal stability. Nanocomposites without citrate showed a displacement of the band, and their bandwidths were larger due to an increase of particle size distribution (polydispersity). This range of sizes implies lower stability.

The stability parameters of the nanocomposites synthesized in this study are summarized in Table 02. Hydrodynamic diameter (HD) was closely related to the size of nanoparticles plus their interaction with solvent molecules. Citrate-capped nanocomposites showed the lowest polydispersity, with sizes in the 22–45 nm range. Nanocomposites without citrate showed a higher polydispersity, with particle sizes in the 110–274 nm range. Nanocomposites were classified according to HD for Utrera’s limestones (Table 02). The two nanocomposites with HD < 0.1 \(\mu\)m might penetrate better through the porous system of this limestone, which has a pore size greater than 0.1 \(\mu\)m.

<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>Ag (mg/mL)</th>
<th>TiO\textsubscript{2} (mg/mL)</th>
<th>AC (mg/mL)</th>
<th>Citrate</th>
<th>Concentration for assays (mg/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag@cit</td>
<td>0.005</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.03</td>
</tr>
<tr>
<td>Ag/(1/2)TiO\textsubscript{2}@cit</td>
<td>0.005</td>
<td>0.06</td>
<td>-</td>
<td>-</td>
<td>0.16</td>
</tr>
<tr>
<td>Ag/TiO\textsubscript{2}/AC</td>
<td>0.02</td>
<td>0.12</td>
<td>0.83</td>
<td>-</td>
<td>0.22</td>
</tr>
<tr>
<td>Ag/TiO\textsubscript{2}</td>
<td>0.02</td>
<td>0.12</td>
<td>-</td>
<td>-</td>
<td>0.20</td>
</tr>
<tr>
<td>1/4Ag/TiO\textsubscript{2}</td>
<td>0.005</td>
<td>0.12</td>
<td>-</td>
<td>-</td>
<td>0.66</td>
</tr>
<tr>
<td>TiO\textsubscript{2}</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Table 01. Nanocomposites composition and concentrations

<table>
<thead>
<tr>
<th>Nomenclature</th>
<th>Hydrodynamic Diameter (HD)\textsuperscript{1}</th>
<th>Zeta Potential (ZP)\textsuperscript{2}</th>
<th>Biopatina Formation Inhibition (BFI)\textsuperscript{3}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag@cit</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Ag/(1/2)TiO\textsubscript{2}@cit</td>
<td>+</td>
<td>-</td>
<td>+ +</td>
</tr>
<tr>
<td>Ag/TiO\textsubscript{2}/AC</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ag/TiO\textsubscript{2}</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1/4Ag/TiO\textsubscript{2}</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>TiO\textsubscript{2}</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

\textsuperscript{1}According to porous limestone sizes. (-): HD > 1 \(\mu\)m; (+): 0.1 < HD < 1 \(\mu\)m; (+ +): HD < 0.1 \(\mu\)m.

\textsuperscript{2}According to Koutsoukos et al.\textsuperscript{9}. (- -): ZP < 20 mV; (-): 20 < ZP < 30 mV; (+): ZP < 30 mV.

\textsuperscript{3}According to total colour change of biopatina growth. (-): BFI > 20; (+): 20 > BFI > 10; (+ +): BFI < 10.

Table 02. Nanocomposite stability and biocide effect evaluation for stone
According to Koutsoukos et al.,\textsuperscript{11} the zeta potential (ZP) of 30 mV is taken as a line between stable and unstable dispersions. Citrate-capped nanocomposites showed values around 30 mV, while nanocomposites without citrate showed values lower than 20 mV. In conclusion, citrate-capped nanocomposites were more stable due to their lower capacity to form aggregates (Table 02).

**Antibacterial Activity**

All nanocomposites tested in liquid cultures caused a decrease of *E. coli* growth (Fig. 2). Generally, the higher nanocomposite concentration was associated with higher inhibition. The $\frac{1}{4}$Ag/TiO$_2$ nanocomposite achieved the highest inhibition activity.

**Biocide Assays of Utreran Limestone**

BFI was detected by comparing the surface color before and after the trial. Biopatina formation was generally reduced in the presence of each tested nanocomposite, excepting Ag/TiO$_2$/AC and Ag/TiO$_2$ (Table 02). The color change ($\Delta E^*$) was below 10 in the slab with $\frac{1}{4}$Ag/TiO$_2$ and Ag/$\frac{1}{2}$TiO$_2$@cit in comparison with the slab before the trial, so those nanocomposites showed the best biocide properties. Nevertheless, citrate-capped nanocomposites with TiO$_2$ (Ag/$\frac{1}{2}$TiO$_2$@cit) were more efficient because the final concentration applied was lower than in nanocomposites without citrate (Table 01).

**CONCLUSIONS**

This preliminary evaluation of Ag/TiO$_2$ nanocomposites as biocides showed that citrate-capped nanocomposites gave the best results. They had a smaller particle size, formed colloids that were more stable, and exhibited excellent biocide properties. Further studies should be carried out on stones to establish conditions of application and durability.

**Acknowledgements**

This study was partially supported by the projects Art-Risk, RETOS project of the Ministerio de Economía y Competitividad and Fondo Europeo de Desarrollo Regional (FEDER) (code: BIA2015-64878-R (MINECO/FEDER, UE)), CTQ2013-48396-P of the Fondo Europeo de Desarrollo Regional (FEDER-Unión Europea) and the Ministerio Economía y Competitividad and the research teams P10-FQM-6615, PAIDI FQM-319, and TEP-199 from Junta Andalucía. J. Becerra is grateful to the Ministerio de Educación, Cultura y Deporte for his predoctoral fellowship.
**CURRICULUM VITAE**

Javier Becerra Luna has a degree in conservation and restoration from the Universidad de Sevilla and an MsC in Diagnosis of the State of Preservation of the Historical Heritage. His PhD thesis focuses on applications of nanotechnology to cultural heritage.

Ana P. Zaderenko Partida has a PhD in chemistry and is a professor at the Universidad Pablo de Olavide. Her research activity focuses on the synthesis and study of nanostructures applied to biomedicine, sensors, and cultural heritage.

Pilar Ortiz Calderón has a PhD in chemistry and is a professor at the Universidad Pablo de Olavide. Her research activity focuses on risk and vulnerability diagnosis and preventive conservation of cultural heritage.

**BIBLIOGRAPHY**


(Endnotes)


Testing of Nanostructured Products for Stone Protection and Consolidation: The Palazzo Alliata Pietratagliata in Palermo

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INTRODUCTION

The focus of this study was stone from the tower of the Palazzo Alliata Pietratagliata in Palermo, built in the 15th century and one of the most important examples of late-medieval civil architecture in Sicily. To characterize the stone, small samples collected in situ were subjected to chemical and morphological analysis using X-ray diffractometry (XRD), scanning electron microscopy (SEM), and polarized light optical microscopy (PLM). Nanostructured products were then tested for stone consolidation. Because the necessary volume of samples could not be obtained directly from the tower, this portion of the study used Marsala limestone intended for lithotypy, with structural and textural characteristics similar to those used in the tower battlements, which are characterized by a complex porosimetric distribution. The stone was investigated through the gas expansion method and laboratory XRD. SEM analyses, conducted from a mineralogical-petrographic point of view, were used to determine the bulk and real density of the water open porosity.

Moreover, after artificially aging the specimens to simulate the degradation of the stone, two nanostructured products for consolidation, were applied. The effectiveness of the tested products were noninvasively assessed by means of nuclear magnetic resonance (NMR) relaxometry and static contact angle.

METHODS & METHODOLOGY

Material from the battlements of the tower of the Palazzo Alliata Pietratagliata was sampled.
The samples were generally composed of highly disaggregated biocalcarenite. The first investigations thus involved mineralogical-petrographic analyses by XRD, optical microscopy, and SEM.\(^2\)

The second phase of research involved testing the effectiveness of nanostructured products for consolidating and protecting the type of stone used in the tower. These investigations were carried out on samples of Marsala biocalcarenite. The following analyses were performed: determination of mass volume apparent (MVA) and mass/volume ratio (MVR); the porosity accessible to water; and chemical and morphological analysis via XRD and SEM.

Subsequently, the samples underwent artificial aging (using the method of determining the resistance to salt crystallization) to achieve a similar deterioration level to the limestone of the palace battlements. Two nanostructured products for consolidation were then applied: (1) product A, based on micronized acrylic resins in aqueous micro-emulsion; (2) product B, a consolidating nanotechnology-based colloidal silica. Furthermore, a nanotechnological siloxane-based protective was tested to evaluate its hydrophobic properties (product C). For each tested product, three cubic samples (5 cm per side) were examined.

To assess the effectiveness of the selected products, NMR relaxometry analyses were conducted, with measurements were made using a single-side Bruker mq-ProFiler relaxometer.\(^3\) Longitudinal and transverse relaxation times were obtained by saturation recovery-spin-echo and Carr-Purcell-Meiboom-Gill pulse sequences respectively.

Finally, to evaluate water-repellent ability, static contact angle was determined.

RESULTS & DISCUSSION

Optical microscopy of the biocalcarenite extracted from the battlements of the tower showed a poorly homogeneous texture with high densification of bioclasts with a size range of 0.3–0.5 mm and the presence of intergranular and intragranular empties with highly irregular shape due to erosion phenomena involving the micritic matrix. The XRD mineralogical analysis showed that the stone was composed of calcite (85%) and quartz (15%).

The analyses of the Marsala limestone showed that it was characterized by a yellowish color, with average-size sand particles and grain diameter in the 0.2–0.6 mm range. The limestone consisted primarily of bioclasts and secondarily of limestone lithic fragments characterized by rounded contours. This stone had a rather low degree of cementation. At numerous locations, a thin microporiferous calcite layer was observed to have formed around the grains. The XRD mineralogical analysis found that this limestone was composed of calcite (90%) and quartz (10%).

MVA, MVR, and the consequent total porosity and porosity index were measured on six untreated samples. The total high porosity for all samples was found to be 1,416 ± 44 kg/m\(^3\) (MVA) and 48.2% porosity. After application of the nanostructured products, the surface of the samples was observed to determine what morphological changes (if any) had occurred. SEM was used to investigate whether the products penetrated the stone and, if so, to what extent they were distributed.

In the samples treated with product A, the consolidating material seemed to envelop the granules of stone with a nanometer film without occluding the micropores. The product appeared to be widely distributed both in micritic and microsparitic areas.

In the samples treated with product B, nanosilica particles created a gluey film on the calcite grains in the micritic area. The consolidation reached a depth of 200–400 μm, reaching in a more widespread manner the intercrystalline spaces of the micritic matrix.
In the samples treated with product C, the level of penetration interesting a layer of about 1 cm, which presents itself completely nonwettable (Fig. 1).

Comparisons of the longitudinal $T_1$ and transverse $T_2$ NMR relaxation times of the various samples before and after treatment are reported in Figure 2. NMR relaxometry provided information to a depth of 2–3 mm, much greater than what can be obtained from SEM. According to Yao and Liu, $T_2$ values below 5 ms are associated with mesopores (radius 0.01–0.1 μm), $T_2$ values in the 5–500 ms range are associated with macropores (radius > 0.1 μm), and $T_2$ values above 500 ms are associated with fractures.

The application of product A reduced water penetration inside the mesopores (Plots A and B). Product B slightly influenced pore size distribution (Plots C and D). Product C reduced the penetration of water inside pores and slightly increased the ratio of macropores to fractures. However, for this kind of stone the product that best modified the pore size distribution was product A.

The hydrophobic properties of the consolidating products were also assessed via contact angle measurements. Product A registered a contact angle value of 137°, a good level of effectiveness. In contrast, product B’s hydrophobic properties proved unsuitable. Both samples treated with product C yielded good results: no significant changes, with a constant angle of contact of 143°.

**CONCLUSIONS**

The investigation integrated various experimental techniques to obtain detailed information about the effects of treating stone with various consolidants. Of the three tested products, product A proved most effective at improving consolidation and water repellency and should be considered for use in conservation and restoration work.

**Acknowledgments**

The research was carried out within the framework of the “Distretto di Alta Tecnologia per i Beni Culturali della Sicilia” Progetto di Formazione TECLA PON03PE-00214-1/
F7 “Ricercatori ed Esperti di Alta Tecnologica e Innovazione Tecnologica Applicata al Settore dei Beni Culturali” OF1, Master “Esperto di Nanotecnologie e Nanomateriali per i Beni Culturali”—CUP B79G14001460007, with the collaboration of Geolab srl.

CURRICULUM VITAE

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Federica Fernandez has a PhD in architecture and is an expert on the research and development of nanomaterials for architecture. She was the technical director of the master’s degree program in nanotechnologies and nanomaterials for cultural heritage at the Università degli Studi di Palermo.

Luigi Tranchina has a PhD in physics and is a laboratory technician at the ATeN Center, Università degli Studi di Palermo. He has dealt with the chemometrical/physiochemical characterization of materials in the field of cultural heritage, using noninvasive and nondestructive techniques.

Maria Brai is a professor in applied physics at the Università degli Studi di Palermo. Her research topics include dosimetry for medical applications, retrospective dosimetry via electron spin resonance and thermoluminescence, and the application of physics to cultural heritage.

Patrizia Livreri is a professor of electronics in the Engineering School of the Università degli Studi di Palermo, is the scientific director of the Laboratory of Nanotechnologies and Nanomaterials for Cultural Heritage—BCNANOLAB at the Università degli Studi di Palermo.

Renato Giarrusso is a geologist with expertise in mineralogy and petrography applied to materials of interest in industry, civil engineering, and cultural heritage. He is a researcher at Geolab srl.

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(Endnotes)


CULTURAL HERITAGE, EDUCATION & DISSEMINATION PROJECTS
INTRODUCTION

From far away, cities usually emerge like castles or, on the plains, they engulf the horizon, making it look thicker. Matera, however, appears all of a sudden. But facing it is like looking into a well. There, in the void, lies the yeast of its bread. Nothing that has any sense for life ever totally disappears; it is not merely a matter of conservation or survival but of a leavening, “strange form” of time that reappears from the bottom, finding new roads—as if it were the water of an aquifer, in the cracks of the crisis, producing that which, in biology, are the traits of DNA. This “strange form” of existence, about the complex history of the city, is nothing other than the “time to live”—a time that is always different. Like life. From the “Gravina” (canyon) out of which the city materialized, to the streets of the Sassi, to the Corso (main road of the city), to the “alternative” street of the “Beccherie” (historic way), to the pathways in the modern neighborhoods, Matera is a hybrid. To understand the complex system of the city, 16 international workshops were
required, which took place from 2013 until 2016, following the program of the Nature-City—LAB3 Dicem: “FareStrada Matera” (“GoingDeep Matera”)3 (Fig. 01).

BACKGROUND: ABOUT OUR RESEARCH

To measure the resilience of an urban reality or even to identify indicators that can help the researcher in this task is a complex, multipart process that requires wide-ranging research into the numerous features that make a city livable.

Architecture, especially urban architecture, is like an “autopoietic,” self-organizing system. This definition merges with that of resilience, which we define not only as the property of recovering from an unpredictable event but an innate capability to find new resources in response to negative events. The rigid vertical organization model typical of modern Western democracies and their institutions was to be replaced by an experimental continuous learning model, just as had been done by the smart enterprises.4 From the management point of view, it is necessary that government choose an organizational system that favors the independence and responsibility of the people. From the planning tools point of view, we should use the most flexible tool possible to define the principles of the planning. Identity and new technologies are both important to build resiliency (Fig. 02). In his independent report, Fabrizio Barca (former minister for territorial cohesion of the Italian Republic) describes a model for territorial development that contains a concept of a resilient community.

MATERA: THE NATURE-CITY REGENERATION STRATEGY

The most interesting example of this regeneration strategy is the environmental and architectural rescue of the Sassi di Matera.5 Matera is one of the most representative examples of a city where tourism is used for its sustainable development. (This is the path the city chose for its development plan. The strategy made Matera what it today.) Matera changed its destiny from that of a dying city to that of a Nature-City. It is now a symbol. How many cities have been regenerated in nature as well as in civilization? Many cities have been rebuilt—for example, after being bombed or struck by natural disaster. But what city has recovered from the shame of its history,6 and how? Only Berlin has done so much! (Fig. 03).

The regeneration processes of Matera and Berlin occurred under different circumstances. The subhuman conditions present in the historical center of Matera (in the Sassi), in opposition to an extraordinary human and environmental landscape, is the key to the new way of the city. A description of how Matera and the Sassi became a United Nations Educational, Scientific and Cultural Organization World Heritage Site and the European Capital of Culture in 2019 are beyond the scope of this article, which can only summarize the identity of the city.

CONCLUSIONS

What can Matera and its territory tell other cities in Europe? What aspects of this city’s identity are shared
by other European cities? Cities must develop creative projects that respond to Europe’s challenges by encouraging citizens and local governments to develop new programs with lasting effects that can be fit into the long-term growth of the city itself. Within this context, the role of the actors present in the city is important, because thanks to the support of the university it is possible to create an organic city. This objective can be an opportunity for future cultural aggregation through a collaborative network of people and cities that want to share experiences related to urban regeneration projects. Matera is now the European Capital of Culture 2019, but after that . . . what comes next?

**Curriculum Vitae**

Ina Macaione is a professor at Università degli Studi della Basilicata. Her research interests concern the relationship between the built environment and urban regeneration, starting from the relation between city and nature.

Enrico Anello is a practicing architect and PhD in cities and landscapes. His research investigated the city of Shenzhen, China.

Armando Sichenze is an architect who took part in several projects and research initiatives on the relationship between architecture and Nature-City. He is the cofounder and president of the Organizing Committee of Architecture Faculty of Matera.

Antonio Ippolito is a PhD candidate at the Università degli Studi della Basilicata. His research investigates the role of the steel industry in Taranto, Italy.

**BIBLIOGRAPHY**


Matera, located in the Southern Italian region of Basilicata has been awarded the title of the 2019 European Capital of Culture in Italy. Matera won this title for its history and its capacity renewal, having gone from being the “shame of Italy” to being designated a UNESCO World Heritage Site. The Sassi comprises cave dwellings and rock churches built on and dug into the sides of the canyon (Gravina).

Nature_City Lab was established in Matera at the Department of European Cultures and the Mediterranean: Architecture, Environment, Cultural Heritage (DiCEM) of the Università degli Studi della Basilicata. It is an interdisciplinary organization working in the fields of architectural design, urban sociology, landscape, and environmental sustainability with a multidisciplinary team of architects, urban planners, urban anthropologist, visual ethnographers, and agronomists. Nature_City Lab organizes workshops, lectures, and surveys related to laboratories for urban regeneration. These workshops are linked to the strategic plan of the city and to some guidelines for the candidacy of Matera for European Capital of Culture 2019. The workshops are the hub of the construction of an international network of universities, institutions, architectural firms, and interdisciplinary associations from various cities (Beijing, Dublin, Bremen, Thessaloniki, Vienna, Rome, Palermo). The workshops are open to experts in urban studies, as well as to stakeholders, citizens, and students of architecture engaged in the fields of urban and housing policies, the use of renewable energy, and participatory planning and sustainability.

This research is part of a series of design experiences in which the relationship between architecture and city, which featured the most significant lines of research of the Italian school of the project, are currently evolving into a new school of the project, in which the theme of emptiness, which is also of major importance in Eastern cultures, is decisive. According to this new approach, nature takes on a new centrality in the disciplines involved in the project. This means that the thought of the limit in architecture, as a result of the analysis that goes down from the city to the building, has an opposite correspondence (from the particular to the general) in the translimitation that occurs through a sensible void-making in the built environment. The Italian School of Nature-City, proposed and established 20 years ago by Armando Sichenze and Ina Macaione, has been developed along two parallel lines of research. The first concerns the comparative reading of about 150 cities in Mediterranean Europe, especially in Basilicata (the region that includes Matera), where over the millennia a close comparison of Western and Eastern cultures has taken place. This reading is useful to discover the conditions of existence of urban qualities through which a settlement recognizes itself as a city. The second study concerns the reinterpretation of Italian architects’ thinking about the city in the late-20th century.


The Sassi is a prehistoric settlement, suspected to be among the first human settlements in Italy. It includes houses dug into the calcarenitic rock itself, which is characteristic of Basilicata and the Apulia region. The ancient city grew up on one slope of the ravine created by a river that is now a small stream. The ravine is known locally as “la Gravina” (the canyon).

The Imbalance of Urban Development between Eastern and Western Tissue: The Case of Taranto (Italy)

INTRODUCTION

This article describes the second phase of a study intended to identify urban regeneration strategies in Taranto. In particular, the article aims to present the results of the imbalance of urban development between east and west of the city. The city is strongly conditioned by the presence of industrial development. An analysis of “urban events” allows us to highlight how urban planning has been used by the local government as a tool to solve “hardships” or emergencies while neglecting real potential and the generation of long-term development plans. The urban events, linked factors of the plans of the city, cover a period that begins with the plan of the architect Davide Conversano (1865) and ends with the variant of Calza-Bini drawn up by the architect Giovanni Barbin and the engineer Francesco Vinciguerra. The research is divided into two steps: first, an analysis of the urban plans that have contributed to the current shape of the city (Fig. 01); second, an analysis of the plans and projects underway in the city today. To understand the dynamics and processes that have affected the area and still determine factors that affect development, we must begin with the city during the period before Italian unification. How has the city responded to exogenous factors such as the arsenal, which marks the transition from a town devoted to agriculture and fishing to a city reliant on its industrial sector? And how has it responded to endogenous factors, such as the environmental, health, and employment crisis caused by the presence of the industrial sector after 1960?

METHODS & METHODOLOGY

The study began by “reconstructing” the historical evolution of the development of Taranto, whose phases are linked to development plans that contributed to the current urban structure. The objectives were to identify the institutional dynamics that led to the current land configuration; the processes that have characterized the territorial imbalance in Taranto due to the presence of the exogenous and endogenous factors; and the factors that have helped to consolidate and increase the imbalance between the western and eastern parts of the territory.

Primary and secondary literature was analyzed. The review of primary literature was conducted by consulting bibliographic databases and archives of the local administration. The review of secondary literature encompassed doctoral theses, publications, and scientific journals covering the urban development of Taranto.

RESULTS & DISCUSSION

The actual shape of Taranto is the result of a series of processes and urban development plans linked to the development of the industrial sector. The master plan of 1865 was the first to describe the territory. Drafted by Conversano (1865), this plan proposed to reduce the settlement pressure...
in the historic area through the development of two areas, in the east and west part, to allow for the growth of the population. The idea of a western suburb proposed by the plan was supported through the construction of the railway station and the commercial port (Porto Mercantile). The presence of these two infrastructures (train station and Porto Mercantile) reinforced the idea that the western suburb would become the main center of commercial and industrial activity for the city. Development of the suburb was halted in part for geological reasons, but mainly because the building of a naval arsenal to the east refocused attention to that part of town. Plans for the western suburb were abandoned and not reconsidered in subsequent zoning. From that point the expansion was directed to the east (Fig. 02). A new plan was thus needed, and the task was entrusted in 1920 to Giulio Tian. The plan was never approved, but it served as a reference point for the urban interventions of the 1920s and 1930s. In 1936 Alberto Calza Bini received the commission to draft a new plan. The area was still governed by the “Piano Conversano” of 1865. However, the earlier plan included no zoning regulations and was not designed to accommodate the population increases that had occurred from 1865 to 1936. The Calza Bini plan tried to remedy the problems created by the spontaneous appearance of the new areas in response to the housing emergency, but the plan, which was finished in 1939, was never approved. Thus, at the end of Second World
War, Taranto found itself still without a master plan. In 1950, Calza Bini was again appointed to develop a new plan. Essentially an update to the plan of 1936, it was approved in 1954 (Fig. 03). The culture of that historic national period is reflected in the design of the new urban plan (e.g., road accommodation, increased density, and the reorganization of areas of expansion into functional blocks). The new plan was inadequate, however, because it lacked a real perspective on the development of the territory and because it had no regulation. Moreover, it was unable to contain the new industrial phase with the presence of the steel factory. For these reasons, the task of developing a new plan was given to the architect Barbin and the engineer Vinciguerra. Their plan was approved in 1978 and remains in force. The plan might have been an opportunity to recalibrate the imbalances of the past and to create an integrated view of Taranto, but this opportunity, too, was lost. The plan sought balance based on a polycentric system that included a relationship between the urban settlement and its hinterland, expanding containment in the southeast, and the enhancement of the historic center. The plan had the idea of developing, along the east-west axis, a series of attractive poles (infrastructure, services, and so forth) with which to rebalance the development of the city. The latter goal is the most interesting. The idea was to right the “historical imbalance” between the east and west areas of the city, but in reality this did not happen. In the plan report, the description of the axis ends in the historic center, cutting off, once again, the western part from any logic of future development.

CONCLUSIONS

The “Piano Conversano,” which favored the development of the eastern parts of Taranto over the western parts; the lack of implementation of policies that would allow development of the entire city fabric; the Calza Bini plan, which in its growth forecasts focused on the eastern part of the city and failed to implement the development proposed in the Barbin-Vinciguerra plan—together they constitute an “oversight” on the part of the administration of the western part of its territory, an oversight that continues to prevent this area from being incorporated into a comprehensive development project with the rest of the city.

CURRICULUM VITAE

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Wartime Damage to Cultural Heritage and the Croatian Experience in Renovation of Damaged Heritage

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INTRODUCTION

The total count of casualties from the war-stricken areas in the Republic of Croatia during the 1990s should include the vast injuries to cultural heritage. According to records of the former Institute for the Protection of Cultural Monuments of the Ministry of Culture, by the end of 1991 as many as 507 historical buildings had been damaged. By the end of the war in 1995, that number had grown to 2,440 historical buildings, mainly churches, museums, theaters, historical and urban protected zones of historic cities, as well as many baroque and historicist mansions. In mid-November 1991, a team made up of employees of the former Zagreb City Institute for the Protection and Restoration of Cultural and Natural Monuments, the Institute for the Protection of Cultural Monuments of the Ministry of Culture, the Institute for Restoration of Works of Art from Zagreb, museum employees, and civil
defense units evacuated, with the help of the Croatian army, a large amount of movable furnishings from the damaged churches, museums, and historic buildings.

The evacuated objects were then redistributed away from war-torn areas to various locations in northwest Croatia and Istria, where, due to a lack of appropriate storage facilities, they were kept in a variety of microclimate conditions. Pieces that were exposed to dry air and heath suffered the most damage. The special commission for listing and assessing war damage to cultural monuments confirmed the damage, an effect of war, to 2,440 historical monuments and buildings located in the historic cores of towns from Dubrovnik to Vukovar. Some 237 cultural monuments were destroyed, and 2,029 were seriously damaged. Despite the imminent threat, assessment and restoration of damaged cultural heritage sites, including those near the battlefield, began as soon as the injuries were inflicted. This effort prevented further destruction and deterioration of the damaged structures. Within a short period of time and under difficult conditions, 230 valuable monuments were restored in Croatia. A further 250 damage monuments are still in renovation.

LUDBREG RESTORATION CENTRE, ARTWORK RENOVATION AND EXPERTS EDUCATION

The Ludbreg Restoration Centre was founded because of the need for urgent evacuation of church and museum artifacts from war-stricken regions in Croatia. Referred to as “war hospital for artworks” in those years, the Ludbreg Restoration Centre was established in 1992 in the Batthyány Mansion. In recent years, several new workshops have been opened. The more important ones are located in Ludbreg, Dubrovnik, Split, Rijeka, Zadar, Osijek, Zagreb, and in Istria. The project also included the Academy of Fine Arts in Zagreb, the University of Split, and the University of Dubrovnik’s department for the restoration of artworks made of wood, stone, metal, ceramics, paper, and textiles. At the beginning of the war in Croatia in 1991, experts from the Bayerisches Landesamt für Denkmalpflege transported the necessary equipment and supplies to Ludbreg. The municipality had agreed to accepted the artworks evacuated from east and west Slavonia and from Karlovac County and Sisak-Moslavina County, and it used the Batthyány Mansion to house them (Fig. 01).

In Ludbreg, the center has organized more than thirty international courses and workshops on art restoration. Courses and workshops have been organized in cooperation with the International Council on Monuments and Sites and the International Council of Museums and in cooperation with experts from the Technische Universität München, the Technische Hochschule Köln, the Fachhochschule für Restaurierung Potsdam, the Istituto per l’Arte e il Restauro Palazzo Spinelli in Florence, and the Canadian Conservation Institute. Topics have included the materials and techniques of the old masters, baroque altars in Central Europe, stucco marble, conservation and restoration of wooden artifacts, conservation and restoration of paintings, pigments and binders, documentation in the restoration profession, old

Fig.02. Vukovar, Eltz family maison after restoration, 2010.
varnishes, and restoration of paper. Each workshop lasts three to seven days, and the themes are selected based on the needs of the Croatian experts.

In recent years, numerous European experts have helped their Croatian colleagues protect and save national cultural heritage. In the last ten years, Croatian universities have educated more than three hundred young experts in art restoration, and many of these, with the help of the Ministry of Culture and the Croatian Conservation Institute, now work on restoring Croatian cultural heritage. The biggest restoration institution in Croatia is the Croatian Conservation Institute, which has 350 experts in all fields of art restoration, laboratories for natural science and photography, a documentation center, a library, depositories for artworks, a fumigation chamber, a central national digital database of restored artworks (Baza restauriranih umjetnina u Hrvatskoj), and nine workshops across Croatia (in Ludbreg, Osijek, Dubrovnik, Split, Šibenik, Zadar, Rijeka, Vodnjan-Istria, and Zagreb).

THE BIGGEST RESTORATION AND REVITALIZATION PROJECT FOR CULTURAL HERITAGE IN CROATIA

The interdisciplinary project Research, Restoration and Revitalization of the Cultural Heritage of Ilok-Vukovar-Vučedol, funded by the Croatian government and the Council of Europe Development Bank (2005–2012) and coordinated by the Croatian Ministry of Culture, is part of the national and regional strategy to protect and renovate both movable and immovable cultural heritage. At the national level, this is one of the most complex programs in the implementation of research, restoration, and valorization of national cultural heritage. The project is primarily aimed at professionals in the field of cultural heritage protection, museum activities, and the legislative authorities who were supposed to expand the legislative framework to ensure the project’s successful implementation. However, it also seeks to target the local communities that have or might benefit economically because of increased tourism. In addition, investments have been made in research, restoration, and revitalization of historical and cultural heritage; in scientific facilities (e.g., a research center in Vučedol); in museums (e.g., a new museum in Šaldin Castle in Ilok, the Eltz Mansion in Vukovar, and the new national Museum of Vučedol Culture at the archaeological site of Vučedol); and in facilities intended for further professional development (Fig. 02, fig.3).

The Croatian Conservation Institute took part in the reconstruction of twelve houses in the baroque center of Vukovar, the Eltz Mansion complex in Vukovar, as well as several properties in Ilok, including the Šaldin Castle, a medieval fortress plateau and walls, a Franciscan monastery, and the church of St. John Capistrano.

The Vukovar Municipal Museum has opened a new Museum of Vučedol Culture. The Institute of Archaeology took part in archaeological research in Ilok. The Department of Archaeology of the Faculty of Humanities and Social Sciences in Zagreb and the Archaeological Museum in Zagreb have begun archaeological research and sponsored an international school of archaeology at the Vučedol archaeological site.
Numerous experts from Croatia have also been involved in smaller projects in the Vukovar-Vučedol-Ilok area. The overall project is part of a new multidisciplinary program of sustainable development in the area, with a common goal of development based on the principles of the protection and promotion of the cultural landscape as economic components of the project and encouraging the development of this area through a complete restoration of historical buildings for the needs of the Vukovar Municipal Museum and the construction of the new Museum of Vučedol Culture.

A NEW APPROACH TO THE PROTECTION OF CULTURAL HERITAGE

The tragic war has shown the need to take a new approach to the protection, restoration, and preservation of cultural heritage in Croatia. The reconstruction of heritage is an input of the present into the past: a necessary intervention conditioned by a violent interruption of historical continuity. We need to believe that the new approach to the world’s endangered heritage will be more efficient than the one used in the case of war in Croatia.

ACKNOWLEDGEMENTS

I thank the Ministry of Culture of the Republic of Croatia, the Croatian Conservation Institute, and the University of Dubrovnik for the information and texts needed to complete this article.

CURRICULUM VITAE

Davor Bešvir has a master’s degree in archaeology and the history of art from the Zagreb University Faculty of Humanities and Social Sciences and a master of science degree in restoration and conservation of works of art from the University of Dubrovnik. He works in the department of polychrome sculpture of the Croatian Conservation Institute—Ludbreg Restoration Centre.

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The Publicizing of Conservation-Restoration in the Media: Is This a New Effort to Educate the Public on Conservation or Just for Show?

Elena Ciliberto

INTRODUCTION

Conservation of works of art is one of the oldest professions inside museums. Conservator-restorers are the first guarantors of the safety of art objects. They have the responsibility to establish and cultivate conservation guidelines that will ensure the entire spectrum of a collection is protected. Although they play an essential role inside cultural institutions, the profession is not well known to museum visitors because it is commonly performed in parts of the museum where only staff members are allowed. Even so, museums today are facing new challenges as they expand their themes and establish new relationships with cultural heritage and build new links to the public. Institutions have thus begun to unveil, through presentations both spectacular and less so, this hidden work, to demonstrate how they care for, restore, and preventatively conserve their collections. Exhibitions, guided tours of storage areas and studios, and live conservation and restoration interventions are being showcased in museum galleries. The behind-the-scenes work is being revealed with the intention of raising public awareness of heritage preservation. In the fall of 2015, for example, the Musée d’Orsay (Paris) launched a crowd-funding campaign for the restoration of Gustave Courbet’s L’atelier du peintre (The Painter’s Studio, 1855). In addition to raising funding, “the aim of this project was to make as many people as possible aware of all that is involved in a restoration.” A restoration studio was installed in the museum gallery housing Courbet’s large-scale painting, with an elaborate plan for the public to “step into” the painting and discover some of its mysteries. The project sparked many questions among museum professionals. Some saw it as a possibility of communicating with the public on conservation issues, while others saw it as a stunt used primarily for its publicity value.

The objective of the present research was to explore the various ways European museums have attempted to raise awareness of heritage conservation. What value do such practices have? What are their objectives? What is at stake? Is this new approach intended to educate the public on conservation, or is priority given to the show?

METHODS & METHODOLOGY

Data were gathered from sources such as exhibition catalogues, articles, and interviews with conservation professionals working in museums. These data were then used to help analyze the circumstances within which museum events were developed by experts and professionals and also how the “hidden” conservation work was presented to visitors.

The research encompassed

- The long history of restoration since the 18th century in France and its underlying political and economic intentions.
- A group of researchers who opened conservation studios to visitors (e.g., Magdelaine Hours) and
conducted programs to involve the public in heritage safeguarding (e.g., International Centre for the Study of the Preservation and Restoration of Cultural Property, or ICCROM). The research focused specifically on the following: (a) exhibitions of conservation-restoration methods (e.g., God in Colors,4 a touring exhibition in 2004); (b) guided tours of museum storage areas5 (e.g., Louvre-Lens); (c) live conservation-restoration treatments (e.g., the restoration of L’atelier du peintre at the Musée d’Orsay in 20155); (d) project activities led by conservation centers (e.g., Archeological Site of Ostia Antica,8 organized by ICCROM, 1997; and Caught in Time at the National Conservation Centre in Liverpool, 19966).

• The importance of public involvement in heritage preservation and an analysis of the roles that conservators and restorers currently perform in cultural institutions.

RESULTS & DISCUSSION

Showcasing live interventions and providing public access to these types of exhibitions entails the risk of undermining the work of the professionals. Museums frequently organize events10 to find out what the general public is interested in and how museums can satisfy those interests in ways that will appeal to visitors’ imaginations and emotions. Ultimately, projects undertaken by museums tend to play on the scientific character of the profession by offering visitors opportunities to consult documents such as X-ray photographs, infrared, ultraviolet images, and so on. Ongoing interventions on masterpieces showcased in museum galleries allow visitors to observe and compare works before and after they are treated. Guided tours of museum storage areas can help visitors understand how and why these conservation spaces are used. However, granting visitors access to such areas is keenly debated.11 Such projects and activities contrast with those organized and led by conservation centers such as ICCROM that are expected to increase public awareness of the fragility of cultural heritage.

CONCLUSION

By capitalizing on cultural heritage, museums can create live, direct links with their users. However, some educational initiatives, in their efforts to captivate the public, may skew the reality of conservation work by presenting it via methods more commonly associated with the entertainment and leisure industry. Hence to help increase awareness, one solution is to develop specific collective lines, set up information and communication campaigns, and invite communities and museum staff to actively participate in these programs. The commitment to cultural heritage is sustainable only if it is fully integrated into the overall objectives of an institution. This implies that conservators/restorers must communicate, target several audiences, and continually rethink the experience of attending their museum.12 A powerful and effective strategy plan on cultural heritage, focusing on its accessibility and its conservation, can only add success to the preservation of cultural heritage.

CURRICULUM VITAE

Elena Ciliberto earned her master’s degree in the conservation and restoration of cultural heritage from the Ecole de Condé in Paris, specializing in paintings on canvas. She holds a second master’s degree, in museum studies, from the University of Montreal, where she further developed museum management, collection care, and museum activities. She has had several work experiences in European and Canadian museums.

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The research took place from January to August 2015 as part of the author’s master’s degree program in museum studies at the University of Montreal. Three professionals involved in heritage conservation in Europe and Canada were interviewed. These meetings were an opportunity to discuss questions raised by visits to storage areas and observations of live restorations. Per the university ethics code, the interviewees remain anonymous.


Guillermard, D., “Variations sur le thème de la réserve visitable, ce que voir veut dire, ce que dire fait voir”, CRBC, n. 28, pp. 3–8.

INTRODUCTION

Among Spain’s national heritage in ceramics can be found a few great examples of wall art, despite this type of art being uncommon in Spain. The current case study examines twelve large-format ceramic walls located in the service areas of one of the busiest roads in Spain, the North-East Highway or AP-2, which goes from Zaragoza to Barcelona. The ceramic murals that can be visited along the AP-2 are the winners of a contest organized in 1976 by the Patronato de Autopistas del Ebro (today known as Abertis). Twelve of the 280 entries were installed on the outer walls of the service areas (except for two that were installed inside the Lleida service area).

Each service area has two ceramic walls, one pointing to Zaragoza and the other to the Mediterranean coast. The two walls are linked, so both can be visited at each stop (i.e., without having to access the service area from the other direction) (Table 01).

As a group, the ceramic walls are an important referent in the ceramic wall category, not only because of their authors but for the singularity of their creation and layout.

However, these artworks are not well identified. As a result, they have been damaged by lack of maintenance and environmental exposure, which makes understanding, interpreting, and viewing them even more difficult.

<table>
<thead>
<tr>
<th>Área de Servicio</th>
<th>Km.</th>
<th>Dir. Zaragoza</th>
<th>Dir. Mediterráneo</th>
</tr>
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<tbody>
<tr>
<td>Los Monegros</td>
<td>86</td>
<td>Ángel Garraza</td>
<td>Rosa María Espí</td>
</tr>
<tr>
<td>Fraga</td>
<td>119</td>
<td>Carme Coma y Joan Roselló</td>
<td>Benet Ferrer</td>
</tr>
<tr>
<td>Lleida</td>
<td>142</td>
<td>Jordi Aguadé y Joan Vila-Grau</td>
<td>Arcadio Blasco</td>
</tr>
<tr>
<td>Les Garrigueues</td>
<td>163</td>
<td>Pilar Monner Solá</td>
<td>Eduardo Noriega</td>
</tr>
<tr>
<td>Montblanc</td>
<td>195</td>
<td>Joan Rebés</td>
<td>Lluis Castaldo</td>
</tr>
<tr>
<td>Alt Camp</td>
<td>214</td>
<td>Jaume Satorras</td>
<td>Manolo Safont</td>
</tr>
</tbody>
</table>

Tab. 01. Mural locations.
These issues have motivated the current study, which is still in progress; its objectives are to recognize and revalue the ceramic murals along the AP-2 in two ways: first, by making the murals’ existence and artistic relevance better known to the public; second, by improving the conservation state of the pieces and their environment.

METHODS & METHODOLOGY

The investigation involved:

1. Research of documentation about ceramic murals in general and about the murals along the AP-2 in particular.

2. Contacting and interviewing artists and others involved with the contest and the murals, including members of the jury, 20th-century Spanish ceramics experts, local councils, and the promoting company.

3. On-site study of the murals to identify, photographically record, and analyze the pathologies and agents of deterioration.

4. Elaboration of a proposal for the treatment, maintenance and promotion of the murals.

RESULTS & DISCUSSION

Description of the Artworks

The wall murals were made according to the contest specifications: using ceramic materials and 200 by 700 cm in size (Fig. 01). Most of the murals were made with a high-fired ceramic paste, mostly stoneware and tough refractory materials, which made preservation easier. These works of art have retained their original appearance. Each mural has a unique design and
composition, which can include glazed surfaces, engobes, and unglazed pastes. The final pieces were fired in electric, gas, or even wood-fired kilns with reducing or oxidizing atmospheres (Fig. 02).

The artists took inspiration from the motorway in devising themes for their works, which abstractly capture concepts such as velocity, movement, sound, and direction.

**Issues Registered**

The overall preservation level is good except for three cases. Two walls show damage where tiles have failed to adhere. A third, by artist José Noriega, has severe material problems and requires urgent action to prevent the loss of the artwork in its entirety (Fig. 03).

Earlier actions taken to preserve the murals were not in agreement with the preservation and restoration principles of contemporary art. For example, traces of adhesives and mortar can be found beyond the gaps they were meant to fill.

In addition to the materials problems, general issues affect the artistic concepts and make the artworks difficult to study, understand, or observe. These include indifference, lack of maintenance, reduced visibility caused by other elements in the surroundings (billboards, trees, banners, etc.), inaccurate information boards, or simply a lack of any information at all.

**CONCLUSIONS**

The issues that affect the walls along the AP-2 are common to many ceramic artworks located outdoors or in areas beyond the care of museums.

A revaluation of these artworks is necessary. A goal of deeper analysis would be the development of a plan to examine this part of our heritage from multiple perspectives. In some cases, a simple program of basic preservation procedures, maintenance, and marketing would be sufficient, at least until further resources are available to carry out more important actions.

Several factors have harmed (or at least not helped) the AP-2’s ceramic walls: incorrect preservation actions, lack of visibility caused by elements located in the field of vision, lack of maintenance, risk of total or partial loss, and lack of information signs.

An appropriate intervention would include:

1. Restoration of those walls in an insufficient state of conservation.
2. Conditioning of the spaces where the murals are located. This could include the upgrading of buildings and gardens, the elimination of elements that hide the walls, correction of errors in signage, and the addition of signs where they are currently lacking, in order to facilitate awareness and improve viewers’ understanding of the artwork.
3. A control plan and ongoing monitoring through periodic inspection.

Most important, the ceramic walls of the AP-2 need to be visited. Simply describing them is not enough. Their artistic quality is best enjoyed in person, because even 40 years after their installation their language remains active.

**Acknowledgments**

This article is part of the author’s pre-PhD research, financed by the Euskal Herriko Unibertsitatea / Universidad del País Vasco. I thank my project mentors, María Pilar Bustinduy Fernández and Ángel Garraza Salanueva, for their help. I also thank Dirección Para la Igualdad de la UPV/EHU for the chance to participate in the II Semana de Escritura para Investigadoras, during which this text was written.

**Curriculum Vitae**

Amparo Lozano Sancha is a trainee researcher at the Euskal Herriko Unibertsitatea / Universidad del País Vasco. She studies the preservation-restoration and revaluation of contemporary ceramics, especially outdoor large-format pieces, in order to promote their visibility among the public.
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1. The most relevant ceramic walls in Spain might be those made by Joan Miró and Llorens Artigas for the Prats Airport in Barcelona (1970), the Palacio de Congresos de Madrid (XX), and José Luis Zumeta’s in Usurbil (1973), among others.

2. Among the unselected participants are important icons of 20th-century Spanish ceramic arts, including Enric Mestre, Claudi Casanovas, Madola, and Pepe Noguera.


INTRODUCTION

Can museums play a role in urban regeneration? The Oxford English Dictionary defines a museum as “a building in which objects of historical, scientific, artistic, or cultural interest are stored and exhibited.” However, this concept can be extended to everything that is a vehicle for information and memories. Therefore, whether a physical space encloses the objects may be irrelevant. This is the case with open air museums where old buildings and archaeological and/or historical sites are preserved and exhibited, generally with the intent of recreating past lifestyles. The first open museum to be established was King Oscar II’s collection in Bygdøy, Norway, in 1881, where the two main buildings were opened to the public. Other examples in Europe are the Chiltern Open Air Museum in England, where historical buildings have been preserved and fixed thanks to the work of volunteers; the Open Museum of Glasgow, which organizes traveling exhibitions and interactive events to bring the museum’s collections into the community; the Den Gamle By in Denmark, the first open museum to recreate life during
the 1700s, 1800s, and 1900s. Most of these museums aim to recreate rural cultures or particular historical periods, but none of them illustrate the story of an area by bringing together the memories of the people who have lived there and the buildings where everything happened. Recently the role that museums can play in the context of their territory has become clearer; in particular, they can provide social, cultural, and economic benefits that go beyond their primary function. Examples include Medellin, Colombia, and Nantes, France, where art and culture have become key aspects of the economic development of the city, as well as Rotterdam, where the city and the local community are actively involved in the activities of the city museum.

San Lorenzo Urban Memory Museum (SLUMM) was created by bringing together the main ideas behind the open air museum and the city museum with the aim of preserving and promoting the memories of one of Rome’s most important districts, San Lorenzo. SLUMM does not simply display objects; it is a vehicle for the cultural regeneration of the area and, therefore, of the whole city. The museum tries to balance business requirements with the needs of the local community by building a close relationship with the people who create the community. The projects that have been developed might seem small and local, but when viewed as a whole they clearly help the museum blend in with the culture and the community.

SAN LORENZO AND SLUMM

San Lorenzo’s popularity is the result not only of its history—it is the site of the monumental Verano Cemetery, the Porta Tiburtina, the first Montessori school in Rome, and heavy bombing in 1943—but of its nightlife. Pubs, bars, and breweries are numerous, and many have been established just in the last few years in response to the growing number of students living in the area. In the past, San Lorenzo was occupied mostly by workers and their families, with an economy based on small factories and family-run businesses. A working-class district based on a well-established social and political identity, it was nonetheless able to welcome and integrate the stranger. Because of its distinct traits, the cultural and artistic experiments of the 1980s (especially by Gruppo di San Lorenzo, leading to the creation of Fondazione Cerere), and its strong political identity, San Lorenzo had long attracted artists and celebrities from all over the world. Today these features coexist in the same area but without cohesion, and this is leading to a loss of local identity. Fast transformations are changing the main traits of the area, and several local public services and spaces are being replaced by bars and nightclubs, causing a deterioration of citizens’ quality of life.

With the aim to recover, preserve, and share San Lorenzo’s memories and identity, ANPI San Lorenzo and Youth in Conservation of Cultural Heritage (YOCOCU) created SLUMM (Fig. 01). The idea is to involve citizens, students, schools, private and public institutions, and everyone engaged in the life of San Lorenzo in the social and cultural rebirth of this quarter, using buildings, libraries, craft shops, and workshops as an open, collective museum. The main strategies are guided and self-guided tours (Fig. 02), a museum website, and artistic installations. SLUMM’s guided tours use a mobile app called Mapcast.

MAPCAST

The creation of a museum that includes multiple subjects, ideas, and topics requires an instrument that allows
effective coordination and easy communication. The solution came about through a collaboration between YOCOCU and Etcware. The result was Mapcast,8 a system consisting of a mobile app (available on iOS and Android markets in multiple languages) and a geosemantic repository. Once users download Mapcast onto their mobile devices, they can use it to discover nearby places, itineraries, and monuments through the GPS system (Fig. 03). When visiting open-air spaces and buildings, users can scan QR codes to gain access to detailed historical and cultural information on their devices. Mapcast offers open museums the following innovative functions:

- Georeferenced location of the user;
- Cultural and historical information about buildings and cultural heritage in the area;
- Information about restaurants, small shops, workshops, local festivals, and traditions;
- Classification system based on a multilingual thesaurus;
- Tourist navigator that tells users how to get to places of interest and suggests things to look at; also allows users to listen to stories uploaded by other users;
- Ability to create personal itineraries; and
- Ability to share personal itineraries.

Moreover, with the editor panel available via the Web, Mapcast allows the users—whether schools, citizens, or cultural associations—to add their own information so they can be actively involved in enriching the content and thus in creating culture and knowledge. Voting on content then allows users to perform a quality-control function.

CONCLUSIONS

San Lorenzo is one of the richest areas of Rome for cultural, political, and artistic history and the perfect setting for the creation of an open museum. SLUMM was created with the intent of collecting San Lorenzo’s memories and preserving the social and cultural transformations that happened in this area through the voices and places that had characterized it. SLUMM is a museum with libraries instead of bookshops, laboratories instead of gift shops, where the workers are the citizens, and where educational projects and nightlife events are linked. The integration of Mapcast represents an essential step in improving accessibility and awareness of culture. The app’s simple, interactive way of exploring local heritage allows users to be both provider and consumer of culture, so the community can be the creator and narrator of its own identity. The app brings together traditions and the latest technologies, creating georeferenced cultural itineraries that guide users in the discovery of local cultural, historical, and artistic identity. SLUMM’s Mapcast app represents a virtual place where memories are preserved and shared, where culture is made accessible and interactive, and where past and future generations are brought together.
ACKNOWLEDGMENTS

SLUMM is promoted by ANPI San Lorenzo and YOCOCU. The project would not be possible without the invaluable active collaboration of the local community.

CURRICULUM VITAE

Andrea Macchia is a conservation scientist with a PhD in science applied to environmental protection and cultural heritage conservation. He is the founder and president of Youth in Conservation of Cultural Heritage.

Laura Rivaroli is a graduate of I.S.C.R. A freelance professional restorer for the private and public sector, she also teaches courses on archaeological excavation first aid and restoration.

Marta Fiacconi has a master’s degree in cultural heritage conservation and is a PhD student in cave palynology at Liverpool John Moores University. She is the international relations officer for Youth in Conservation of Cultural Heritage Italy.

Marta Rivaroli is a historian at Sapienza—Università di Roma and has been an official guide in Rome since 2001. She is the cofounder of “I Gatti del Foro,” which has promoted Rome’s cultural heritage through guided tours of the city since 1996.

Alessandra Donnini is technical manager at Etcware s.r.l., and has been a lecturer in engineering at the Università degli Studi di Roma Tor Vergata for ten years. She is the author of several articles on the semantic Web and cultural heritage.

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Genius Loci: A Web-Based Initiative to Enhance Archaeological Resources

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INTRODUCTION

Archaeology belongs to communities: it defines, enriches, and enhances them.¹ For this reason, the Associazione Culturale Egeria plans to create a Web portal that can offer useful services to citizens, both professional archaeologists and amateurs, involving them directly in the dissemination of archaeological resources where they live. Genius Loci wants to be an archaeological website that offers various types of information depending on who uses it.

Despite accounting for less revenue than manufacturing or services, the tourism sector, which depends on Italy’s cultural heritage, is likely to be the most reliable sector of the national economy over the long term.² The mission of Genius Loci will be to take care of and protect our cultural heritage by explaining its value to as many people as possible.

METHODS & METHODOLOGY

The Associazione Culturale Egeria is an association of archaeologists with experience in archaeology-oriented school activities.

Our journey started in November 2015 with an informal survey of more than 100 people to understand which archaeological sites they would like to know more about.

Although our region, northern Milan, includes more than 30 archaeological points of interest, the survey revealed that few people are aware of more than one or two of the sites closest to their home and that knowledge of even those is poor. We then went further and tried to determine how interested citizens were in learning about the local archaeological sites and what interest there was in the rest of our country.

The results were clear and similar to national survey results: people are interested in cultural heritage sites, but only the main ones are known and visited (figs. 01–02). This is further confirmed by tourism reports. Although tourism is increasing and famous places are seeing more visitors, smaller and lesser-known places have not yet benefited.³

Our study raises several important issues.

1. Knowledge should return to the people. Many cultural activities do not have a significant impact on local and/or nonprofessional audiences.

2. Knowledge should be reachable. Information about archaeological sites is hard to find and irregularly (or never) updated.

3. Knowledge should be easier. Nonspecialists, whether adults or schoolchildren, should be able to learn about local cultural heritage from sources that are understandable without compromising quality.

We decided to develop a program that could connect the three key participants in the archaeological panorama—schools, archaeologists, and interested people (e.g., tourists)—and allow them to participate.
Since when does Milan exist, in your opinion?

![Pie chart showing distribution of responses.](image)

**Fig. 01.** Chiara Bozzi, Milan survey results, 2015. Free to use the picture.

Note: Right answer is From before Romans - Almost 1/3 (19) of interviewed was really wrong!

We want to promote high-quality archaeology-oriented activities in schools. As a result of these activities, with the help of the students, we will produce shareable data sheets describing local cultural heritage sites of interest. These sheets will provide useful geographic details about local sites, a bibliography, images, addresses, and other information that can be useful for visiting the site.

We proposed to make these sheets available on a Web-based database with a map interface for easy access and the possibility to select specific reports. Because participating schools would include both primary and secondary schools, materials of varying complexity would be presented.

Archaeologists could then supplement, improve, and research the database records. Linking to relevant articles and publications would result in a georeferenced bibliographic database. Such a research tool does not yet exist but would be extremely useful for the archaeological community.

Sharing the database via the Internet would allow everybody, including tourists, to quickly access information and to provide updates (e.g., new hours of operation, changes in access, or other logistical details).4

The portal that would host this database could be expanded to host additional features (including those requested by the audience); for example, it could host a database of teaching sheets, a virtual museum, experimental and laboratory results from our laboratories, and acknowledgment pages our collaborators.5

In addition, our related laboratory activities could be inserted into the Italian “school-job interchange,” which requires high school students to gain practical experience. In this way students could actively participate in the enhancement of the cultural heritage of their territory.

**RESULTS & DISCUSSION**

We submitted our project to Link On Labour, a European prize for young startups in northern Milan. After winning, we used the prize money to start our first round of school activities. These commenced in December 2016 at the Zandonai primary and secondary school in Cinisello Balsamo and will expand to other schools as agreements are signed and fundraising allows. In April 2016 we realized an exhibition that presented the results of our work to the public and provided a tactile visit, thanks to the realization of some 3D printed archaeological finds.

Already in development is an agreement with Virtus Loci, an institutional website that maps and locates interesting buildings in northern Milan.6 The agreement will allow us to implement a professional georeference website with a wide area of coverage, jumping from six cities to 33 without even publishing our beta website. The agreement will also allow us to concentrate on future developments, such as smartphone accessibility and new classroom activities (3D scans and reconstructions, conferences, etc.), and to develop communications campaigns.

**CONCLUSIONS**

Interest in Italian archaeology is high but imperfectly matched to available resources.
Providing people with a way to access the information they want, at the technical depth they want, is likely to attract more people to cultural heritage and make students aware of the resources that surround them. That will in turn improve attendance at and the protection of local points of interest.

Archaeology should stop being seen as a “boring topic” and start being offered to people in ways that are less threatening.

**Curriculum Vitae**

Chiara Bozzi is a freelance archaeologist. She collaborates with the Università Cattolica del Sacro Cuore of Milan as a subject matter expert for the teaching of classical archaeology. She has expertise in the creation of educational workshops.

Matteo Tortosa is a technical product designer at Miasuki.com, a major startup in Milan in the luxury apparel sector. He holds a degree in industrial product design from the Politecnico di Milano. He is interested in new technologies.

Alessandro Bona is an archaeologist and subject matter expert for the teaching of numismatics at the Università Cattolica del Sacro Cuore in Milan. He is also an external collaborator with the Pontificio Istituto di Archeologia Cristiana in Rome.

Ricky Radaelli is an archaeologist. He has worked as a designer of archaeological finds in an international research project involving the University of Manchester, Cambridge University, and the University of South Florida.

Riccardo Valente is an archaeologist. He completed a PhD at the Politecnico di Milano on the application of relevant advanced methods for archaeological excavation (3D photogrammetry).

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3 In 2016, attendance at Italian museums increased by 12% compared to 2015 (i.e., 1.2 million persons in more), which led to a 12% increase in receipts (up €18.5 million). For example, the Lombard museums were visited by 1.791,931 people. See Ministero dei beni e delle attività culturali e del turismo, “2016. Tutti i numeri dei #museiitaliani”, 7 January 2017, http://www.beniculturali.it/mibac/export/MiBAC/sito-MiBAC/Contenuti/MibacUnif/Comunicati/visualizza_asset.html_892096923.html [15-03-2016]. The Milan Expo drew 21.5 million visitors (of which only 6.5 million were foreigners) in 184 days. See ANSA, “Expo, tutti i numeri di Milano 2015”, 31 October 2015, http://www.ansa.it/canale_expo2015/notizie/news/2015/10/31/expo-tutti-i-numeri-di-milano-2015_95c81616-fb76-4814-a2de-78e86b10be0.html [25-07-2016]. However, tourists visit the same places. TripAdvisor.it’s ranking of the top ten things to do in Milan includes the Dome (with the terraces), the Last Supper, the Vittorio Emanuele II Gallery, the Sforzesco Castle, and the Monumental Cemetery.


5 An example of an archaeology-themed Web portal was recently presented to the city of Milan thanks to the collaboration of public institutions and four universities. Soprintendenza Archeologia della Lombardia, *Milano Archeologia*, http://www.milanoarcheologia.beniculturali.it/ [25-07-2016].

Bell Ringing Nowadays: New Perspectives for an Intangible Heritage

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INTRODUCTION

Bell ringing has been a common practice for much of recorded history. The music of bells has been a shared code and language known by communities and used to build time and space.

One of the principal functions of bell ringing involves the construction of time—both social and common time as well as religious time. Religious and nonreligious bell ringing together constitute one of the most useful means of communication ever devised. Communities have also rung bells to protect themselves.

The variety of techniques used to ring bells is almost unlimited, as every tower or every town or at least every city had its own, local way of ringing. The language of bells is thus an almost infinite sequence of local codes, rich and diverse. Bells are a musical instrument for expressing feelings of joy, mourning, alarm, and keeping the community aware.

This traditional cultural expression is still alive in some communities, although many have allowed the practice to disappear. In some cases, the ever creative and ephemeral works of the bell ringers have been substituted by engines and electric mechanisms that cannot reproduce the original scores and hamper manual ringing.

Bell ringing, which is an example of intangible cultural heritage (ICH) is an ancient tradition deserving of recovery and preservation. The present article reports on a case...
study that took place in València, where, after a 40-year absence, bells are again rung by the community and a new model has been developed for managing the tangible and intangible issues associated with this cultural practice.

METHODS & METHODOLOGY

This study case of the “Campaners de la Catedral de València” (Bell Ringers of València’s Cathedral) (Fig. 1) is based in part on the author’s experience with a long-term project involving the new bell-ringing movement. Since 2002 I have been part of the bell-ringing team as well as an active participant managing some issues of the team. Participation as a bell ringer led me to direct my professional career toward ICH, including the bell-ringing tradition, its spread, conservation, and education.

The analysis of this cultural expression is based in anthropology, sociology, history, and geography, because to explore and understand the historical importance of bell ringing, all of these disciplines must be joined. By comparing existing studies that relate these approaches to bell ringing, a complete research frame can be defined.

Significant work in this area has already been completed by Francesc Llop i Bayo, whose essays explore the anthropological aspects of bell ringing, bell restoration, the intangible perspective of bell ringing, and the community implications of bell ringing for cultural heritage. Llop i Bayo has been one of the forefathers of bell-ringing research and study and, more important, about its spread in society.

Since we are presenting a new way of managing this heritage, we are also studying it from a social perspective. How is society interacting with this heritage? How are people taking part in conservations about it and furthering its transmission to future generations?

Fieldwork at the local, national, and European levels also informs the analysis by collecting examples of the various ways communities are preserving their bell-ringing heritage.

RESULTS & DISCUSSION

Since the 1960s, two processes have significantly affected bell ringing. During the 1960s and 1970s, in response to a “false” modernity, many bell-ringing traditions were lost. Local music and techniques were forgotten. Traditions were thought to be blocking progress and societal advancement. In addition, religious ceremonies were simplified, leading to a considerable reduction in bell ringing.

Then, during the 1980s and 1990s, forgotten or nearly lost traditions were labeled “heritage” so they could be appraised and preserved. One such tradition was bell ringing in València and its surroundings.

This important shift, which helped people “see” bell ringing as something worthy of keeping, inspired a group of passionate volunteers to start ringing bells manually again in the city, first in a small tower and later in the cathedral’s tower. Once they had climbed the tower for the first time, the process of formalizing the group began and an annual calendar of ringing was settled. The group has been ringing bells in València since 1988.

The group is a nonprofit cultural organization run by a four-to-five-person management team elected by all members. Any interested person can join the group. From the beginning, several experts in heritage and bell ringing have had important roles, including Llop i Bayo, who is currently the president of the organization.

Besides ringing the annual calendar in La Torre del Micalet (the cathedral’s tower; see Fig. 02), the other main goals of the group are to know, use, keep,
and spread the tangible and intangible elements of bell-ringing heritage through the study, research, conservation, and restoration of bells and their original sound. Thus, the group is more than just a collection of volunteers who share an interest in ringing bells. The group’s members are committed to taking care of this cultural heritage in a professional (unpaid) manner.

The existence of this cultural movement has attracted the attention of the public institutions that oversee cultural heritage management. In a “bottom up” approach, the management of the city’s bell-ringing heritage is now a collaborative effort between the institutions and the citizen volunteers.

Cultural departments of local and regional governments now set policies for the restoration and conservation of bells according to the new methodologies and respectful techniques introduced by expert research, including by members of the València bell-ringing group.

The model is even being “exported” to other regional, national, and international communities that are beginning to preserve their local traditions.

Shared management should be interpreted as a success both for the group and for society.

CONCLUSIONS

The bell ringers of València have set out on a hopeful, positive path to keep alive a historic tradition. The model they have established, based on citizen participation in cooperation with cultural agents, could be an effective tool for the management of ICH, since bell ringing is not the only cultural expression in need of solutions for protection and conservation.

ACKNOWLEDGMENTS

Thanks to all members of “Campaners de la Catedral de València,” colleagues and friends. Special thanks to Francesc Llop i Bayo, who is always helping.

CURRICULUM VITAE

Eliseo Martínez Roig has a degree in English studies and a master’s in cultural heritage management. His research focuses on intangible cultural heritage, especially bell ringing, its education, and conservation. He participates in congresses, publishes papers and monographs, and coordinates bell restorations. He is also in charge of the bell-ringing heritage project “Europe Is Ringing!”

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INTRODUCTION

This article highlights the experience of a shared effort between the Instituto Nacional de Antropología e Historia (INAH) and society (in this case the inhabitants of the village of San Felipe Ecatepec), where INAH responded to assist several communities in the state of Chiapas in preserving their historical and cultural heritage, without which they would be unable to maintain the continuity of their communities.

Located in the municipality of San Cristobal de las Casas, in the highlands region of Chiapas, San Felipe Ecatepec is a small community of indigenous (Tzotzil) origin. The main decision-making body is the community assembly, where a traditional authority, represented by the Commissariat and based on the voice and vote of the people, decides key issues. Decisions are “based on a traditional legislation which does not always correspond with the system of law in the Mexican state.”

Fig. 01. Source: Section of Conservation. INAH Chiapas Center. Title: Restoration of the main facade of the Temple of San Felipe. Author: Nayeli Pacheco Pedraza. Photographer: Nayeli Pacheco Pedraza. Image Owner: INAH Chiapas Center
According to the director of the Chiapas INAH center, anthropologist Hector Alvarez, “The belief system (worldview) and religion (practices) play a role in the identity and social cohesion; maintaining the current sacred places helps these ideological aspects to be preserved as physical nodes where ritual behaviors take place and, therefore where the bonds of community cohesion are strengthened.”

METHODS & METHODOLOGY

INAH’s work with the residents of San Felipe Ecatepec was based on the exchange of knowledge and experience. A horizontal, joint work relationship was established to encourage the sharing of responsibilities with residents interested in preserving their historical and cultural heritage.

Turning the conservation of cultural heritage into a sustainable activity can be achieved only by involving people who use and appreciate the objects of the conservation. The idea of sharing this work is to show that there are forms of action-participation in which responsibility is shared between institutions and society. Enrique Leff, quoting Michel Foucault, mentions, “we dread the difference, we aim at achieving a common language, a common epistemological framework, a common discourse so we could understand, and at the same time thoroughly defend our disciplinary identities, and therefore ourselves, as economists, anthropologists, sociologists.”

The conservation activities included outreach activities as well as visits organized for primary and secondary schools. This approach considers that, in all forms of education, the active participation of citizens is the best way to create a sense of belonging and to foster the care of their heritage. Concerning intercultural studies and his work experience in Chiapas, Schemelkes writes, “Intercultural education will involve different challenges for different populations, over a long period, mainly because the long history of discrimination and cultural domination in Mexico implies working with the indigenous population, very importantly and almost central to the principle of valuation of their own heritage, which due to racism introjection, has often been scorned by themselves.” INAH therefore had to investigate the interests of the residents of San Felipe Ecatepec and with them propose actions that were viable for all, with tangible benefits that have become an incentive to give continuity to conservation efforts.

RESULTS & DISCUSSION

Since 2008, the conservation section of INAH in Chiapas has participated in the conservation and restoration of movable property at the request of the main board of the temple and the committee for improvements of the temple.

The idea that care for cultural heritage could or should be left in the hands of a single group is today unacceptable. No single institution can respond to all matters related to cultural heritage, nor do people in local communities have all the tools to successfully execute these tasks. However, between the institutions and the local communities is a breadth of knowledge and experience that can be shared and put into action for the benefit of the elements that the inhabitants of a territory consider relevant: “Levi-Strauss called ‘science of the concrete’ the indigenous knowledge on nature and societies” and was one of those who showed Western scientists the importance of this knowledge. “Despite progress in many areas and collective efforts to rescue this kind of knowledge, indigenous knowledge has not been considered to create horizontal dialogues.” The projects undertaken with the local communities have allowed several movable and immovable heritage elements to be conserved.

Subsequently, a working group comprising locals and conservation specialists from the INAH center was created to give continuity to the activities of conservation and restoration. This group works with the traditional authorities. In a community assembly, participants collectively decided that the INAH’s traditional specialists/authorities, some of the participants in the meeting, and some of members of the local Improvements Committee would start to manage conservation activities.
A year later the group was reelected to continue work on the historic buildings in the community.

Understanding of conservation and restoration processes has improved among traditional agencies responsible for the care of the temple. This was reflected in the community’s rejection of a proposal to use latex paint to maintain the historic temple. They understood that such materials would be incompatible with the original materials used in the building. Instead, the use of traditional materials for the conservation of heritage objects was promoted. This included the use of materials from the region, which inhabitants have extracted and prepared.

Local traditional agencies are now involved in the maintenance of their historic heritage, and the local population has even begun to organize fundraising activities for conservation projects.

CONCLUSIONS

The ongoing presence of INAH’s conservation professionals was a key element in reaching positive results. Dialogue and joint decision-making with residents who showed an interest in safeguarding their community’s historic assets are part of a process that has developed in tandem with conservation activities. This is considered essential for the proper development of conservation tasks.

The revival of traditional forms of construction and carpentry, as well as the use of regional materials, is a way to value and establish a link to a kind of knowledge that has existed in the local community and is being displaced by modern materials and industrial techniques, many of which (e.g., cement and synthetic paints and varnishes) are not the best options for the correct preservation of heritage assets.

The “Declaration of Mexico on Cultural Policies,” a document issued by UNESCO in 1982 at the World Conference on Cultural Policies, notes, “Every culture represents a unique set of values and is irreplaceable, as traditions and forms of expression of each people are its most effective means of being present in the world.” That is why it is vital, in addition to preserving material remains, to rescue, preserve, and enhance the value of traditional knowledge that, to a greater or lesser extent, is being replaced by modern materials and techniques.

INAH’s experience in San Felipe Ecatepec has led us to find ways to contribute further to this process of exchange in which, every day, institutions and society relearn and rethink knowledge that cannot be acquired in a classroom or in academia.

CURRICULUM VITAE

Nayeli Pacheco Pedraza is a graduate in conservation and restoration of mural painting from the Escuela de Conservación y Restauración de Occidente. She is currently studying for a diploma in cultural analysis in the national coordination of anthropology and a diploma of history and theories of conservation restoration of cultural heritage at the Escuela Nacional de Conservación, Restauración y Museografía “Manuel del Castillo Negrete”.

Fig. 03. Source: Section of Conservation. INAH Chiapas Center. Title: Paint color tests with lime wing. Author: Nayeli Pacheco Pedraza. Photographer: Nayeli Pacheco Pedraza. Image Owner: INAH Chiapas Center
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The Museum of America in Madrid: A Problematic Colonial Heritage in Postcolonial Times

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INTRODUCTION

This article proposes a critical approach to the Spanish colonial heritage through the case of the Museum of America in Madrid, which exhibits under classical ethnographical criteria a collection derived mainly from 18th-century scientific expeditions and 19th-century acquisitions. The museum was projected trying to recuperate the history of the continent in a postcolonial time, a problematic aspect of Spanish heritage, 70 years ago.

In recent years the museum has worked to renovate its image though initiatives such as international research conferences, activities with migrant collectives and artists, internships for young students, integration projects, and scholar visits. Despite these initiatives, the collection continues to be displayed in ways that highlight the canonical narrative and thus clash with the goals of cultural diversity and the aims of the academics, researchers, and artists trying to give a new meaning to the museum (not by celebrating its importance as heritage but by trying to create postcolonial, postmodern, or decolonial discourses, art pieces, and exhibitions).

Taking as a conceptual framework postcolonial theories and the notion of the museum of ethnology as a space for encounters with other cultures that hides past and present power relations, the Museum of America is presented as a case in which the ethnological approach to American cultures in Spain hides power relationships that the museum tries to convey through its public and educational programs. The objective of the research was to analyze how the museum exhibits that heritage and communicates the difficulties of approaching these kinds of heritage in a postcolonial context.
METHODS & METHODOLOGY

The motivation for this research was the lack of constructive studies about the colonial heritage that the Museum of America represents. The characteristics of the collection and its display make the collection easy to misunderstand in an epoch when postcolonial studies are common in the main universities and centers of higher learning. This makes the museum an object of criticism, especially by Latin American researchers. Marisa González de Oleaga, for example, has directed two projects in which she complains about how the museum universalizes a particular point of view of the past.1 Elena Delgado has studied how diversity is emplaced in the museum and the relation of the museum with the migrant community in Spain.2 Jorge Luis Marzo curated an exhibition that noted the many colonial cultural symptoms related to Spanish heritage.3 And Esther Gabara showed in her work how the museum negates its colonial background.4 The aim of the present research was to recognize the problems of the museum not in a theoretical way but in its display and communicational strategy.

A qualitative analysis of the curatorial and communicational performance of the museum was completed. Its current display was systematically studied to determine which parts were shown in a problematic way in relation to the postcolonial theories of Adolfo Albán,5 James Clifford,6 Johannes Fabian,7 Edgardo Lander,8 Silvia Rivera Cusicanqui,9 and Grínor Rojo.10 The public and educational programs were analyzed in the same way, under the hypothesis that this heritage is still displayed from a colonial point of view wherein the key to the discourse is Spain’s role in “discovery” and the scientific rationalization the museum uses to justify its presentation of pre-Columbian cultures.

RESULTS & DISCUSSION

After analyzing how the museum exhibits heritage and how it communicates heritage through the lens of postcolonial theories, several key points can be recognized as problematic. The collection is organized and exhibited under classical ethnographic criteria in five sections inside a building shaped like a church (a reference to the evangelization of the Americas). The first section introduces knowledge resources about the Americas, from legends and literary chronicles to illustrated scientific documents such as maps, thus presenting the museum to the visitor as an authorized narrator of the history of the Americas by taking American civilizations as natural phenomena to be studied. The second section introduces the geography and demography of the Americas by using, without explanation, the “Casta paintings” as illustrations. This genre of painting shows a hierarchical system of race classification, and the presence of a population with African origins is treated as a “migration,” thus ignoring slavery and human trafficking (Fig. 01). The third section proposes that American societies fit a universal lifecycle that mixes contemporary images with ancient photography and pre-Columbian objects, creating a double temporality in which American societies are unified through an unvaried way of living (Fig. 02). The fourth section explains religions and mixes liturgical objects from pre-Columbian religions with Catholic material culture, thus creating an image connivance and syncretism that includes the “Quimbayas treasure” (Fig. 03), privileging its material value instead of cultural criteria. (The Colombian government has demanded the treasure’s repatriation.) The last section mixes different forms of communication. The visit finishes with the idea of Castilian language as a unifier of these peoples regarding the future.

Fig. 02. Explanations about lifecycle in the Museum of America. Elena Díaz. 2016.
Regarding the museum’s communications efforts, its regularly organized conferences contribute to enhancing its position as a scientific authority and official narrator of the history of the Americas in Spain. Other communicational efforts are intended to improve the museum’s image in society. These include folk culture activities organized with Latin American embassies (e.g., visits by musicians and dance companies, craftspeople, or film festivals); or activities for migrant communities, such as the project “To Migrate Is Culture,” which emphasized the cultural characteristics of the migration processes. Such activities were developed with good intentions but carried out in a way that had little in common with the collection and its display.

CONCLUSIONS

The museum’s character as a scientific authority exhibiting its collection in closed displays does not allow for dialogue and lacks national self-criticism and historical memory of the negative aspects of Spain’s relationship with the Americas. At the same time, the curatorial display homogenizes American cultures while also ignoring political or economic issues. Finally, the displays are not synchronized with the museum’s public programs, which make more of an attempt to integrate the population, including migrant communities.

Given the characteristics of the collection, finding common ground among the museum’s directors, external critics, and local migrant communities may be difficult. Management of the Museum of America and the heritage it hosts will require that all of these actors be taken account of, however. To ignore even one of them could represent a failure, but to get consensus may be impossible if the collection is not reorganized under new meanings.

Curriculum Vitae

Marta Souto Martín has a degree in the history of art from Universidad Autónoma de Madrid and a MSc in contemporary art history and visual culture from the Universidad Autónoma de Madrid, the Universidad Complutense de Madrid, and the Museo Nacional Centro de Arte Reina Sofía. She was an intern at the Museum of America in Madrid and a student at the Universidad de Chile with a scholarship from the Center for Latin American Studies of the Universidad Autónoma de Madrid.

Daniel Palacios González has a degree in the history of art from Universidad Autónoma de Madrid and a MSc in community cultural development from the Universidad de Oriente (Cuba). He was an intern at the Museum of America in Madrid and a student at the Universidad de Chile with a scholarship from the Center for Latin American Studies of the Universidad Autónoma de Madrid.

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Local Perceptions of Cultural Heritage and Tourism Development

INTRODUCTION

Many studies have shown that cultural tourism brings increased revenue to heritage sites and the communities that host it. In many cases cultural tourism is considered a potential engine of local development, especially in regions struggling to maintain rural and local economies. Therefore, the aim of the research presented in this article was to explore whether cultural heritage in Bač, a small town in northwest Serbia that is on the United Nations Educational, Scientific and Cultural Organization’s Tentative List, could be the driving force for development of cultural tourism and in that way be an engine of local community development.

The concepts of sustainability and community involvement have come to the forefront of tourism development, placing local people at the center of that development. Since residents can influence the success or failure of the local tourism industry, an important question for this research was whether the local community recognized the value and potential of cultural heritage in Bač. Specifically, what attitudes did locals hold about the tourism industry? Is the attractiveness of the Bač Fortress and the Franciscan monastery sufficient motivation for the local community to get involved in providing complementary services to tourists?

RESULTS & DISCUSSION

The interviews revealed that the local community is not at the stage of being an initiator of tourism development and does not think about being more actively engaged in tourism activity. In general, respondents had positive attitudes toward tourist potentials and attractions in Bač. Moreover, they thought that cultural heritage was significant and attractive to visitors. Nevertheless, although they were not against the idea of tourism development, they were not satisfied with the organization or with the current results of tourism.
development. Respondents connected their attitudes/perceptions with some of the problems hindering tourism development in Bač municipality. They expected the authorities not only to provide tourist content and offer improvements but solve infrastructure issues too. Some answers demonstrated that although locals believed they could benefit from tourism, risks remained, limiting investment possibilities. Even those who might consider investing in a private business felt they could not do so for financial reasons. In general, the local community seemed not to be educated about the benefits of tourism, yet another factor influencing their attitude.

CONCLUSIONS

According to Ap’s theory of social exchange, so long as residents perceive the benefits of tourism, they have sufficient reason to view it favorably. Thus, residents appear willing to engage in exchanges with tourists if they feel the transaction will result in a gain. At present in Bač, however, residents are not certain of gain. The “passive,” lack-of-initiative state may be related to (1) dissatisfaction with the level of organization; (2) insufficient tangible results from tourism development; (3) expectation that others (local authorities) will address problems; (4) perceptions that costs outweigh benefits; (5) lack of knowledge and education about the possible gains tourism might bring and how residents could be involved in such activities. Consequently, despite the potential around them, people in Bač do not have sufficient motivation, encouragement, or support to get involved in tourism activity.

To develop cultural tourism, the local community should recognize cultural heritage more from the point of view of opportunities and benefits, as an (untapped) economic resource.

ACKNOWLEDGMENTS

I express my warm thanks to the kind people of Bač for their willingness to participate in this research. I also thank professor Dragica Tomka for her suggestions, knowledge, and continual support.

CURRICULUM VITAE

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INTRODUCTION

Economy and culture have always been intimately related. The study of economic context is essential to understanding any artistic period. Contemporary art is no exception. The worldwide financial crisis that started in 2008 has had a deep impact not only on the conservation of contemporary art but on its exhibition and promotion.

From the mid-1980s to 2005, Spain prospered. Arts and culture in turn profited from the enthusiasm of both political figures and society at large. Art was a way to express prosperity, and Spaniards took pride in the country’s role as an international cultural powerhouse. Tourism increasingly became the most powerful engine of the Spanish economy, and, ever since, has gone hand in hand with culture in the national vocabulary and popular belief.

As J.M. Costa noted in 2014, this general mood led to the frenetic development and construction of contemporary museums and similar institutions: The following quotation by Costa clarifies the idea of freneticism in regard to the way in which the construction commenced. “La construcción de museos/centros de arte tuvo lugar en los años de vacas gordas y aún se mantiene esa tendencia cuando no hay ni para mantener a las vacas” (The construction of museums/art centers occurred in times of prosperity [literal translation: “years of fat cows”], and this tendency has continued even when no money remains to sustain the cows).1

The conclusion suggests useful measures for positively reinterpreting these museums and cultural centers. We will have to be imaginative enough to take these exquisite corpses and reactivate their potential if we are to create new paths of, if not highly successful, at least sustainable institutions. In each case, although we must remain realistic and seek to create not ex nihilo but ex materia, the efficient resolution of problems may require us to call upon deep reserves of imagination and creativity.

The keys to achieving these goals are, on the one hand, to allow museums greater flexibility to self-fund; and, on the other hand, to encourage institutions to diversify their activities and to prioritize a strategy of massive communication with the public.

METHODS & METHODOLOGY

A critical reading of the main Spanish newspapers was helpful for understanding how the mood of society evolved over the past thirty years. The enthusiasm and blossoming of new, modern institutions was followed by fear and uncertainty before and during the recent financial crisis. Specialists are now pointing out that these years impacted not only the economics of museums but their values and missions and even the very concept of the museum itself.2

For this article, national statistics and studies about museums were analyzed (Table 01). Two variables were considered: the number of museums created or closed and their typology (public, private, or mixed). The analysis then focused on museums (whether
public, private, or mixed) that receive financial support from any organ of public administration, their attendance figures, and their activities (e.g., exhibitions, conferences, courses, even refurbishment work).

RESULTS & DISCUSSION

The analysis showed that Spain has an enormous cultural heritage worthy of protection and exhibition. Traditionally, museums are where art is expected to be kept and shown. If these missions are still deemed obligatory, museums represent one of society’s essential tools for guaranteeing the conservation of its heritage.

The economic crisis of the early 2000s showed that museums’ lack of foresight affected not only their viability but the physical preservation of their collections. To ensure financial stability in the creation and long-term running of a museum, a set of mandatory measures must be established by the government. These measures would require a financial plan that guarantees the viability of the museum, taking into account the type and number of visitors expected, the infrastructures needed to serve them (transportation, restaurants, lodging, etc.), other cultural activities nearby, and the economic strength of the place where the museum will be located.

However, no formula can apply to all situations. When revitalizing institutions, each case must be separately studied.

CONCLUSIONS

These megalomaniacal projects are no longer affordable. Even though they were intended to democratize culture,
democracy does not mean “huge”; it means “people.”
So the mission of a museum must be focused on the
people who will visit its exhibitions. Local museums
or those placed in small towns should develop a
wider and more varied range of activities to attract
what limited public they have. A richer program
will be more likely to respond to the interests of
different sectors of the population: children, youth,
professionals, national and foreign tourists, and so
on. Even if the economy flourishes as never before,
the focus of investment should be on the contents
of museums, since we have already invested in
the containers. Let us take advantage of Spain’s 20
years of construction and fill the numerous available
containers with the alternatives society demands.

Curriculum Vitae

Alejandra Alonso Tak holds a degree in art history from the
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the Faculty of Geography and History. Her research includes
museums’ politics of acquisitions, patronage, and the art market
or Spanish art and craftsmanship in the 16th-18th centuries.

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arqueologico-nacional-listo-y-sin-poder-abrir-por-falta-de-vigilantes_46570/ [10-07-2016].
Analysis of the Criteria of Choice of the Variable Determinants of an Economic Index of the Value of the Historic Center of Cartagena

Maria Dolores Pujol Galindo, Gemma Ramírez Pacheco, Pablo Aragonés Beltrán

INTRODUCTION

The measurement of the economic value of inherited cultural heritage is considered an essential part of the cultural policy. Scientific contributions on this issue come from different perspectives (financing of culture, evaluation of public expenditures, cost-benefit analysis, etc.).

Several international organizations have dealt with historic centers. The main objective of these organizations was the physical preservation of the historic centers.

In the 1960s the recovery and value of such historic centers began to be studied in addition to their physical, socioeconomic, and sociological aspects, highlighting the influence that the different public administrations have on the economic development of these centers.

Research on the monetary valuation of historic sites is scarce (five studies worldwide), if only those that determine the economic value of a living historic complex are considered. The methodologies used are the traditional ones of neoclassical economics: the contingent valuation method (60%) and the travel-cost method (40%).

The characteristics proposed when valuing patrimonial assets (subjectivity associated to culture, legacy to future generations, complexity in the process of establishing value, absence of comparable goods, etc.) invite us to look for solutions that are more flexible (procedural rationality) and more realistic than the strict neoclassical economics (substantive rationality).

Work applying the techniques of multiple-criteria decision analysis (MCDA) in the field of cultural heritage have developed extensively over the last decade. However, their objective is not economic valuation but decision making in planning processes, management and/or the implementation of conservation projects, and recovery or reuse of these goods.

Attention to the capital-image of a historic center leads to understand it as a living entity that evolves toward new functions, including tourist, residential, or educational, energizing and turning them into an important economic resource. This development is intangible and relies on a certain degree of complexity and synergy between the elements that define the historic city.

Some authors oppose this commercialization and defend valuation methodologies other than the economic. However, a worldwide literature review in this area reveals a total of 41 works that establish an economic value to patrimonial assets with different scopes.

Being able to determine an economic indicator for a historic center can guide the consumer society in which we live toward greater consideration and recognition. Thus, the information generated can be used for different purposes: from increasing
citizens’ awareness of their own heritage to analyzing the cost-benefit of including policy planning in those aspects that enhance its value.

The main objective here is to design a model to evaluate historic centers, applying the MCDA to the case of Cartagena to verify its viability.

To this end, the processes of transformation and urban regeneration were analyzed, and possible socioeconomic, physical, institutional, and cultural variables were established (97 in total) and defined in technical data sheets as shown in Figure 01.

The practical application of the model must be made viable by establishing the variables that determine the value of the historic center of Cartagena.

The next step is to reduce the number of variables by establishing selection criteria. The present article reports on those efforts.

METHODS & METHODOLOGY

MCDA techniques include processes and mechanisms to resolve difficult issues involving people and criteria, grouping tangible and intangible attributes to make appropriate decisions, taking into account the opinion of experts.

To reduce the number of variables, experts from the private and institutional sectors of the Cartagena historic center were interviewed. Within each sector, competent authorities on the physical environment (architects, urbanists), on social aspects (human geographers), on economic aspects (economists and trade associations), and on institutional aspects (local administration) were interviewed.

The results led to differences of opinions and produced a large number of variables. To meet the goal of reducing the number of variables, the following criteria were used:

C.1. Consensus of 100% of all the experts.
C.2. Giving greater weight to the expert’s choice in those variables in which they have greater specialization.
C.3. Consensus of 100% of both sectors with a simple majority of the experts within each sector, for the selection of variables.

**Fig. 01. Sample data sheet of one of the 97 variables.**
RESULTS AND DISCUSSION

The implementation of the above three criteria led to:

C.1. 25 variables.
C.2. 50 variables.
C.3. 60 variables.

Twenty variables were common to all criteria, so they were considered fundamental to the economic index we intended to establish.

The reason for reducing the number of variables as much as possible was to simplify the following session of surveys for the experts: the goal of the next phase of the research was to establish the degree of influence between the selected variables, if applicable, according to the judgment of the selected experts.

Thus, the questions to be posed meet the formula: \( n^* (n-1)/2 \), where \( n \) is the number of variables.

Therefore, based on the three aforementioned criteria, the number of questions for the experts will be:

C.1. 300.
C.2. 1.225.
C.3. 1.770.

For the model and the methodology applied to be viable, C.1 should be selected, although the nuance of the expert’s weight on the environment being judged would be lost.

Another option is to go one level up in the model’s scheme (fig. 02).

As a result, the variable level would be omitted, and the questions would be raised at the fields’ level. Thus, using criterion C.2, there would be 27 fields, and 351 questions would be required.

The next step is to highlight the limitations of the study and the research lines that emerge after the work is done, to check whether the model loses validity by making it viable.

CONCLUSIONS

The results aim at the feasibility of the model, and it is necessary to carry out a comparative study of the results that would be obtained with the three criteria to analyze the reliability of the synthesis we strive to achieve.

The contributions of this research project can lead to a greater understanding of the institutions that are the guardians of our historic centers, and can aid their efficiency in planning and management.

CURRICULUM VITAE

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INTRODUCTION

The definition of cultural heritage has changed significantly over time, and today, according to the United Nations Educational, Scientific and Cultural Organization (UNESCO), it represents all that is inherited from past generations, that is preserved in the present, and that can be transmitted for the benefit of future generations.1 Usually it is described as “intangible” or “tangible.” Tangible heritage is further classified as “movable” and “immovable” cultural heritage, the latter being the focus of this article (archaeological heritage).

In Serbia, the protection and use of cultural goods is regulated by the Law on Cultural Goods, which divides immovable cultural goods into monuments, cultural-historical areas, archaeological sites, and places of significance.2 The present law, from 1994, is outdated and does not allow for the implementation of the newest theories and practices. The work of institutions in the field of cultural heritage has thus stagnated for the past decade in Serbia, the result of economic, political, and administrative problems.3 One of the biggest issues confronting the cultural heritage system in Serbia is its dependence on funding from the state. Allocation of subsidies and grants, however, is unsystematic and does not follow clear financial criteria.4 Current projects of integrative conservation of archaeological sites receive funds in an uneven, irregular, and insecure manner because of the financial crisis.5 Due to a lack of strategic budget planning, the process of revitalizing even a single archaeological site can be prolonged for many years.6 Most sites are closed or unavailable to the public, a waste of potential.

The current Law on Cultural Goods does not oblige the state to finance the protection of cultural heritage, nor does it instruct institutions to identify additional sources of financing.7 One approach would be to seek alternative ways to increase funding, especially from the private sector, which is an established practice in many countries. Serbia lacks the sort of mixed-fund, public-private partnerships found elsewhere in the world, however,8 despite the recent passage of the Public-Private Partnership and Concessions Act, which allows cooperation between public and private partners in the sectors of culture and tourism. The law has not yet been used for the purpose of conservation of cultural heritage, however.

The aim of this article is to investigate whether the current legislative and economic context of Serbia is suitable for introducing partnerships as an official instrument of cultural policy. This research seeks to address the following hypotheses:

Partnerships are a suitable legal instrument to introduce in Serbia as an additional source of funding for cultural heritage projects.

The benefits of implementation could overcome likely threats and obstacles.

Private stakeholders would be more interested in these partnerships if the state were to introduce quality incentives.
METHODS & METHODOLOGY

Two research methods were followed: desk research and semistructured interviews.

Desk research consisted of:

Analyzing international conventions, charters, and recommendations in the field of cultural heritage (e.g., UNESCO, International Council on Monuments and Sites, International Centre for the Study of the Preservation and Restoration of Cultural Property, Council of Europe).

Analyzing available foreign and domestic literature in the fields of cultural policies, partnerships in cultural heritage, cultural economics, integrative heritage conservation, and so on.

Analyzing the legal framework of Serbia and other countries that have introduced or accepted partnerships as an instrument, as well as examples of good practice.

Semistructured interviews were carried out with experts working in the field of cultural heritage.

RESULTS & DISCUSSION

The potential of culture and cultural heritage as a tool and vehicle for socioeconomic development has been increasingly recognized in recent decades. Prior to this, only its intrinsic value was recognized, and it has never been seen as a part of sustainable human development. Today, culture is increasingly taking center stage in new development concepts, reaching the peak of its importance. This is evident in many new documents; for example, the Hangzhou Declaration (2013), “Cultural Heritage as a Strategic Resource for a Sustainable Europe” (2014), and the Work Plan for Culture (2015–2018). They all recognize cultural heritage as a major asset and resource of great social, cultural, and economic impact, as a driving force of sustainable people-centered development, with the ability to contribute to the achievement of other policy objectives (social cohesion, agriculture, environment, tourism, education, research, etc.).

Many studies have been conducted on the economic feasibility and impact of heritage conservation and rehabilitation projects, which have several areas of positive impact, such as jobs and household income, revitalization of cities, heritage tourism, property value improvement, and so on.9 Of these, heritage tourism is the sector that reaps most benefits from archaeological sites and is perceived as an economic engine for many countries and a major contributor to their income. Furthermore, equipping archaeological sites to take part in heritage tourism networks makes them a source of jobs and increases household income. Immovable cultural heritage thus has great economic potential that can be materialized only if it is put to use and adequately conserved, presented, and managed.

Partnerships have proved to be a suitable means of achieving successful and sustainable conservation, presentation, and management goals. This is accomplished when synergy between stakeholders is reached, roles and obligations are clearly defined, and risk is clearly allocated. Successful examples include Herculaneum, the Ubjan Monument, Sviyaga island, and the ancient city of Bolgar.

When discussion turns to introducing this type of instrument in Serbia, however, views are conflicted. Some believe that without sufficient incentives, the private sector will not be interested in investing in this cultural heritage sector, while others believe this type of instrument is suitable only once political instability, corruption, and lack of transparency are significantly lower. Concern that the interests of sites will be taken for granted is legitimate since heritage sites are a nonrenewable source and easily degradable. This is further linked with the obvious lack of transparency and insufficient accountability of the state, which is evident in the absence of a Public Contracts Register, whose existence is regulated by article 74 of the Public-Private Partnerships and Concessions Act of Serbia.10 Another concern is that heritage conservation is being sacrificed for short-term profits11 by turning heritage monuments into consumer-oriented projects while inflicting considerable destruction. Furthermore, Serbia lacks sufficient personnel trained in preventive conservation, as well as the educational training programs needed to develop the expertise and skills required to perform such roles.12 All of these threats and concerns need to be addressed if Serbia is to implement public-private partnerships successfully.

CONCLUSIONS

Even though Serbia’s Public-Private Partnership and Concessions Act could be successfully implemented in the field of cultural heritage (many examples of good practice are available worldwide), whether it can be implemented right now is the question. Currently, too many obstacles are preventing implementation or even threatening the very existence of the legislation. First, the state’s strategic documents for culture and tourism still do not recognize it. Therefore, cultural heritage workers are seldom informed about it, since the topic
is not included in their education. On the other hand, political instability in the country, the slow pace of administration, and general economic insecurity prevent the private sector from investing. Furthermore, the presence of the third sector in the field of cultural heritage is weak, so they have little influence, and their role in cultural heritage public-private partnerships (PPPs) is of utmost importance. The three sectors must work together if the instrument is to be introduced successfully. The state would have to promote PPPs and carry out educational workshops and seminars to increase the law’s visibility and equip cultural workers with the knowledge and “know-how” needed to approach the private sector. In order to attract investment, the state would need to introduce incentives (financial, regulatory, tax, etc.) and create a more stable environment. Finally, the role of the third sector would need to be reinforced, because it provides the necessary monitoring activity, assuring a transparent process, while its presence greatly decreases the chances of failure and negative outcomes.

**Curriculum Vitae**

Kristina Radovic has a bachelor’s degree in archaeology and is a student in the cultural policy and management master’s program at the University of Arts, Belgrade. She is interested in various aspects of integrative rehabilitation and management of cultural heritage.

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Case Studies of the Utility of the Application of New Three-Dimensional Technologies for the Study and Diffusion of Heritage from a Historical-Technical Perspective

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INTRODUCTION

In recent years the field of cultural heritage has become an undisputed protagonist in the development of three-dimensional (3D) technology. This article discusses the applications of 3D techniques in a variety of cases.

The confrontation of these cases with distinct different purposes, intended to clarify and shed new perspectives on their usefulness, such as delineating its limits and requirements.

The first case study is the purification chapel of the church of Santa Maria del Carmine in Milan. Based on a model by Donato Bramante, it consists of a hemispherical dome supported by a drum held by pendentives. The reliefs of the ceilings, columns, and spandrels are both decorative and figurative. Painted surfaces are primarily in fresco, while decorating high and bas-relief is plaster stucco with gold leaf. The decoration of the whole space responds to a unitary project attributed to the painter Giovanni Mauro della Rovere (“Il Fiammenghino”). The restoration was sponsored by the parish with funding from Fondazione Cariplo.

The second case is the Collegiate Church of St. Mary of the Body of Daroca. Like much cultural heritage, it is the result of several phases of construction in different periods. The early church had a semicircular, east-facing apse that became a chapel during the Renaissance reform. The primitive apse was then hidden by a new vault. During the restoration of the church carried out in the 1990s by architects Fernando Aguerri and Javier Ibarguen, a metal staircase was installed behind the altarpiece of the new chapel to allow access to the apse. Due to the physical characteristics of the space, the access is too narrow to allow the public through, thus depriving them of the possibility of enjoying the murals. Unless informed of them by the guides, most visitors are unaware of the existence of the apse and its murals.
The third case involves the application of 3D reproduction technologies that had a strong educational and informative character that completes the research and makes useful and understandable to the general public the results of two R + D + I projects: “Reconstrucción y restauración en España 1938–1958: Las Direcciones Generales de Regiones Devastadas y de Bellas Artes” (ref. HUM 2007-62699) and “Restauración monumental y desarrollismo en España 1959–1975” (ref. HAR2011-23918). This research was conducted with public funding.

METHODS & METHODOLOGY

1. Three-Dimensional Reproduction of the Mural Paintings of the Chapel of the Purification in the Church of Santa Maria del Carmine in Milan

A 3D survey was made in draft form using convergent photogrammetry (creation of a model with the same geometry as the original by using conventional photographs that are interpreted by a computer program that also generates 3D model texture—mapping—applied to the three-dimensional model). This technique was chosen because the goal was to create a map of faithful colors applied to a three-dimensional model, which is essential for our purposes. The cameras of the scanner do not allow us to obtain a high-quality result.

Conventional digital photography applied allowed us to perform white balance and all necessary corrections before taking the photographs, resulting in a high-quality texture.

The main advantage of this system is the possibility of obtaining a complete model of the interior of an architectural space, thus revealing its physical characteristics. The system allows researchers to work in three dimensions and create the spatial projections needed to develop plans, elevations and sections, damage maps, typological classifications, and intervention proposals.

The ability to take orthophotographs (photographs that present an orthogonal projection without perspective effects; Fig. 1) allowed the space to be completely and quickly documented. Flat surfaces were measured directly, and the dimensions of curves, such as of vaults and domes, were obtained almost immediately. Such accuracy would previously, without this technology, have been almost impossible to obtain so quickly and with such minimal set-up (Fig. 2).

2. Three-Dimensional Model of the Romanesque Apse Paintings in the Collegiate Church of Daroca, Spain

In this case, convergent photogrammetry proved suitable for reproducing mural paintings and could be used for...
further study of the paintings or for displaying them to the general public. The advantage of this type of reproduction (compared to traditional photography) is the ability to fully document the space in a single file (Fig. 3), which facilitates the understanding of the mural painting’s iconographic program and context, allowing users to move inside with a real perspective, which can prove extremely useful when paintings must be preserved in situ.

The 3D reproduction in this case opened up new possibilities for the study and diffusion of these paintings. With the space fully documented, viewers can browse freely and zoom in to study details (up to the limit of accuracy applied when making the model). (The accuracy of convergent photogrammetry is defined by the level of detail that can be seen, which in turn is determined by the relationship between pixel size, lens distance from the source, and the focal length employed.)

3. The Use of Three-Dimensional Models for Diffusion of the Results of an R + D + I Research Project

The aim of this project was to help correct the patent historiographical deficiency and to improve the knowledge of the conservation and restoration activity during the Francoist period. The results of the research completed as part of the project have been presented in numerous publications, scientific articles, and conference proceedings. These are, however, typically consumed only by specialized groups.

These investigations broadly established that many of the monuments restored during the Francoist period underwent profound changes. Architectural elements were added or removed with the idea of returning the objects to their “original” state, the goal being to present a glorious image of ancient Spain.

A proposal was made to create 3D models of the most significant buildings modified during the Franco era. Using survey data derived from convergent or existing-plane photogrammetry, the models could clearly show the buildings’ various transformations.

A 3D model created using descriptive geometry and not intended to be a faithful reproduction of reality, allowed the different phases of construction and restoration to be seen, while also virtually recreating parts of the buildings that have been lost. (In most cases, these parts belonged to the Baroque period).

Such models are essential when communicating the results of this research to the public.

Fig. 03. A 3D view of the mural paintings of the Collegiate Church of St. Mary of the Body of Daroca, made by convergent photogrammetry.
RESULTS & DISCUSSION

The utility of 3D reproduction technology depends on when during an intervention it will be used (i.e., before, during, or after). Will the technology be used to improve the intervention itself or just to help disseminate the results?

Furthermore, how accessible are the resultant models? Many interventions in Europe have been documented with 3D techniques, but access to models remains difficult and often impossible.

CONCLUSIONS

In order to make this technology useful and to promote accessibility, a standard output format is required, preferably one that can be opened on widely available programs such as Internet browsers. Possibilities include the now-universal portable document format (PDF) and the newer WebGL and HTML5. By outputting models to such formats, anyone could open them without having to install a 3D modeling program. However, rules and protocols still need to developed; for example, to specify the file type to be used when saving views, or display characteristics such as precision, scale of assessment, number of polygons, color control, and so on.

CURRICULUM VITAE

Irene Ruiz, a PhD candidate at the Universidad de Zaragoza, is a technical architect with an MsArch in building restoration. She has also studied photography at the Accademia di Brera (Milan) and has extensive experience in building restoration projects.

Gianluca Vita is a teacher at the Politecnico di Milano and the Accademia di Brera, where he teaches 3D design. He has extensive experience in building restoration projects.

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New Techniques for Documentation and Re-creation: Santa María de la Almudena Church in Madrid, Spain

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INTRODUCTION

Madrid’s Santa María de la Almudena Church was located on a block bounded by Mayor Street, Bailén Street, Almudena Passage, and Santa María Square, by the Royal Alcázar of Madrid, inside the Arab walls of the city. Unfortunately, in 1868 this church was knocked down due to an urban remodeling project, a result of the Segovia Viaduct construction, which included a new proposal for the outline of Bailén Street.

METHODS & METHODOLOGY

The Facade of the Church by Ventura Rodríguez

Research articles have been written about the Santa María de la Almudena Church from various points of view. Tovar and Castellanos formulated hypotheses about the evolution of the church’s room distribution resulting from different reconstructions. An 1830 model by León Gil de Palacio, the city’s general plan of 1749, and a picture taken by Laurent in 1868 are documents of the period in which the sanctuary appeared. A model by José Monasterio, although preserved, has to be considered a secondary source because it was made in 1950—long after the church was demolished.

Although it was an important building in Madrid’s cultural heritage, only a few primary graphic documents confirm its existence, and none of these provide specific graphic documentation about the building.

The aim of the present study was to use new digital techniques to determine, from the representations shown in the available documents, the elevation of the facade of Santa María de la Almudena Church on Mayor Street—designed by the architect Ventura Rodríguez in 1777.

The picture taken by Laurent in 1868 offers real data about its composition. Geometrical analysis and geometric restitution of the perspective allowed the exact geometry of the facade in the picture to be determined (Fig. 01).

To get the elevations from the 1830 and 1950 models, Agisoft Photoscan was used. This software product performs photogrammetric processing of digital images to generate 3D spatial data. After processing a collection of only 20 pictures taken from different points of view, the software generated a 3D model. This innovative technique requires only portable equipment: a digital camera (a 12.2-megapixel digital reflex camera with a 17–55 mm lens was used) and a standard computer are enough. In addition, complete spatial information is provided, which can be used to reach different goals. The digital process started with taking pictures of the models. Every point must appear in more than one picture so that the software can join them. Then, using Agisoft Photoscan, a digital photogrammetry software, the pictures were aligned. In this step, the software finds common points on different photographs and generates a “points cloud.” After that, the software built a “dense points cloud.” Later, using those points, a mesh was built. After adding texture, the 3D model was built (Fig. 02). All steps are completed automatically by the software.
The main advantage of the digital model is that it is a complete information source about the church which can be used by many people, each with their own goals.

To get the elevations from the digital model, I placed three markers on each facade and then exported orthophotographs using those markers.

The result was three elevations of the facade—one from each source—which could then be compared (Fig. 03).

RESULTS & DISCUSSION

The orthophotographs of both models showed information about the composition of the elevation but did not allow its real size to be determined. Knowing that Madrid’s general plan was made in 1749, León Gil de Palacio would have used it to measure the block of the church in his model made in 1830, and consequently, the length of the facade was determined.

The elevation was superimposed on the orthophotographs to find similarities between them. The model made in 1830 by Gil de Palacio presents narrower proportions than the elevation derived from the photography by Laurent.

Because of the small size of the 1830 model (it was created as part of a larger model of the urban plan of Madrid), more attention was paid to the general volume than to details. In addition, the model is not well conserved, and corners are damaged. The model by Monasterio, made after the demolition of the church is more exact: its implied elevation is within one meter of the real elevation.

Monasterio’s model, although created after the building had been demolished, has several points in common with the restitution obtained from the geometrical process. Gil de Palacio’s model does not consider the real proportions of the church, showing only a general volume. In contrast, Monasterio’s much larger model is more accurate.

CONCLUSIONS

When concluding this research and reading all the steps as a whole, something I was aware of since the topic was considered: due to the few resources available, these documents had to be deeply analyzed before being considered.

A critical analysis of documentation about Santa María de la Almudena Church was completed to determine whether the information provided was true. This graphical and analytical process revealed disparities in the interpretations of authors who had studied the building. On the one hand, the arch situated over the main access to the church was described by Castellanos as a semicircular voussoir arch. However, the geometric restitution of the perspective reveals a half-oval arch. On the other hand, the analytical process allowed the location of the church tower to be specified. Earlier researchers had been close to this piece of information, but their conclusions about its placement differed from the information obtained from the photograph.

Future researchers will be able to use the 3D digital models of the two historical models of the temple to obtain spatial data that might be useful for their studies. Digital documentation of cultural heritage is essential when evaluating the restoration and consolidation of architectural heritage.

Finally, this process was made thanks to digital photogrammetry software. This technology helps architects generate archives with complete 3D virtual documentation and helps us recreate our cultural heritage—and does so with no damage to existing buildings.

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Using Geographic Information Systems to Study, Systematize, and Account for Cultural Heritage in the Perm Region (the Case of Perm and Usolie)

INTRODUCTION

Perm and Usolie—two cities in the Perm region (the Middle Urals)—are rich in cultural heritage. Within the historical center of Usolie, which was founded in 1606 as a settlement for workers involved in the Stroganoff salt production, there are forty cultural heritage objects, built in a variety of architectural styles—from baroque to eclecticism. After the commissioning and construction of the Kama hydroelectric station, the historic part of the city was flooded, the houses of locals moved to higher land. Stone buildings built

Fig. 01. Example attachments from geospatial model “Cultural and historical heritage of Usolie” (screenshot). Image owners: Maria K. Dmitrieva and Yuliya V. Bushmakina.
from the seventeenth to twentieth centuries are no longer used as first intended, and the island part of the city is in the doldrums, in need of a strategy for conserving its cultural heritage. Usolie’s cultural heritage has not been the subject of special studies. The planning development of the city, however, has been studied by V. Kostochkin\(^1\) and G. Golovchanskiy.\(^2\)

Perm, founded in 1723 as a settlement for workers at the Egoshikhinskiy copper smelting plant, became the provincial capital in 1781. Nowadays Perm is the center of the Perm region. The city contains more than 300 objects of cultural heritage, mostly from the prerevolutionary period. A. Terekhin\(^3\) and P. Korchagin\(^4\) have been studied the formation of the architectural and historical environment of Egoshikha-Perm.

**METHODS & METHODOLOGY**

For the study of the cultural heritage of Perm and Usolie, numerous cartographic sources from the eighteenth and nineteenth centuries were reviewed. Geographic information systems (GIS) are an excellent instrument for analyzing and representing geospatial data.

Urban history is one of the most developed research areas involving GIS. For example, research projects have studied the urban planning, infrastructure development, and architectural appearance of Tambov, Tomsk, and Nizhniy Novgorod.\(^5\) GIS technologies have also been used for the study of cultural heritage. Historical and Cultural Heritage of Perm Region: The Preservation, Study and Visualization of GIS Technology Tools is a research project implemented by the Center for Geographic Information Systems and Technology and the historical and political informatics laboratory of Perm State University (PSU).\(^6\)

The current research was carried out using licensed software ArcGIS 10.2 (ESRI). Before the data could be properly analyzed, a common coordinate system for all spatial data, including historical data, had to be developed. Therefore, all available cartographic sources were brought into a single coordinate system WGS 1984. For the substrate we used photographs of varying spatial resolution from the PSU Space Monitoring Center archive, as well as base maps from ArcGIS Online.

With the cooperation of the department of ancient and medieval history of Russia at Perm State Humanitarian Pedagogical University and the department of cartography and geoinformatics at PSU, two GIS-projects (geospatial models) were developed: “Architectural and Historical Environment of Perm” and “Cultural and Historical Heritage of Usolie.” Each project was carried out in several stages.\(^7\) Quality cartographic material was selected, historical topographic data was matched with modern topographic data, city plans were digitized, and then information from the following classes of objects was recorded in the geodatabase:

- boundaries of the city;
- buildings;
- city quarters;
- bodies of water;
• infrastructure (roads, pipelines, tram and railway tracks);
• other infrastructure (e.g., bridges, dams, fire hydrants).

Each geodatabase allows information to be stored in an orderly method making it easier to work with. Information can be viewed, edited, added, sorted, and analyzed. The storage format used for the geographical spatial data in the geodatabase allows attachments to be created. With attachments, detailed nongeographic information about objects can be stored and called up at the user’s request. All these characteristics are generated in a PDF document. By clicking on an object, the user can pull up the desired data and view basic information.

Cartographic and iconographic archival materials from the funds of the Russian State Archive of Ancient Acts, Russian State Historical Archives, State Archives of the Sverdlovsk Region, State Archive of the Perm Region, History and Art Museum of Berezni, the Solikamsk local history museum, and Usoilie historical and architectural museum, dating from the eighteenth to twentieth centuries (some of the maps found and published by researchers are mentioned in the bibliography), were used to prepare the projects. Methodological aspects of the analysis of urban plans were developed based on a methodology published by P. A. Korchagin.8

Information about the cultural heritage objects was provided by the Perm Regional Center for the Protection of Cultural Heritage to the extent allowed by Russian law.

RESULTS & DISCUSSION

Two geodatabases were created with information about the urban planning and development of Usoilie and Perm from the eighteenth to twentieth century. Attachments provide information about all the objects of cultural heritage dating to this period and located in Perm (200 objects) and Usoilie (40 objects).

The attachments contain publicly available information from the Russian Federation’s unified state register of cultural heritage objects. The information includes the name and type of the object, its location, when it was created and/or dates related to historical events, and the object’s category of historical and cultural importance. In addition, attachments may include archival and contemporary photographs of objects, information about architects or builders (if known), a brief historical background, and an architectural description (Fig. 01). If necessary, the geodatabase can be supplemented with additional information about the cultural heritage objects.

By matching archival cartographic materials to the modern topographic base, the urban planning and development of Perm (Fig. 02) and Usoilie could be recreated. By overlaying the plans, we obtained information not reflected in historical sources, such as the fixed quarterly distribution of the network of water bodies, the appearance or changing configuration of existing stone buildings, and new details about the construction history of the objects of cultural heritage.

The use of GIS allowed the propagation of urban development to be observed, highlighting the historical
city center and functional zones. Overlaying plans helped to localize historical building lines from the eighteenth to early twentieth centuries, including the reconstruction of the now lost quarters in Usolie, land ownership, and urban density (Fig. 03). By correlating proposed plans (proposed development project) with actual urban development, we identified deviations from the original plans and instances where planning decisions had failed and were abandoned.

The use of GIS allowed new information to be obtained, especially about the effects of channel processes and anthropogenic factors on the cultural landscape. With the exception of the Kama River, most bodies of water in Perm are small, and numerous brooks have been filled in or enclosed in underground sewers. Drawing these channels on the modern map of the city would allow potential construction problems to be identified during the design stage. GIS helped established how the boundaries of waterways, including the location of oxbow lakes and the banks of the Kama, were altered in Usolie due to active channel processes.

CONCLUSIONS

The information obtained in this study can be applied during archaeological research, conservation of cultural heritage in new construction, the study and teaching of regional history, and the development of tourist routes. Work on creating architectural and historical models of Usolie and Perm will continue, and data will be added about the impact of Soviet construction on the twentieth-century architectural and historical environment.

ACKNOWLEDGEMENTS

We thank Pavel Korchagin for proofreading the manuscript and offering valuable comments.

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INTRODUCTION

The Maxentius 3D project began with a workshop conducted by the Laboratorio Archeo & Arte 3D Digilab, Sapienza—Università di Roma. The aim of the project was to develop a full 3D model of the Circus of Maxentius in Rome, encompassing all aspects of the environment, as well as the architectural system.

The Circus of Maxentius, located between the second and the third mile on the Via Appia, is part of a complex that also includes the Mausoleum of Romulus and Maxentius’s villa.1

The circus, built in latericum, is 520 meters long and could accommodate around 10,000 spectators. The central spine was 283 meters long and was decorated...
with an obelisk from the temple of Isis (the obelisk is now part of Gian Lorenzo Bernini’s Fontana dei Quattro Fiumi in the Piazza Navona in Rome).² The complex was abandoned after Maxentius’s death, and the circus may never have been used (archaeologists have not found sand, used to cover the racetrack, on the site).³

Today the ruins include stands and spine and are the best circus sample preserved. The Maxentius complex is also a natural park. Vegetation is the main problem for archaeological surveys and tourism. For this reason, a 3D reconstruction would be useful for both a scientific and public audience.

METHODS & METHODOLOGY

The first step of the project was to study archaeological data. The archaeological team then carried out a survey to integrate published data with new information that might be useful in creating a metrically correct reconstruction. Every element was modeled using archaeological plans and axonometrics.

To model both the landscape and the architectural structures, Blender, an open-source software, was used. Altimetry data provided by the Istituto Geografico Militare allowed the morphology to be reconstructed. After importing the contour lines into Blender, the curves were converted to a mesh, after which, by using the add-on Delaunay triangulation and Voronoi Diagram, the 3D model was generated (Fig. 01).

The next step was to elaborate the architectural 3D model, including the hydraulic system and the decorative program. To model the architectural structure, we used plans realized by Ippolo and Sartorio and published in *La residenza imperiale di Massenzio: Villa, mausoleo e circo*. To obtain an accurate and metrically correct model in a short amount of time, the team used the mirror modifier, which allows users to generate a full object after modeling only half of the structure. Another useful tool was the add-on archimesh, which allows users to quickly insert accurate architectural elements (Fig. 02).

Finally, the team textured the models by using the Node Editor in Cycles Render to obtain a photorealistic rendering.

RESULTS & DISCUSSION

A metrically correct 3D reconstruction of an ancient structure can be useful to verify hypotheses about the reconstruction of a monument (Fig. 03).

To produce a full 3D model, however, an in-depth study is needed to understand the relation between the architectonic elements and the environment.

In addition to aiding in the study of an ancient structure, an accurate 3D model could be the starting point.
for developing hypotheses about the arrangement of decorations. Although many fragments of statues have been found, the decoration system is only partially known, and for this reason more study is needed.

CONCLUSION

The team produced a metrically correct model of all the architectural aspects of the Circus of Maxentius and the surrounding landscape. The model is useful for both scientific and public audiences.

Interaction between the user and the 3D model can offer a deeper understanding of archaeological and historical data, allowing audiences to see the monument as it looked during the fourth century CE. A full 3D reconstruction of an ancient site can also be the first step in creating an online virtual archaeological museum.

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