OrganicaMente

Pisa 4-6 Febbraio

AIAr 2026

Caratterizzare Proteggere Datare

Racconti della materia

OrganicaMente

CONVEGNO TEMATICO

Pisa, 4-6 Febbraio 2026

Book of abstract

ASSOCIAZIONE ITALIANA DI ARCHEOMETRIA

ORGANIZZATO DA

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PROGRAMMA

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9.00-11.00	Registrazione	9.00-9.30	PLENARY LECTURE	9.00-9.30	PLENARY LECTURE
11.00-11.20	Saluti e apertura lavori	9.30-11.00	Sessione IV	9.30-11.10	Sessione VII
11.20-11.50	PREMIO MARIO MILAZZO				
11.50-13.10	Sessione I	11.00-11.30	Pausa Caffè/Sessione Poster	11.10-11.40	Pausa Caffè/ Sessione Poster
		11.30-13.00	Sessione V	11.40-12.40	Sessione VIII
				12.40-13.10	Premiazioni e Chiusura
13.10-14.30	Pranzo	13.00-14.30	Pranzo	13.10-4.30	Pranzo
14.30-16.10	Sessione II	14.30-15.50	Sessione VI	Conservazione, Monitoraggio, Restauro	
				Materiali archeologici	
				Caratterizzazione e Diagnostica	
16.10-16.40	Pausa Caffè/ Sessione Poster	15.50-16.40	Sessione Poster/Coffee Break	Provenienza e Datazione	
16.40-18.30	Sessione III	16.40	Assemblea Soci	Nuove metodologie	
19.00-20.00	Cocktail di benvenuto	20.30	Cena sociale	Materiali dell'arte	

Comitato Scientifico

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Prefazione

La materia, nei beni culturali, non è mai un semplice supporto: è testimonianza del tempo, esito di scelte tecnologiche e culturali, e memoria delle trasformazioni attraversate nel corso della sua esistenza. Ogni materiale, dalla fase di produzione ai processi di degrado, custodisce informazioni preziose, leggibili e interpretabili attraverso un dialogo continuo tra scienze, conservazione e storia, capace di restituirne pienamente il valore e il significato.

Il convegno tematico **AIAr O**rganica**M**ente, che si svolge a **Pisa dal 4 al 6 febbraio 2026**, nasce con l'obiettivo di esplorare la materia come **testimone privilegiato della cultura umana**, attraverso una prospettiva multidisciplinare. L'evento è organizzato dall'**Università di Pisa** e l'**Associazione Italiana di Archeometria (AIAr)** e si propone come luogo di confronto tra ricercatori, conservatori, restauratori e studiosi dei materiali dei beni culturali.

L'incontro tra scienze applicate, diagnostica, conservazione e discipline storico-artistiche consente di costruire percorsi di lettura complessi, capaci di connettere contesti, tecnologie, provenienze e cronologie. In questo quadro, le metodologie scientifiche rivestono un ruolo centrale: dalla caratterizzazione chimico-fisica alla datazione, dallo studio delle trasformazioni nel tempo alla progettazione di interventi conservativi, ogni approccio contribuisce a delineare un racconto coerente e scientificamente fondato della materia.

Il programma di **O**rganica**M**ente si articola attorno a sei principali aree tematiche:

- **Caratterizzazione e Diagnostica**,
- **Provenienza e Datazione**,
- **Nuove metodologie**,
- **Materiali archeologici**,
- **Materiali dell'arte**,
- **Conservazione, Monitoraggio e Restauro**.

Queste sessioni riflettono la varietà degli approcci e la ricchezza delle ricerche attualmente in corso, evidenziando il carattere fortemente interdisciplinare del settore.

Il presente **Book of Abstracts** raccoglie i contributi presentati durante il convegno e restituisce un quadro articolato delle attività di ricerca, delle sperimentazioni metodologiche e delle riflessioni teoriche nel campo della diagnostica e della conservazione dei beni culturali. La materia emerge così come elemento dinamico, in continua trasformazione, e come chiave interpretativa fondamentale per comprendere il passato e orientare le pratiche di tutela future.
OrganicaMente si configura dunque come un'occasione di dialogo e condivisione, in cui la materia diventa il punto di partenza per raccontare storie, processi ed evoluzioni, e per costruire nuove prospettive nel campo dell'archeometria e della conservazione.

INTERVENTI ORALI

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34	**O-20**	Buonincontri	From mortars to territory: chronology, environment and resources in The Times of Castles Project
35	**O-21**	Maspero	Chronological Modelling and Probability Density Mapping of a Coralligenous Build-up off SE Sicily within the CRESCIBLUEREEF Project
		NUOVE METODOLOGIE	
36	**O-22**	Festa	Spectroscopy and Machine Learning for Cultural Heritage
37	**O-23**	Longo	Advancing Computed Tomography in Heritage Science: Hounsfield Unit CT Imaging for Wood Species Determination
38	**O-24**	Pantuso	Exploring Stone Weathering in Cultural Heritage through Geochemical Modelling
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41	**O-27**	Caroti	Pre-polymerized oils: how different pre-treatments can influence the curing of linseed oil paints
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45	**O-31**	Busto	From analysis to intervention: a scientific approach to the restoration of Saint Onofrio's Parchments
46	**O-32**	Porcari	Development and Assessment of Nanocomposites for the Conservation of Peperino Stone
47	**O-33**	Zicarelli	Lime-based mortars with the incorporation of agricultural wastes: the case of Powdered Olive Stone (POS)
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49		Bruker -Sali	Chemical Imaging and molecular spectroscopy: future is now
51		Agilent - Cimino	Intelligence That Inspires Confidence: Agilent 6495 triple quadrupole LC/MS system
52		Brachi Testing Services - Brachi	The habit of the stigmata of St. Francis of Assisi – commodity characterization of the fabric.

POSTER

MATERIALI DELL'ARTE			
80	**P-28**	Certo	Living Matter and Instability: Material Choices in Arte Povera Between Poetics, Transformation Over Time, and Conservation
CONSERVAZIONE, MONITORAGGIO, RESTAURO			
81	**P-29**	Boragina	Monitoring the Conservation of the Bronze Statue of Apollo through Electrochemical Diagnostics
82	**P-30**	Ferrarese	Microclimatic conditions in the King's Apartment, Royal Palace of Turin
83	**P-31**	Barca	The restoration of the mosaic floor of room 29 in the Roman Villa of Palazzi di Casignana (RC) – Calabria Italy
84	**P-32**	Tuccio	Essential-oil-loaded mesoporous silica nanoparticles as long-lasting biocidal nanocarrier system for stone conservation: case studies from the Fountain of the...
85	**P-33**	Liotta	A sustainable approach for the removal of undesired organic layers on marble artifacts
86	**P-34**	Giordano	Preliminary insights from a multidisciplinary assessment of marine–coastal impacts on ancient watchtowers in Calabria (Southern Italy)
87	**P-35**	Vergelli	Environment-induced risk assessment as a preventive conservation strategy for an effective long-term management of safety cinematographic archives
NUOVE METODOLOGIE			
88	**P-36**	Belfiore	A 3D-based Web Platform as an innovative tool to support the Management and Visualization of Multi-source Diagnostic Data
89	**P-37**	Rossi	3D survey and machine learning for the archaeometric reading of a section of Siena's walls near Porta Camollia
90	**P-38**	Di Leo	The chemometric approach to understand technology of ancient ceramics: The matt painted pottery case study from the North Lucanian district (Basilicata region)
91	**P-39**	Ricca	The Digital Supply Chain of Cultural Heritage: From Knowledge to Valorization
92	**P-40**	Re	The PITCH project: a laboratory-based phase-contrast X-ray imaging system for the analysis of Cultural Heritage materials
93	**P-41**	Bonifazi	Perceive Isis' Colours: Diagnostics and Communication of Ancient Polychromy
94	**P-42**	Bonifazi	MuLaX: A Visual and Interpretative Platform for Managing Variability in Cultural Heritage Diagnostics
95	**P-43**	Gulmini	Hyperspectral UV-Induced Fluorescence Imaging and Multivariate Statistical Analysis for Assessing Cleaning Processes...
SPONSOR			
50	**P-44**	Soll	Splitless injection with forced gas venting to increase the throughput and sensitivity of pyrolysis-based analytical methods in cultural heritage - FrontierLab

Non-Invasive Spectroscopy in Cultural Heritage: A Brief Review

M. Bacci

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This lecture traces the historical path from the first destructive investigations of cultural heritage to the current methodologies that allow for non-invasive and in-situ study of the works under examination. Attention is paid to spectroscopic technologies using optical fibers. The advantages and limitations of these techniques will be discussed.

Organic Materials Through the Lens of Science: Analytical Strategies Between In-House Expertise and Field Specialists

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The characterization of organic materials in cultural heritage objects is particularly challenging due to their chemical complexity, intrinsic heterogeneity, and sensitivity to degradation processes such as hydrolysis, oxidation, or cross-linking over time. These challenges are often compounded by the need for non-invasive analysis or restricted sampling, as well as by limitations in available in-house instrumentation and expertise. In this context, the success of analytical investigations largely depends on the ability to formulate the right questions at the appropriate stage of the study.

This contribution presents the extent of activities of the Centro per la Conservazione ed il Restauro dei Beni Culturali (CCR) "La Venaria Reale", highlighting its lively involvement not only in conservation treatments but also in research projects, international cooperation programs, education and training, and dissemination events. In terms of scientific analysis, a specific focus is placed on organic materials—such as binders, adhesives, and varnishes—and on the role of preliminary investigations in defining meaningful and achievable research questions.

Given the limited in-house instrumental facilities for the analysis of organic materials, the CCR plays a coordinating role within a broader scientific framework, relying when necessary on collaborations with external academic and research institutions to address specific analytical questions. Preliminary investigations are used to assess an object's condition and material complexity, to guide sampling strategies, and to critically define the research objectives. Selected case studies will illustrate how well-posed diagnostic questions, grounded in preliminary data, enhance the value and interpretability of advanced analyses performed by field specialists, ultimately supporting informed conservation decisions while fostering effective dialogue, knowledge exchange, and collaboration between conservation professionals and academic experts.

Conservation treatment in progress at the CCR "La Venaria Reale", highlighting the applied context in which diagnostic questions are defined and addressed.

Ancient proteins: current challenges in identification and characterization

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Lessons from the past. Materials used in the past in artworks and crafts have been the subject of numerous investigations. The recent technical advances in bioanalytical chemistry and mass spectrometry (MS) allowed the emergence of methods fully adapted to the study of ancient proteins in works and objects of our cultural heritage, and specifically are central to several paleoproteomic projects aimed to develop knowledge as well as to provide molecular details useful for conscious restoring interventions.

While, early in this century, the big question was whether it was possible to identify proteins in degraded and complex environments such as those of artistic objects and archaeological finds, the biggest challenges we are facing today in relation to proteins in cultural heritage materials, relate to the characterization of their modifications and degradation profile, their networks and interaction with other components (organic and inorganic material). The molecular signatures impressed in the primary structure reflect the environment and the age the objects lived in, but also the conformational changes the proteins underwent upon interacting with the other chemical component the objects were made of. Study cases will be presented ranging from proteins within the pictorial matrices of paintings to collagen based animal glues[1], to bone proteins exposed to peculiar burial environments such as those experienced by victims of volcanic eruption[2].

On the other side, methodology development is now in the direction of facing the compelling request for less invasive and more sensitive analyses that can meet the needs of the world of cultural heritage. The development and implementation of innovative tools for sampling proteins in ancient objects will be presented[3].

References

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ORAL

The Potential of Padina Pavonica L. Extract in Treating Bio-corrosion on Archaeological Metal Finds

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Objective: Biocorrosion, caused by microbial colonization and biofilm formation, poses a significant threat to the integrity of metal artifacts, particularly those made of copper and its alloys [1]. This study investigates the potential of the brown alga Padina pavonica L., a species of the Dictyotaceae family found in the Mediterranean Sea, as a sustainable biological inhibitor of corrosion induced by Enterococcus faecalis, Gram-positive a bacterium that plays a key role in this process [2-3].
Method: The antibacterial and antibiofilm activities of the algal extract, rich in polyphenols, were evaluated using minimum inhibitory concentration (MIC) assays, time-kill kinetics, and biofilm prevention and removal tests on bronze samples. Bacterial growth and biofilm density were quantified using spectrophotometric and microbiological methods [3].
Results: In the antibiofilm test, the extract proved effective in both preventing biofilm formation and strongly disrupting existing biofilm until its complete elimination. After 72 hours, the number of bacterial colonies on the surface decreased by 95% compared to the control sample.
Conclusions: These promising results confirm the importance of natural substances as environmentally friendly alternatives the conservation of metal objects in cultural heritage.

References

[1] A. Acharjee, Y. Keskin, B. M. Peyton, M. W. Fields, and R. Amendola, “Effect of surface roughness on the microbiologically influenced corrosion (MIC) of copper 101,” 2024, Frontiers in Materials, vol. 11, p. 1496162 https://doi.org/10.3389/fmats.2024.1496162
[2] F. Woitschach et al., “Bacterial adhesion and biofilm formation of Enterococcus faecalis on zwitterionic methylmethacrylat and polysulfones,” 2022, Frontiers in Cellular and Infection Microbiology, vol. 12 https://doi.org/10.3389/fcimb.2022.868338
[3] Ç. Özdemir, L. Emanuele, M. Kotlar, M. Brailo Šćepanović, L. Scrano, and S. A. Bufo, “The potential of Aloe vera and Opuntia ficus-indica extracts as biobased agents for the conservation of cultural heritage metals,” 2025, Metabolites vol. 15, no. 6, p. 386, https://doi.org/10.3390/metabo15060386
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Stone cleaning using formulations derived from crude microbial extracts and essential oils with antimicrobial properties

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The growth of biodeteriogens on stone can cause its weakening and instability. However, the Cultural Heritage (CH) inhabiting microbial community hides microorganisms with biocleaning potential granted by the antimicrobial and antibiofilm properties of substances they produce. Amongst them, microbial biosurfactants can be combined with essential oils to increase their antimicrobial effects and applicability and gain maximum efficiency in conservation practices.
Two cell-free centrifuged supernatants of Bacillus strains isolated from the mosaics of the Villa Romana Palazzi di Casignana (RC), Italy, were tested in combination with essential oils of lavender, myrtle and orange for antimicrobial/antibiofilm activity. They were then applied on marble mock-ups in laboratory conditions and in situ. The physico-chemical alterations and antimicrobial effects of the formulations were monitored for two weeks ex situ and on site.
The formulations based on extracts from microbial biosurfactant-producing strains (Bacillus subtilis and velezensis) and essential oils tested have antimicrobial/antibiofilm activity against pathogens and microbial strains isolated from the same CH site. When applied on marble in laboratory conditions they cause little alterations to the physico-chemical properties of the substratum and, when used for preventive and cleaning applications against Aspergillus niger colonization, they caused a reduction of microbial activity, delayed sporulation, and minimal proliferation. On site efficacy was evaluated by viable cell counts expressed as colony-forming units (CFU) on nutritive media for bacteria and fungi after incubation and the microbial activity was measured using ATP as proxy for living cells presence. Colorimetric variation was also measured before and after 14 days.
Microbial biosurfactants can be a valid alternative to synthetic products for restoration, and their combination with essential oils ensures sustainability, environmental stewardship, and circular bioeconomy applications. The formulations based on Bacillus strains extracts and essential oils tested may be a promising base for developing green products for Cultural Heritage conservation.

References

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[3] Reale et al., 2024. Sustainability (Switzerland), 16(12), 5110.

Electrochemical Strategies for Immobilizing Essential Oils on Mesoporous Silica: Towards Smart Air Purification in Heritage Environments

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Maintaining clean, controlled indoor environments, particularly in spaces dedicated to the conservation and display of cultural heritage, requires innovative materials capable of both filtering and actively neutralizing contaminants. Although essential oils have strong antimicrobial potential, their high volatility limits direct application [1]. Immobilization on solid supports can transform them into effective, sustained-release biocides. Promising supports are mesoporous silica membranes generated by ***Electrochemically Assisted Self-Assembly*** (EASA) method, as they offer a regularly open structure, attractive vertical orientation of nanochannels with very high surface areas, which can be easily functionalized by a variety of compounds [2].

This multidisciplinary work focuses on electrochemical design and functionalization of mesoporous silica membranes. Vertically oriented films were first grown on conductive substrates (indium-tin oxide (ITO), glassy carbon) and extended to high-surface-area carbon felts. Internal surfaces were modified with isocyanate-based groups, enabling covalent immobilization of both abundant pure components (e.g., eugenol, terpineol) and complex mixtures such as essential oils (e.g., tea tree oil).

Physico-chemical techniques—including profilometry and cyclic voltammetry—guided the synthesis, providing fine control over porosity, surface reactivity, and immobilization efficiency. Characterization by FTIR, XPS and SEM confirmed film composition and structure [3]. Preliminary filtration and inactivation tests were performed to assess the membranes' potential for selective air purification.

Ultimately, this approach lays the foundation for **smart, sensor-integrated systems** capable of real-time monitoring and adaptive, feedback-driven air purification. The combination of electrochemically engineered films and versatile bioactive functionalization highlights the potential of this work and paves the way for **next-generation indoor air purification systems** in cultural heritage environments.

References

[1] Ž. Savković, A. Džamić, J. Veselinović, M. Ljaljević Grbić, M. Stupar, *Sci. Nat.* **2025**, *112, 32*. DOI: 10.1007/s00114-025-01983-3.
[2] A. Walcarius, *Acc. Chem. Res.*, **2021**, *54*, 3563. DOI: 10.1021/acs.accounts.1c00233.
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A conservation project for the polychrome stone inlays of the southern transept of the Cathedral in Pisa

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The conservation and restoration of a historic monument requires a multilayered understanding of the building. It involves recognizing the symbolic and cultural values it embodies, placing it within its historical context, and documenting its evolution over time. This is the methodological approach consistently adopted by the *Opera della Primaziale Pisana* in all interventions on its monuments, as well as in more specific regard to the conservation project of the southern transept of the Cathedral.

This project focuses on the stone inlays of the apse of the southern transept. The exterior walls of the Cathedral display both bichrome masonry and polychrome inlays created through the juxtaposition of stone elements of various geometric shapes. In the southern transept, the inlays adorn the arches of the first order. Their presence can be studied from a historical-artistic perspective: the polychrome inlays seem to date back to the original decorative designs, and their presence could be related to the access routes to the square, which allowed for optimal visual appreciation of the southern side of the Church.
The initial investigations allowed for an identification of potentially original lithotypes and lithotypes more likely to be attributed to modern replacement interventions. Furthermore, preliminary analyses conducted on the mortars enabled research on specific construction techniques and opened up to identifying different phases of the construction works. In addition to this, the varied state of conservation of the stone materials provided the opportunity to launch an *in situ* testing campaign aimed at identifying tailored conservation and consolidation methods for stones of differing nature (limestone, serpentinite).

This overview provide an exemplary insight into the inherently multidisciplinary nature of the conservation activities carried out by the conservators of the *Opera del Duomo* and other specialists collaborating with the institution.

Polychrome stone inlays, southern transept of the Cathedral

References

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Bonding technologies in bonding societies: mapping adhesive distribution in prehistoric Italy (Neolithic-Iron Age) through Py-GC/MS and GC/MS

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Among the different organic materials that can be found in an archaeological context, adhesives, often underrated, represent an important source of information, for example about commercial and technological exchanges [1], [2]. From this perspective, this work aims to reconstruct how knowledge about bonding technologies was distributed across the Italian peninsula, from the Neolithic period up to the Iron Age, in order to fill the gap in the literature on this topic. Several archaeological sites across Italy were considered, collecting samples from both everyday use objects, such as agricultural tools [3], and decorative artefacts. The sites covered a time frame which span from the 5000 to 500 BC. The oldest sites are geographically spread across Italy, from the Po river area to the central-south area, with the site of Rio Tana (province of L'Aquila) and Fossacesia (province of Chieti) as the southeast. As a link between the Neolithic sites to the more recent ones, the results obtained from Lucone di Polpennazze site are reported. This site covered a time frame that spans from the Neolithic to the Iron Age (5300-500 B.C.), where its major period of occupation was during Bronze Age (2200-1200 B.C.). Lastly, also proto-Etruscans artefacts from Pisa area and Grosseto area were considered in this study, covering a period between the 10th to the 8th centuries BCE. To fulfil this aim, Gas Chromatography/Mass Spectrometry (GC/MS) and Pyrolysis Gas Chromatography coupled with Mass Spectrometry (Py-GC/MS) were applied to completely characterize at a molecular level the organic material collected from the artifacts. Especially Py-GC/MS has proven to be an extremely powerful tool, requiring a minimum amount of sample and avoiding long chemical pretreatment [4]. By this way, it was possible to thoroughly characterize the investigated samples and determine the use of pine pitch, bitumen, birch bark tar and beeswax. These results highlighted a complex distribution of adhesive materials that reflects the interconnection not only among Italian regions but also with the northern part of Europe. As an example, one of the most employed adhesives was found to be the birch bark tar, even at lower latitudes such as central-south Italy.

References

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Organic and inorganic component in hydraulic roman mortars: the case of Carsulae cistern (Italy)

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The ancient city of *Carsulae* (Terni), whose early development remains uncertain, expanded significantly with the construction of the Via Flaminia, becoming a prosperous center between the 1st and 3rd centuries CE. Among its public infrastructures, the large cistern near the theatre–amphitheater complex represents an example of Roman hydraulic architecture in Central Italy. This study examines the mortars used in the cistern to identify the raw materials, technological choices, and any specific components, both inorganic and organic, that could have enhanced the **waterproofing.** Minero-petrographic and geochemical analyses (XRD, OM, TGA, FTIR, SEM–EDS) reveal the composition and origin of the stones used for the production of binder and for the aggregate. Carbonate rock fragments, cherts, and radiolarites typical of the Umbrian–Marchigian succession are abundant in all the samples; these mortars also contain significant volcanic components, including tuff fragments, basaltic glasses, pyroxenes, and olivine. The geochemistry of volcanic glass and the composition of pyroxene suggest provenance from monogenetic centers of the ULUD province [1]. In addition to volcanic materials, non-volcanic glasses were documented. These glasses appear within fractures or along rims of carbonate clasts and are interpreted as resulting from the partial melting of impure siliceous limestones during firing for natural hydraulic lime production. A key finding of this study is the detection of organic matter within the binder combining ATR-FTIR and FPA- FTIR analyses with GC–MS and PY-GC-MS [2]. The identification of lipid based substances, natural wax and proteinaceous material suggests the deliberate addition of organic substances to enhance the water-resistant properties of the mortar, complementing the pozzolanic contribution of volcanic materials and natural hydraulic lime. Overall, the *Carsulae* cistern mortars reflect a sophisticated technological approach that combined local carbonate resources, volcanic aggregates, and organic additives. This integrated recipe ensured to the cistern high hydraulicity and durability, demonstrating advanced knowledge of materials and a pragmatic adaptation of Vitruvian principles to the geological context of Central Italy.

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Preliminary assessments of DAP treatments for archaeological tusks consolidation

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The Geological Museum "Gemmellaro" in Palermo houses a large collection of Elephas mnaidriensis tusks in poor condition. Many specimens are affected by delamination, and for this reason most of them are stored wrapped in plastic or paper to prevent the loss of external layers.
Based on the composition of tusks [1], primarily calcium phosphate (hydroxyapatite) with residual proteinaceous components such as collagen, di-ammonium hydrogen phosphate (DAP) treatment represents a promising option for consolidation, although several challenges remain. Because bones and tusks are mainly composed of hydroxyapatite, an additional source of calcium or magnesium is required to achieve effective consolidation.
DAP is commonly combined with $Ca(OH)_2$ [2], while the use of magnesia can be considered within a sustainable conservation approach. Magnesium hydroxide, which can be conveniently produced from brine derived from other industrial processes, has been evaluated in other conservation fields in combination with DAP and is also used for stone conservation [3].
This work presents the preliminary results of an investigation conducted on cubic samples made from archaeological bone powder, obtained by grinding spare remains with a composition similar to that of the tusks. The cubic samples were prepared by mixing the powder with water, compacting it in molds, and applying different combinations of DAP paired with nanometric aqueous dispersions of magnesium or calcium. Mechanical tests, Raman spectroscopy, FTIR, and TGA

Dwarf elephants' tusks in Gemmellaro Museum's collection and archives

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Into the deep: refining the paleodietary methodological approach in Pompeian vesuvian site

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As part of a broader multidisciplinary program, this study aims to advance a standardized methodological framework for the application of Compound-Specific Isotope Analysis of Amino Acids (CSIA-AA) within a multidisciplinary program combining anthropological and paleopathological investigations on the human remains from the Pompei' site of Oplontis. The goal of this analytical approach provides a high-resolution tool for disentangling dietary protein sources and assessing trophic dynamics, overcoming the limits of several interpretive limitations of bulk collagen isotope analysis, enabling more precise assessmen ts of protein sources, nutritional stress, and physiological responses in past populations.

Preliminary work has focused on defining, calibrating, and validating an internal laboratory protocol for CSIA-AA, including the creation of in-house amino acid reference standards and the optimization of chromatographic and analytical procedures. Early tests demonstrate promising reproducibility and indicate that the protocol can reliably isolate key amino acids relevant for dietary interpretation. Parallel anthropological and paleopathological analyses, documenting demographic structure, stress markers, and morbidity profiles, are being integrated to contextualize forthcoming isotopic results.

The ongoing development of a robust CSIA-AA protocol provides a critical methodological foundation for future applications to the Oplontis assemblage and other archaeological human remains. By combining high-resolution isotopic analysis with detailed biocultural datasets, this research establishes a powerful framework for reconstructing dietary behavior, ecological adaptations, and metabolic stress in ancient populations. The standardized workflow generated here is expected to significantly improve analytical consistency and broaden the interpretive potential of isotopic archaeometry.

Fire, Minerals, and Machine Learning: Insights from Riparo Mochi and Riparo Gaban

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Evidence of the use of fire is widespread in archaeological contexts and can be traced back to the earliest phases of human prehistory. Its applications encompassed a wide range of domestic and craft activities, including lighting, heating, cooking and transforming raw materials such as bone, wood, horn, stone and pigments, as well as many other uses which are often difficult to identify.
Surviving combustion structures provide essential evidence for these practices. From the Neolithic period onwards, these structures played an increasingly significant role, closely linked to emerging productive activities and the establishment of sedentary lifestyles [1].
In the two main sites under study, Riparo Mochi and Riparo Gaban, several sediment samples from different chronological phases were investigated. At Riparo Gaban, located near Trento in northern Italy, eleven loose sediment samples were analysed from Neolithic ash-rich layers of the site. In contrast, nine samples from the Upper Palaeolithic sequence of Riparo Mochi were examined.
Archaeological materials from these contexts, including heated lithic fragments, ashes, bones, reddened soils and pigments, were studied using a combination of laboratory-based and in situ analytical techniques. This multi-analytical approach primarily relies on methods traditionally employed in cultural heritage research that are particularly suitable for characterising inorganic materials and minerals [2]. A multi-technique strategy was adopted for the analysis of these samples, combining scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM–EDXS), X-ray powder diffraction (XRPD) and Fourier transform infrared spectroscopy (FTIR). Having identified the main mineral phases present in the samples — calcite, quartz, various silicates and hydroxyapatite — it was decided to perform qualitative and quantitative analyses using infrared (IR) spectroscopy. First, a dataset of FTIR spectra was created by measuring KBr pellets containing known concentrations of the primary components identified in the samples: calcite, silicates, quartz and hydroxyapatite. Machine learning techniques were then employed to expand this dataset and generate reference spectra at additional concentration levels beyond those obtained in the laboratory. Using this artificial intelligence (AI)-based approach, it was possible to predict the concentrations of three of the four analysed substances. However, challenges in producing reproducible quartz pellets limited the accuracy of the quartz quantitative predictions. The presence of hydroxyapatite is particularly significant as it may indicate the presence of bone remains at the site given that bone is predominantly composed of this mineral. Furthermore, the crystallinity index derived from hydroxyapatite is a useful parameter for estimating the combustion temperature of the samples, providing valuable information on whether the analysed material is burned bone [3].

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Revealing the hidden signatures of iron gall and logwood inks: a chromatographic protocol to uncover the colours of the past

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Throughout history, inks have been formulated from a wide range of coloured extracts of plant and animal origin. Between the 12th and 19th centuries, iron gall inks — produced by mixing tannins from oak galls with ferrous sulphate and several additives — were the predominant writing materials [1]. Due to their relatively poor long-term stability and incompatibility with pen nibs, these formulations were gradually replaced in the late 18th century by mixed formulations containing both tannins and logwood dyes (*iron gall logwood inks*), and, from the mid-19th century onward, by inks based solely on logwood extracts (*logwood inks*) [2].

Dyes play a critical role in ink formulations, as their degradation can lead to phenomena such as paper corrosion and colour fading. Consequently, their chemical characterisation provides insight into historical ink technologies and supports the development of conservation strategies. However, such analyses are challenging due to the wide variability of historical recipes, unreliable labelling of ink bottles, and molecular alterations caused by ageing and degradation processes.

This study presents an overview of the analytical approach developed by the SCIBEC group (University of Pisa) based on optimised liquid chromatographic methods for the investigation of historical and modern inks [1-3]. Historical formulations (*iron gall*, *iron gall logwood*, and *logwood inks*) were replicated in our laboratory from 19th century technical manuals and applied to paper support (Whatman filter paper, pure cellulose) for obtaining reference ink mock-ups. EDTA-DMF extracts of these references were analysed by our HPLC-DAD-ESI-Q-ToF protocol, yielding characteristic molecular fingerprints for each ink type. Diagnostic markers were identified as gallic and ellagic acids, poly-galloyl glucoses, and poly-galloyl gallates for *iron gall inks* [1, 3]; hematein, hematoxylin, G-compounds, and hematein derivatives for *logwood inks* [2]; and a combination of both markers for mixed formulations (*iron gall logwood inks*).

Artificial ageing experiments (i.e., exposure to natural light and accelerated ageing) enabled us to monitor changes in the molecular profile of the samples and to identify specific ageing markers for each formulation. The validated approach was subsequently applied to micro-samples (10–15 µg) from historical manuscripts and drawings. Analyses of a 16th century Polish manuscript and three documents from the Michelangelo Buonarroti Archive (15th–19th centuries) confirmed the method reliability and provided new insights into the evolution and degradation pathways of dyes in historical manuscripts and drawings.

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Unveiling pigments and dyes on a group of statues from Archaeological Museum of Formia by a multi-modal approach

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The National Archaeological Museum in Formia exhibits a collection of first-century AD sculptures, discovered in the forum of the Roman city. Among these statues, a togatus (draped male figure) and a female statue, notably retain significant traces of their original polychromy. Traces of an organic red dye, which was originally part of the toga decoration, are still clearly visible on the togatus. The sculpture also exhibits evident remnants of skin colour and both eyes are meticulously outlined, showing details of the pupils, irises, eyelashes, and eyebrows.
The female statue, an iconographic representation known as the small Herculaneum Woman, also offers exceptional evidence of the original polychromy, mainly in the form of organic red pigment and, to a lesser extent, Egyptian blue and gold foil.
This study provides an overview of this sculptural group and presents the results of a detailed analysis of the residual colour traces. The investigation employed a suite of non-invasive analytical techniques (Multi-band imaging techniques (MBI), UV-Vis-NIR Fiber Optic Reflectance spectroscopy (FORS), X ray fluorescence (XRF)) which were integrated with Surface Enhanced Raman Scattering (SERS) analyses, specifically powerful in identifying the madder lake in micro-samples from the painting of the drapery of the female statue.

Figure 1. Multi-band imaging of a detail on the drapery of the small Herculaneum Woman. The details show the surface under (a) Visible light (VIS), (b) Visible-Induced Luminescence (VIL), and (c) Ultraviolet Luminescence (UVL)

Investigation of the Chemical Composition and UV-Induced Photodegradation Pathways of Commercial Protective Coatings for Street Art

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Street art has become an internationally recognized form of cultural and artistic expression and an integral part of the contemporary urban landscape. However, its conservation remains challenging due to exposure to environmental and anthropogenic stressors and the lack of protective coatings specifically designed for these substrates. In previous works on compatibility and efficacy of protective coatings, a systematic protocol was developed to evaluate the interaction between organic coatings and representative street-art paint layers. These studies highlighted significant issues such as uneven wetting, chromatic alterations, variable ease of removal, and coating instability depending on the paint type. Interviews with street artists, conservators, and cultural heritage professionals further revealed practical concerns regarding coating durability, reversibility, and the need for materials with minimal aesthetic impact, informing the selection of products analysed in this study. This work investigates eleven commercial protective coatings—acrylic, silane/siloxane, and hybrid formulations—commonly used in conservation but not originally designed for street art. A multi-analytical approach integrating XRF, FT-IR, EGA-MS, Py-GC/MS, and TG-DSC was employed to characterise the coatings before and after artificial UV ageing. Analytical pyrolysis revealed discrepancies between declared and actual compositions in several products, while thermal and MS analyses identified distinct degradation mechanisms, including polymer chain scission, plasticiser loss, and crosslinking. Overall, the results provide a comparative overview of the intrinsic stability and degradation behaviour of these coatings, offering valuable guidelines for selecting suitable protective systems for street-art conservation.

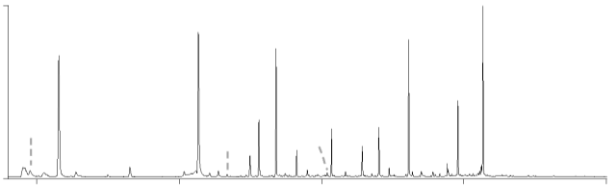

Figure:Py-GC-MS chromatogram at 600 °C of the unaged Pro-stone (Pro) sample.

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Unmixing CuPc-Yellow greens through non-invasive spectroscopies.

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Green in painting can be found in different forms, either as a single green pigment or as a mixture of blue and yellow pigments. The identification of these pigments through non-invasive in-situ techniques can be quite troublesome if only one technique is applied, because they are mostly composed of the same metallic elements (e.g., Cu or Cr) or because very similar features are observed in the reflectance spectra. For this reason, it is not only essential to couple multiple analytical techniques, but it is also important to compare the results with a reliable database of known compounds. The analytical issue is complicated if we consider the case of mixtures, for which it is essential to deconvolve the spectral information to know the endmembers present in the paint and their concentration, and in the real case of paintings, where varnishes, binders, and aging affect the spectral fingerprints. In this work, we will show the analysis of different green mock-up samples obtained as a mixture of phthalocyanine blues and different inorganic and organic yellow pigments, and their raw components. The aim is to distinguish the different mixtures and their components, coupling elemental and molecular data obtained from XRF, FORS, and Raman, which can be easily applied in situ.

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Sustainable SERS sensing for non-invasive Cultural Heritage diagnostics: real-case applications

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This work presents the validation of eco-sustainable SERS platforms designed, as part of the SAMOTHRACE project, for non-invasive diagnostics of pigments, dyes, and alteration products in Cultural Heritage materials. Flexible sensors were fabricated from recycled cellulose substrates deposited with Ag nanostructures via optimized pulsed laser deposition, with complementary tests using Ag colloids. Key morphological and plasmonic parameters were characterized through SEM, UV–Vis and micro-profilometry to identify optimal enhancement conditions. The sensors achieved detection limits down to 10^{-10} M for Rhodamine 6G and 10^{-7} M for the natural probe molecule violacein, supporting a fully green analytical workflow. A dedicated sample-holder prototype was engineered for compatibility with portable and benchtop Raman instruments and was tested on mock-ups simulating wood, canvas, and fresco pictorial layers. Real-case applications (Fig. 1) will be presented to demonstrate the reliable identification of the main historic pigments and heritage-relevant compounds on archaeological and artistic artifacts, confirming the system's suitability for on-site diagnostics and advancing sustainable practices within heritage science.

We thank European Union (Next-Generation UE), through the MUR-PNRR project SAMOTHRACE—Sicilian Micro and Nano Technology Research and Innovation Center (ECS00000022).

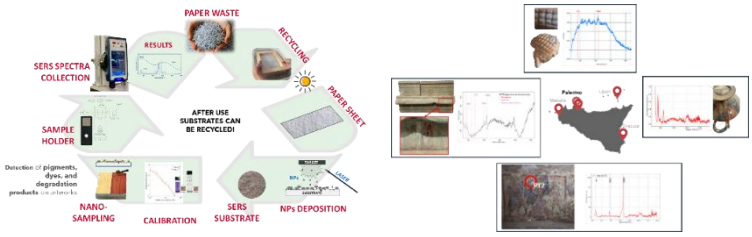

Fig. 1. a. Workflow for the fabrication of SERS sensors. Validation on archaeological sites and museums: Salinas Archaeological Museum (Palermo); Roman domus of Piazza Vittoria (Palermo); Santa Maria della Grotta in Marsala; Regional Museum of Lipari (ME)

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Advancing knowledge and preventive conservation strategies for plastic heritage: a new PESRPECTIVE

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The introduction of plastics in the 19th century marked the beginning of a revolutionary era, characterized by the widespread adoption of semi-synthetic and synthetic polymers in every field of human activity. Initially used for producing everyday and technological objects, these materials quickly expanded into the domains of art and design. Today, plastic artworks and design objects constitute a significant portion of modern and contemporary museum collections. However, the limited long-term stability of these artifacts poses major challenges to conservators and curators, primarily due to their heterogeneous and complex composition. The development of effective investigation methods, a priority in Heritage Science, becomes even more crucial for plastic artworks due to their peculiar vulnerability, heterogeneity, and material complexity. These factors hinder the standardization of effective and repeatable conservation and restoration procedures. In this framework, the interdisciplinary project PRIN2022 PERSPECTIVE—PolymEr Research Studies for PreventivE Conservation Through non invasIVe analytical strategiEs (https://perspective.cnr.it) aims at developing multimodal analytical approaches for the knowledge, monitoring, and preservation of plastic heritage. During the project, several materials were studied using both non-invasive and micro-destructive techniques, to highlight specific features of the most challenging plastics used in art and design objects, to advance our understanding of plastic heritage in art and design museums, and to deepen our knowledge of the degradation processes affecting these materials.

We present the main results obtained by the study with analytical pyrolysis – gas chromatography mass spectrometry (Py-GC/MS) and with evolved gas analysis mass spectrometry (EGA-MS) on the ageing processes undergone by polyurethane foams [1] and cellulose acetate films [2,3]. The effects of the application of consolidants were also studied through the preparation and artificial ageing of reference mock-ups. An innovative approach based on a specific set-up for *online* photodegradation provided us with important insights on the behaviour of photoprotectors added to the consolidant.

Relevant case studies will be presented, thanks to the collaboration with museums and research centres involved in the PERSPECTIVE project consortium.

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Tracing the Organic Complexity of Monumental *Terracruda* Sculpture: Analytical Challenges and Technological Insights

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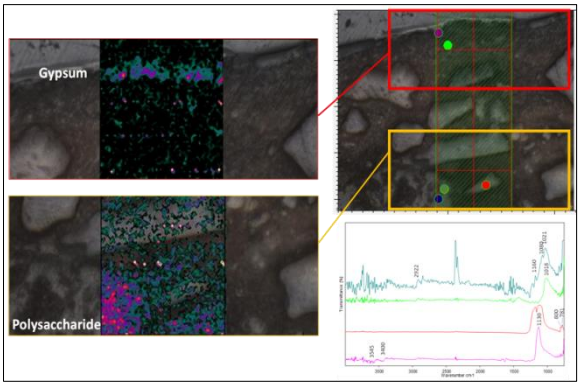
The study investigates the complex occurrence of organic components in the modelling pastes of monumental *terracruda* sculptures from Buddhist archaeological contexts of Central Asia (2nd–11th centuries CE). Building on recent advances in decoding ancient recipes for clays preparation [1, 2], this contribution addresses the analytical challenges associated with identifying natural polymers that may originally have acted as binding, strengthening, or antifungal agents within composite clay systems. The co-presence of diterpenoid, lipid, proteinaceous, polysaccharidic, and lignocellulosic compounds generates overlapping spectral features and ambiguous chromatographic profiles, hindering their discrimination even through the combined use of multiple analytical techniques — FTIR, GC-MS, OMICS approaches, and optical or electron microscopy. These challenges are further compounded by the scarcity of region-specific reference materials and by the variability of both ancient and modern standards across Asian contexts.Nevertheless, such analytical uncertainties open a productive space for dialogue between scientific data, textual sources, and ethnographic analogies. The integration of these perspectives helps guide the interpretation of spectroscopic signatures and highlights the deliberate technological choices underpinning the preparation of modelling pastes. Evidencing their presence and recognizing the functional role of organic additives is therefore essential not only for developing conservation strategies compatible with the heterogeneous and hygroscopic nature of this complex earthen heritage, but also for reconstructing the embedded technical knowledge and practices **aimed at improving the strength and durability of** monumental *terracruda* **sculpture.**



Chemical imaging using micro FTIR (FPA-FTIR) on cross-section of a sculpture fragment from Buddhist site of Kara Tepe, Uzbekistan (2nd-4th CE). Vibrations suggest the presence of a polysaccharide, with a spectral profile possibly associated with starch in the inner layer (yellow square, dark green spectrum; bands at 1250–1021 cm^{-1})

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Tracing Organic Materials in Roman Wall-Painting Surfaces: A Non-invasive Multi-Technique Study of the Sarno Baths Fragments

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This research investigates the potential of integrated non-invasive analytical methods to identify and characterize residues of organic materials on Roman wall-painting surfaces. The study combines the examination of archaeological fragments with the creation of controlled laboratory mock-ups inspired by ancient Roman mural painting techniques, with the aim of building a reference database to support more accurate interpretation of in-situ data. The analytical techniques employed include Fiber Optics Reflectance Spectroscopy (FORS), portable micro-Raman spectroscopy, and portable infrared spectroscopy, selected for their complementarity in detecting both inorganic and organic components.

The case study focuses on a selection of Roman fragmentary painted plasters from the deposit of the Sarno Baths (Pompeii), currently housed in the Cultural Heritage Department of the University of Padua. These fragments derive from a secondary depositional context; their original provenance is unknown.

Preliminary analyses confirmed the expected pigment palette, ochres, earth pigments, and Egyptian blue, consistent with Roman mural practices. Beyond pigment identification, particular attention was given to detecting and characterizing a secco retouchings, applied with organic binders and lime painting on top of the dry painted surface.

The combined application of FORS, micro-Raman, and IR spectroscopy enabled the recognition of spectral features indicative of organic residues on selected areas of the fresco fragments. Comparison with the purpose-built mock-ups strengthened the interpretation of these signals and supported the hypothesis that organic media were employed in localized retouching. While the precise identification of the binder type remains challenging due to degradation and substrate interferences, the results demonstrate the effectiveness of non-invasive multi-technique approaches for assessing the presence and distribution of organic materials in mural paintings. Overall, this study highlights the value of experimentally informed, non-destructive protocols for the analysis of wall-painting technology, offering new insights into painting practices, even when dealing with highly fragmented and decontextualized materials.

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From Clay to Craft: organics and fibers in the ancient mud mortars from the Ajanta UNESCO World Heritage Site

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The Ajanta Caves in Maharashtra, India—an iconic UNESCO World Heritage Site—are celebrated for their remarkably decorated earthen plaster dating from the 2nd century BCE to the 5th century CE. The unique approach of murals of the Ajanta Caves employed clay mortars, carefully prepared with organic additives as a base for murals. Beyond their artistic value, these murals offer evidence of sophisticated ancient craftsmanship, particularly in the clay mortars that form their foundational support. Understanding these mortars is essential not only for conservation but also for reconstructing the materials, technologies, and knowledge systems of the artisans who created them.

This study presents the results of an advanced archaeometric investigation combining material characterization, microstructural analysis, and experimental replication. A suite of complementary techniques—optical microscopy (OM), scanning electron microscopy with energy-dispersive spectroscopy (SEM-EDS), X-ray diffraction (XRD), X-ray fluorescence (XRF), fourier-transform infrared spectroscopy (FT-IR), and X-ray micro-tomography—was applied to six mortar samples collected with exceptional authorization from the site authorities. In parallel, laboratory replicas were produced to test hypotheses about composition and performance, from traditional knowledge of temple stapatis carried over generations, who retain knowledge of regional earthen construction methods.

The results illuminate the artisans' deliberate selection and processing of clays, organic additives, and fibrous inclusions, revealing a sophisticated understanding of material behavior long before the advent of modern construction science. By decoding these ancient practices, the research supports ongoing conservation efforts, informs sustainable restoration strategies, and offers valuable insights for modern eco-efficient building technologies.

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Combined FTIR and chemometric analysis for amber resins provenience and datation

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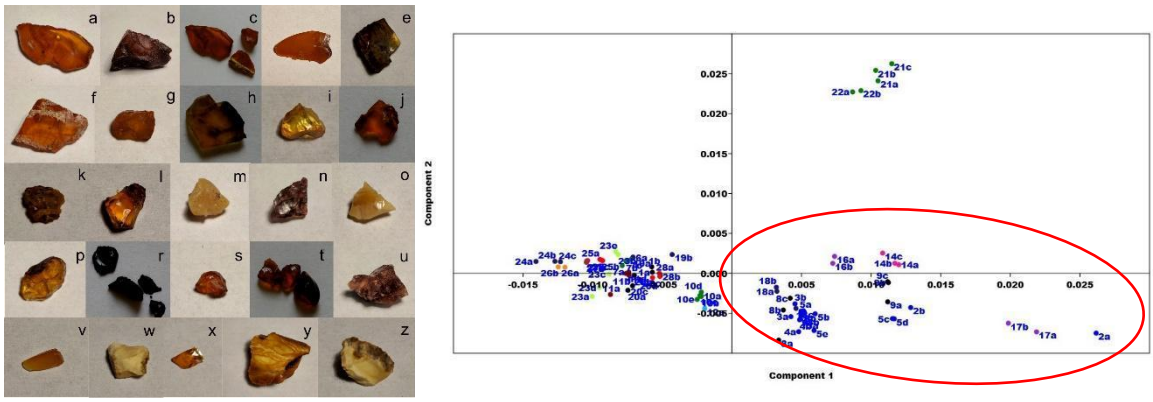
In this study [1], 28 amber fossil resins from Europe, Asia, and the Americas were analyzed using Fourier-transform infrared (FTIR) spectroscopy to investigate molecular features associated with their geological age and provenance. A tailored chemometric workflow was developed to enhance spectral interpretation by reducing non-informative variability and emphasizing relevant structural signals. This approach combines second-derivative spectral processing with segmentation of specific wavenumber intervals to isolate diagnostically significant vibrational bands. The resulting model successfully differentiates amber samples according to both geographic origin and age, while identifying the functional groups that most strongly influence classification. This methodology provides a powerful tool for amber provenance studies, particularly for distinguishing Eastern European succinites, and offers a robust framework for the identification and classification of unknown resin samples based on their molecular signatures.



Analysed amber fossil resins and score plot from PCA analysis of Scores plot in the range 1500-1800 for cm^{-1}

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Decoding Yellow Tuff in Pompeian Architecture: key mineralogical and geochemical constraints for a (re-)evaluation of its geological origin

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Tuff was one of the most widely used construction materials in central and southern Italy, valued since antiquity for its workability, lightness, and insulating properties, despite its intrinsic fragility and limited mechanical strength. In the Roman world, the selection of building materials depended on economic resources, craftsmanship, and structural requirements, as well as, in some cases, urgent rebuilding conditions, such as the post-earthquake reconstruction of Pompeii.

Within this context, the recurrent use of yellow tuff in Pompeii raises important questions, foremost its geological attribution. The nearby *Campi Flegrei* volcanic field emplaced the two deposits most likely to be its sources: the Campanian Ignimbrite (CI, ~40 ka), to which it is attributed the Lithified Yellow Tuff (LYT), a welded and zeolite-rich facies, and the Neapolitan Yellow Tuff (NYT, ~15 ka), which generated the massive yellow tuff widely used in Naples. Distinguishing between these deposits is notoriously challenging due to their internal variability and partial overlap in mineralogy and geochemical composition. This distinction is, therefore, crucial for reconstructing provenance, chronology, and construction choices in Pompeian architecture, particularly during the intense reconstruction and restoration of buildings after the 62/63 CE earthquake. To address this issue, 49 yellow-tuff specimens were collected from 40 Pompeian contexts, focusing on key architectural elements and classifying them as pre- or post-seismic relative to the 62/63 CE earthquake. A multi-analytical approach was applied, combining textural and spectroscopic techniques, quantitative mineralogical analyses, and microanalysis of juvenile matrix glass, which provided the most diagnostic provenance constraints. The samples exhibit the typical mineralogical assemblage of Phlegraean trachytic tuffs, dominated by phillipsite and chabazite in varying proportions, together with analcime, albite, biotite, clinopyroxene, hematite, calcite, and gypsum in minor or trace amounts. Lower sanidine abundances are also observed, except for three sanidine-rich specimens correlated with the Welded Grey Ignimbrite (WGI) facies of the CI, a distinction also supported by spectroscopic data. Quantitative mineralogical analyses revealed variable amounts of amorphous material, likely related to low-ordered and/or amorphous phases such as juvenile clasts, whose composition ranges from tephriphonolite to latite and is essentially homogeneous across pre- and post-seismic contexts. The microanalysis of juvenile matrix glass proved particularly revealing, consistently falling within the compositional field of NYT Member B, clearly distinct from the more evolved silica–alkali-rich signatures typical of CI-derived WGI and LYT.

This provides decisive provenance evidence: mineralogical, spectroscopic, and especially juvenile matrix glass data all converge on a predominantly NYT origin. These results refine long-standing hypotheses on material sourcing, construction practices, and post-seismic rebuilding in the ancient Pompeii.

From mortars to territory: chronology, environment and resources in The Times of Castles Project

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The Times of Castles project (PRIN 2020, Grant No. 20203YX58R) investigated the chronology of construction and transformation of 25 medieval castles (mid-11th to late 12th century) in Piedmont, Liguria and Tuscany. The interdisciplinary approach aimed to significantly narrow the chronological range of construction phases by interpreting new evidence in light of recent studies on castle formation (*incastellamento*) and territorial lordship.

The research involved building archaeology analysis and mortar sampling from masonry structures: 93 samples for mineralogical, petrographic and chemical analyses of the inorganic component (binder and aggregate), and 118 samples for anthracological analyses of the organic component (charcoal from wood fuel used in lime calcination). This was followed by 65 radiocarbon dates on organic and 25 on inorganic fractions. Radiocarbon dating of historic mortars represents an established practice for dating construction typologies. However, the anthracological approach involved complete extraction of charcoal from mortar samples until depletion, yielding 166 charcoal fragments. This enabled an integrated assessment of chronological coherence, considering the number of extracted charcoals, the probability of geogenic carbon contamination, and dating reliability. In addition, taxonomic identification of 119 charcoal fragments identified the tree and shrub species used as fuel, enabling assessment of the presence and exploitation of plant resources across the territory. Results provided insights into firewood selection criteria, raw material provenance, and the composition of exploited woodland communities, contributing to the reconstruction of landscape management dynamics. Correlation with inorganic fraction analyses broadened the perspective on medieval construction site economies, highlighting procurement and utilization strategies for building materials. The research thus offers new methodological frameworks for understanding construction chronologies and territorial organization practices in the Middle Ages.

Chronological Modelling and Probability Density Mapping of a Coralligenous Build-up off SE Sicily within the CRESCIBLUEREEF Project

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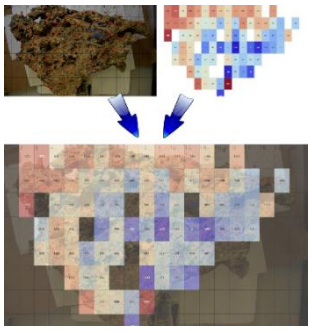
Coralligenous build-ups are biogenic carbonate structures formed by coralline algae, bryozoans, and serpulid polychaetes, acting as both biodiversity hotspots and long-term archives of Mediterranean environmental change [1]. Despite extensive ecological research, their internal chronologies remain poorly resolved. This study applies a spatial Bayesian radiocarbon model to the coralligenous build-up CBR2_3_7c, collected at ~50 m depth off Marzamemi (SE Sicily), within the CRESCIBLUEREEF Project [2].

AMS ^{14}C measurements were obtained on high- and ultra-high-density carbonate fractions after a workflow including ultrasonic cleaning, vacuum digestion, and graphitization. Calibrated ages were processed in OxCal v4.4.4 [3] using the Marine20 calibration curve. Samples were integrated through a spatial Bayesian framework, where each subsample corresponds to a cell within a two-dimensional matrix. Adjacency-based priors promoted local temporal coherence without enforcing strict stratigraphy, producing a posterior probability density field that preserves spatial variability.

Posterior results were visualized as a dynamic probability density map (PDF map), linking spatial structure and temporal evolution. The model reveals a consistent age–density gradient, with ancient ultra-lithified cores (>5 ka BP) surrounded by younger accretionary veneers (<1 ka BP), and shows alternating phases of growth, quiescence, and erosion.

By combining radiocarbon dating, Bayesian inference, and PDF-based visualization, this workflow provides a reproducible tool for reconstructing coralligenous growth histories.



Reconstruction of the age map

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Machine Learning for Cultural Heritage

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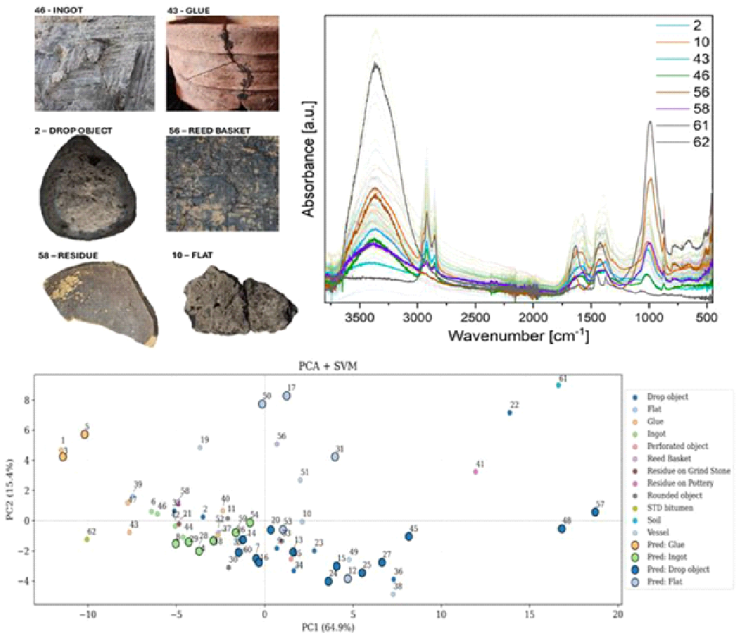
Cultural heritage objects are characterized by a heterogeneous assembly, with intrinsic complexity because of their multiphase composition and degradation resulting from biological and physic-chemical processes. Spectroscopic punctual techniques, such as Fourier transform infrared (FTIR) and X-ray fluorescence (XRF), are widely employed for the identification of constituent elements and compounds. In this context, machine learning (ML), and has proven to be effective tool for interpreting data. Here, an overview of the integration of advanced analytical methodologies and ML techniques for the diagnostics of cultural heritage will be presented, with case studies on Sumerian bitumen and ancient manuscripts. This approach enables the development of advanced protocols aimed at significantly improving analytical accuracy and efficiency in the field of conservation.



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Advancing Computed Tomography in Heritage Science: Hounsfield Unit CT Imaging for Wood Species Determination

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X-ray computed tomography (CT) constitutes one of the most advanced non-invasive diagnostic techniques available for the internal examination of artworks and archaeological artefacts. Its capacity to generate high-resolution three-dimensional reconstructions provides access to structural features that are otherwise inaccessible, thereby offering crucial information for conservation, restoration planning, and historical–technological studies. While CT has traditionally been employed primarily for qualitative and morphological analyses, such as the assessment of internal defects, joinery systems, or manufacturing technologies, its potential for quantitative material characterization remains comparatively underexplored within the field of heritage science. The present study aims to advance this emerging line of research by investigating the applicability of the Hounsfield Unit (HU) scale, a parameter widely used in medical imaging, for the identification of wood species in cultural-heritage objects. The HU scale is directly related to the linear attenuation coefficient of a material and, consequently, to its density and composition. As such, it represents a theoretically robust indicator for distinguishing materials with similar morphological characteristics but differing physical properties. This methodology was applied to two wooden artefacts of significant historical and cultural value: the support of a seventeenth-century panel painting housed at the National Academy of San Luca in Rome, and the wooden substrate of an Egyptian coffin preserved in the Vatican Museums. CT scans of both objects were acquired under carefully controlled and fully documented conditions. The HU values extracted from the tomographic volumes were then systematically compared with those obtained from a dedicated set of reference wood samples scanned under equivalent parameters, ensuring the reliability and comparability of the measurements. The comparative analysis enabled the identification of the most probable wood species used in the construction of each artefact, with a level of accuracy suitable for conservation research. The results clearly demonstrate that HU mapping can function as a robust, reproducible, and completely non-destructive indicator for material identification in wooden artworks. More broadly, the study highlights the potential of CT data to extend beyond purely morphological information, opening new avenues for the quantitative characterization of constituent materials in cultural-heritage objects. By integrating material analysis into standard CT workflows, this approach significantly enhances the diagnostic capabilities of computed tomography and contributes to a more comprehensive, scientifically rigorous understanding of artefacts within conservation, archaeological, and art-historical research.

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Exploring Stone Weathering in Cultural Heritage through Geochemical Modelling

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Stone-built historical monuments are vulnerable to atmospheric agents influenced by climatic and environmental conditions [1]. In this context, climate change presents an additional threat by accelerating degradation processes and contributing to deterioration phenomena. [2]. This research aims to apply geochemical modelling, combined with traditional diagnostic investigation, to simulate the processes involved in the weathering of cultural heritage materials. Modelling is an effective method for analyzing several geochemical processes, including weathering. It is based on the use of software that provides reliable results grounded in the principles of thermodynamics and chemical kinetics [3]. Therefore, the application of geochemical modelling in cultural heritage field could represents a promising tool for studying the processes involved in the interaction between stone materials and specific environmental conditions. The methodological framework of the research includes: i) the selection of four pilot sites in Calabria region (Italy), characterized by granitoid and carbonate lithologies located in urban and non-urban contexts; ii) the collection and processing of environmental data (temperature, precipitation, and CO_2 concentrations) obtained from local monitoring stations; iii) the minero-petrographic characterization of the lithotypes to define the solid phase for geochemical simulations. A first geochemical modelling was performed to investigate the weathering processes associated with the carbonate stone used in the construction of one of the selected pilot sites. PhreeqC software was used to model calcite dissolution, employing site-specific environmental data relating to atmospheric CO2 concentrations and historical monthly average temperatures. The model provided output data on the amount of calcite dissolved as a result of water-stone interactions. The amount of dissolved calcite was then compared to the site's monthly average rainfall, obtaining a final result expressed as the amount of dissolved calcite per square meter of exposed surface. To date, preliminary results demonstrated the applicability of geochemical modelling in the field of cultural heritage and suggest its potential for predicting degradation under future environmental conditions.

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Characterization and uses of Opuntia Dilleni's mucilage as mortar additive

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This work presents a detailed investigation on the extraction, structural characterization and functional assessment of Opuntia dillenii mucilage as an additive for air-lime mortars.
Mucilage is a hydrocolloidal component widely found in plants adapted to arid environments, characterized by high water-retention capacity and a branched polysaccharide structure whose monosaccharide composition varies among species.
In Opuntia spp. mucilage contains arabinose, galactose, rhamnose, xylose, and uronic acids in species-specific proportions and for this case of *Opuntia dillenii* was isolated through a solvent-recycling protocol designed to minimize toxicity and maximize recovery. Chemical characterization was conducted through acid hydrolysis followed by 13C NMR spectroscopy, enabling quantification of constituent monosaccharides: arabinose (36.5%), galactose (32.3%), xylose (15.3%), glucose (10.5%), and rhamnose (5.4%). The mucilage was subsequently incorporated into lime mortars (binder/aggregate ratio 1:3) at four dosages (0.5%, 1%, 2%, 3% relative to the portlandite content), previously determined through simultaneous thermal analysis. Fresh-state behavior was investigated via flow-table tests. Cubic and cylindrical specimens were produced for compressive and indirect tensile strengths, water vapor permeability; and absorption–desorption kinetics. Mechanical tests (UNI EN 13791:2019) on cubic and cylindrical specimens exhibited pronounced intra-series variability, with compressive and indirect tensile strengths showing no statistically significant correlation with mucilage content. Water transport analyses revealed distinct trends: permeability decreased consistently in all mucilage-amended mortars compared to the reference mix, whereas absorption–desorption kinetics remained invariant across formulations, indicating negligible influence of mucilage on capillary water uptake. Overall, O. dillenii mucilage does not induce measurable modifications in the mechanical performance of air-lime mortars but demonstrably reduces their water permeability, suggesting a potential role as a porosity-modulating additive for conservation materials.

Extraction of Opuntia dilleni's mucillage

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Inside Lucio Fontana's atelier: molecular insights into the composition and properties of non-traditional painting materials

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During the mid-20[th] century, many artists began to experiment with unconventional materials that departed from both traditional and industrial paint formulations. Lucio Fontana (1899-1968) was among the pioneers who expanded the concept of the pictorial surface through the introduction of novel binders, additives, plastics, and composite materials. As a result, the technical study of Fontana's artworks is challenging: the materials encountered are often poorly described, highly heterogeneous, frequently modified by the artist himself, and include synthetic formulations that underwent significant chemical and physical transformations over time. Thus, the characterization of atelier materials, whose composition is often unprecise or undeclared, is fundamental for disclosing their properties and clearly identifying them in such complex mixtures on canvas.
Several studies have been carried out on Fontana's painting technique, but most of them are focused on the characterization of pigments and binders constituting artworks. Only few of them have been conducted on the atelier materials, mostly focusing on colored inks.
In this work a wide collection of heterogenous painting materials ranges from more "traditional" ones such inks, water-based paints and painting tubes to more "non-traditional" ones as aerosol fixatives, protective finishes, flatting varnishes, solvents and marble mastic have been investigated. A multi-analytical strategy combining complementary methods, ranging from Infrared Spectroscopy (FT-NIR), μ-Raman Spectroscopy, Scanning Electron Microscope with Energy Dispersive X-ray Analysis (SEM-EDX), to Pyrolysis coupled by Gas Chromatography and Mass Spectrometry (Py-GC/MS), GC-MS and head space solid phase micro extraction (HS-SPME)-GC-MS, have been applied providing detailed insights into the molecular composition of materials associated with Fontana's atelier. Different pyrolysis conditions and GC-MS sample procedures have been tested to fine-tune the most efficient analytical protocol.
This integrative approach not only enhances the understanding of Fontana's material choices and creative processes but also contributes to collecting essential information for the long-term conservation of his artworks. Being Fontana one of the most influential Italian artists of the postwar period, the molecular identification of these novel materials, some of which have never been investigated, would offers a crucial reference for material identification in the artworks of other modern and contemporary artists experimenting with non-traditional media.

A chemical investigation of paint film formation in azurite-based oil paints

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Azurite was one of the most widely used blue pigments in European painting from the Middle Ages through the Renaissance, valued for its vivid color and relative affordability compared to ultramarine blue.[1] Despite its historical importance, azurite is notoriously problematic in oil-based media, where it often exhibits extremely fast drying behavior and color alteration.[2] Historical sources recommend the use of pre-polymerized oils to improve its performance, yet the molecular mechanisms underlying film formation in azurite–oil paints remain insufficiently understood.

This study investigates the curing behavior of azurite-containing paint systems and the role of the binder in governing their chemical and physical evolution. Model paints were prepared using azurite dispersed in cold-pressed and pre-polymerized (boiled) linseed oil, as well as in mixed-media formulations (using linseed oil and egg as binders). A multi-analytical approach was employed, combining thermogravimetric analysis (TGA), ATR-FTIR spectroscopy, solid-phase microextraction gas chromatography–mass spectrometry (SPME-GC-MS), differential scanning calorimetry (DSC), NMR relaxometry (NMR-MOUSE), and colorimetry to monitor oxidation, cross-linking kinetics, molecular mobility, volatile emission, and color evolution during curing.

The results confirm that azurite strongly catalyzes oil curing which has been shown to proceed through Cu(II)-mediated hydroperoxide formation and degradation.[3, 4] Data show that in paints prepared with cold-pressed linseed oil, this leads to extremely rapid and spatially uneven cross-linking, producing inhomogeneous polymer networks and macroscopic oil exudation. In contrast, pre-polymerized linseed oil promotes faster but more uniform curing, suppresses oil separation, and yields stable, homogeneous paint films. Mixed-media systems further enhance copper dissolution and oxidation kinetics through proteinaceous components[5], resulting in immediate curing onset, as well as fast but homogeneous polymerization, resulting in uniform network formation.

Overall, this work provides a molecular-level explanation for the historical recommendations found in artists' treatises and demonstrates how binder selection and pigment preparation critically determines the stability of azurite-based paints.

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Composite Gemstones and the art of counterfeiting in the Middle Ages: A Forgotten Craft Tradition

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Enhancement treatments and gemstone imitation techniques have long attracted human interest. Archaeological and documentary evidence attests to practices aimed at improving color and transparency, as well as producing imitations that closely resembled natural materials. Among these, composite gemstones - e.g., doublets and triplets, namely gems made by two or three layers of different materials glued together - occupy a particularly significant place [1].
Pliny, in Book XXXVII of the *Naturalis Historia*, describes a technique for reproducing the chromatic layers of agates intended for cameos; however, explicit accounts of doublets and triplets appear only in the sixteenth century, with Leonardi (1502) and Cellini (1568). However, scientific studies carried out on fifteenth-century artifacts nonetheless demonstrate that such practices were known and employed well before their formalization in written sources [2].
The analysis of a group of goldsmithing objects dated between the late thirteenth and fifteenth centuries, preserved in Tuscan museums and in the Vatican collections, has revealed for the first time the presence of composite gems alongside natural stones and various treatment methods, anticipating what has so far been reported in the literature [3]. Through an archaeogemological approach, the study reconstructs an overlooked chapter in the history of composite gemstones by integrating documentary sources with non-invasive diagnostic investigations, targeted sampling, and micro-destructive analyses. Gemological analyses, including Raman spectroscopy, together with the study of adhesives through pyrolysis GC–MS, have clarified the manufacturing processes involved.The results show that the systematic production of composite gemstones was already established in specialized workshops by the thirteenth century. This research reveals that the practice was far more widespread in the Middle Ages than previously thought and helps clarify its motivations, techniques, and historical development, restoring depth and complexity to this sophisticated form of gemological counterfeiting.

A composite gems selection from studied art works

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Plastics in museum collections: counteracting microbial deterioration by Essential Oil.

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The historical periodization of dominant raw materials highlights their decisive role in cultural development; in continuity with this perspective, today's "Age of Plastic" reflects the pervasive presence of synthetic, semi-synthetic and, more recently, bio-based polymers. The increasing occurrence of these materials in museum collections poses a significant conservation challenge. In particular, biodeterioration has emerged as a critical issue affecting both historic plastics and contemporary bioplastics.

This study investigates the microbial degradation processes of PLA, PHA and compostable polymer blends by considering both intrinsic and extrinsic factors. It is well established that the activity of major bacterial and fungal biodeteriogens is strongly influenced by the chemical composition and properties of polymers, as well as by environmental conditions such as relative humidity, temperature and particulate deposition [1]. Special attention is given to the synergistic interactions between biodegradation and photo-oxidative or hydrolytic processes, which are especially pronounced in bioplastics [2].

Preliminary experimental results highlight the potential biostatic or biocidal effects of selected essential oils [3], also assessed in their volatile form (VOCs), against targeted bacterial (Gram + / Gram-) and fungal colonies. Furthermore, the photochemical degradation pathways of polymers help define more robust methodological criteria for assessing biological risk in plastic materials.

Overall, the findings emphasize the importance of preventive conservation strategies based on the careful control of environmental parameters to mitigate microbial proliferation. The integrated approach developed here, combining the analysis of degradation mechanisms with in vitro microbiological assays using natural compounds, provides new insights into the vulnerability of historic plastics and emerging bioplastics in museum contexts. This research contributes to the development of diagnostic and conservation guidelines specifically tailored to plastic materials within contemporary heritage collections.

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Organic materials in stucco decorations: sources, functions, and analytical challenges

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This paper illustrates the use of organic materials as additives in stucco decorations. Technically, stucco is a composite technique in which supports (metal, brick, or wood) give the structure to mortars made of lime and/or gypsum, containing sand and marble powder for preparatory and finishing layers. Although historical sources frequently mention the addition of organic substances, their specific presence, function, and composition remain insufficiently understood. This study aims to provide a comprehensive overview of these materials by integrating information from artistic treatises, archival documents, scientific literature and analysis of case studies.

Historical treatises on architecture and artistic techniques mention the use of a variety of organic additives used to improve the properties of plaster and to influence – by delaying or accelerating – the setting time. Finding traces of these in archival documents is more difficult, as these materials were readily available (eggs, oils, etc.) and often, as in the case of casein, were produced directly in artists' workshops.

In general, the analytical detection of organic materials in historical stuccoes is challenging because these components are present in low concentrations (1–2%), are chemically unstable, and deteriorate rapidly, especially in the basic fresh stucco paste. In addition, the porous and heterogeneous nature of stucco decorations promotes contamination and alteration, while interactions with other materials can compromise analytical responses. These factors create interpretive complexities that demand multi-analytical approaches and careful data evaluation.

Scientific analyses of several stucco decorations from Poland, Italy, Switzerland, Great Britain, France, and the Czech Republic reveal the presence of animal hair, proteins, oils, waxes. Some analyses also show that the distribution of these organic substances varies with sampling depth, likely reflecting plaster stratigraphy or specific surface treatments. In addition, products of organic material mineralization like oxalates have often been identified. Our research group conducted extensive analyses of 16th- and 17th-century works in the Canton of Ticino and other European sites associated with Ticino craftsmen, examining more than 200 samples (Caroselli et al 2020, Jean Felici 2025). These studies reveal substantial variability in both the types and quantities of organic additives, reflecting the technical needs and artistic intentions of individual stucco masters.

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From analysis to intervention: a scientific approach to the restoration of Saint Onofrio's Parchments

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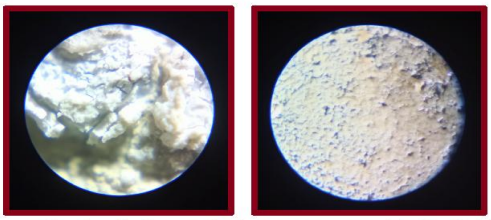
The abstract I propose is about the restoration project I undertook for my thesis in Conservation and Restoration of Cultural Heritage. This one-year MA degree was discussed in 2023 at Tor Vergata University in Rome. The subject of my dissertation is a study and conservation project of a collection named *Saint Onofrio's Parchments*. The collection (13th–19th century), originally belonging to the Monastery of Santa Chiara in Ascoli Piceno (Italy), is currently preserved at the Italian State Library of the National Monument of Santa Scolastica in Subiaco. These documents, mostly parchment manuscripts—some of them with seals—presented different conservation conditions and had other characteristics and, consequently, different criticalities. The entire project was supported by a scientific study of the materials, to investigate the components of the fonds, choose the best practices of intervention, and verify the effectiveness of the methods. For the humanistic part, the summaries behind the parchments are eroded and not well legible because part of the pigment was removed. The UV lamp worked very well with the ink traces and helped to transcribe the texts. The effectiveness of the cleaning was proven by colorimetry, a simple method to determine the color of samples. The results showed that the cleaning methods worked very well without being too aggressive on the supports. After the cleaning, some inks in poor condition were consolidated with a solution of hydroxypropyl cellulose in alcohol, with the help of optical microscope analysis, which was also very helpful in verifying the effectiveness of the consolidation of lead seals with the resin Paraloid B72. To proceed with the intervention and smooth the supports, it was necessary to verify the origin of the inks. The X-ray-fluorescence analysis proved the presence of iron-gall inks, and this influenced the type of humidification chosen. A controlled humidification in a chamber with cold steam made it possible to control the inks during the treatment and to protect them with stencil masks made of Reemay and Melinex, to avoid direct contact with water, which can change the pH of the iron-gall inks. The XRF analysis also proved the pure nature of the gold in one of the documents, and the result guided the choice of purified isinglass for the consolidation, conveyed with alcohol because there were some lifts, and the treatment gave good results, clearly visible under the microscope.X-ray analysis was also used to investigate the metallic materials of the seals, made of lead, but also tin and other metals. The pH stability of some paper sheets sewn into one of the parchment documents was tested, in order to assess the need for a redox treatment, which ultimately proved unnecessary. After the mending and the restoration of the beeswax and lead seals of the documents, a new conservation system was created: folders and accommodation for seals with expanded polyethylene, a conservation material. This work is the result of an interdisciplinary study, in which the restoration was supported by appropriate diagnostic investigations.



Microscopic view before and after treatment with Paraloid B72.

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Development and Assessment of Nanocomposites for the Conservation of Peperino Stone

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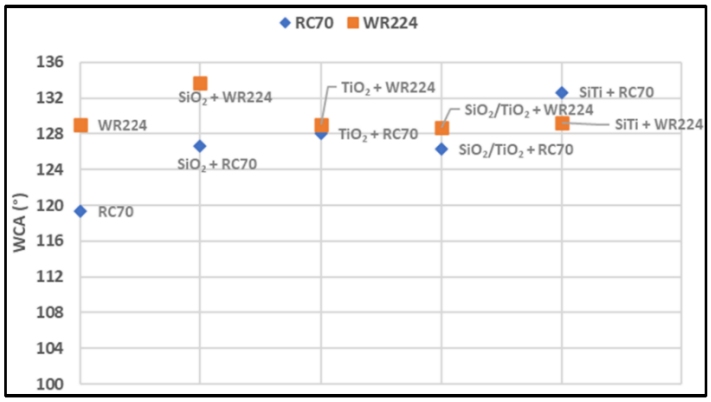
The conservation of outdoor stone cultural heritage, which faces degradation from natural elements, poses a significant challenge. This research focuses on the application of polymer-based nanocomposites, specifically combining the consolidant Rhodorsil RC70 with the protective Rhodorsil WR224, enhanced by nanoparticles of SiO2, TiO2, and a novel oxide mixture called SiTi. The objective is to protect Peperino, a volcanic rock native to Viterbo (Lazio, Italy). To assess the effectiveness of these nanocomposites against traditional conservation methods, a series of experiments were conducted. Initially, a thorough chemical-physical characterization of the products was performed, which included X-ray Diffraction (XRD) measurements on the nanoparticles and thermal analysis of the nanocomposites. Subsequently, the nanocomposites were applied to Peperino samples (dimensions: 5 x 10 x 2 cm). Key evaluations included water absorption tests, measurements of contact angles, and diagnostic studies utilizing Laser Induced Fluorescence (LIF) and Fourier Transform Infrared Spectroscopy (FT-IR). Additionally, colorimetric assessments were carried out to analyze the aesthetic impact of the treatments. The findings revealed that the nanocomposites significantly improve the conservation properties of Peperino by enhancing its hydrophobicity. Overall, these treatments demonstrate their effectiveness not only in preserving Peperino but also in safeguarding stone cultural heritage more broadly, aligning with essential restoration principles such as sustainability and minimal environmental impact.



Contact angle values of conservative products

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Lime-based mortars with the incorporation of agricultural wastes: the case of Powdered Olive Stone (POS)

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According to the most recent statistics, the world's population keeps growing and might reach 9.7 billion by 2050. This rapid population increase threatens agricultural productivity, leading to an ever-increasing amount of food and waste generation and putting the ecosystem at risk. Considering that the world agricultural production should increase by 70% by 2050, waste biomass data may become even more significant in the next few decades [1]. Applying circular economy principles to agricultural waste management holds significant potential for minimizing waste generation, maximizing resource efficiency and thus enhancing sustainability within the agricultural sector. Following this purpose, the use of waste and by-products as mortar admixtures/additives is gaining an increasing awareness, as it reduces the embodied energy of the end-product and the consumption of raw materials [2].
This study investigates the use of Powdered Olive Stone (POS), an agricultural by-product, in lime-based mortars used for the conservation of historical buildings. Lime/aggregate ratio selected for this study was 1:3 by volume, as it is the most common proportion used in literature and in conservation practices. POS was added as a partial replacement of sand in different proportions: 5, 10 and 15 % by volume. Moreover, the adding of nanosilica to the mixture has been tested.
Following curing of 28 and 90 days, the specimens underwent a comprehensive set of analyses, to examine both mechanical and physical properties and their durability. The investigations and tests included colorimetric analysis, microscopic and electron microscopic observations, capillary water absorption tests, ultrasound pulse velocity tests, bulk density measurements, salt weathering assessments and mechanical tests.
Results indicate that the careful formulation and optimization of POS-containing mortars are crucial for meeting the specific requirements of conservation projects, paving the way for future exploration into the long-term performance of these materials in real-world conditions.

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SPONSOR

Chemical Imaging and molecular spectroscopy: future is now

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Molecular spectroscopy is an important analytical area with wide impact and extent. In this field, Raman and Infrared spectroscopies are powerful and complementary techniques, with an extensive use spanning from biomedical, pharmaceutical and material sciences, to name a few.
In last decades applications related to Geological, Mineral and Art samples have become more and more demanding about several topics, like the possibility to perform in situ analysis of organics and inorganics in an easy way with a non invasive and non destructive approach and the possibility to get precise information on micro-scale of layered materials when it is possible to have a sample to be analysed into the laboratory.
The request per the capability to perform chemical imaging on large areas (keeping the high lateral resolution) is continuously increasing.
Today all the latest technologies (both hardware and software) have been applied by Bruker to all the Raman Spectrometers, both for portable and in lab instrumentations, both for dispersive and FT solutions, showing a unique portfolio on the market.
So, latest innovations will be presented in terms of commercial products, with the state of the art compromise between sensitivity and effective usability. In particular, the unpredictable capability to perform large Raman Chemical Images, on centimeters scale, will be shown.
Finally, also the amazing performances in IR imaging, when using FTIR with FPA and QCL as infrared source, will be shown for the first time in an organic way.

Splitless injection with forced gas venting to increase the throughput and sensitivity of pyrolysis-based analytical methods in cultural heritage

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The characterization of organic materials in cultural heritage is often challenged by the complex composition and the very limited sample amount. Pyrolysis-based techniques such as analytical pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) constitute a versatile and powerful tool to characterize both polymeric and non-polymeric organic compounds, providing molecular-level information even for complex mixtures of natural and synthetic species [1]. Recent technological developments in pyrolysis technology have unlocked the possibility of performing Py-GC-MS experiments with splitless injection, increasing the transfer efficiency of the pyrolysis products from the furnace to the GC-MS system, while also avoiding excessive fragmentation due to prolonged exposure to the pyrolysis temperature [2]. This instrumental setup has shown significantly increased sensitivity towards synthetic organic polymers, improving the limits of detection by one or two orders of magnitude [3].
In this study, we propose the application of splitless Py-GC-MS with forced venting of the pyrolysis products when analyzing cultural heritage materials. A study is presented regarding the evaluation of a novel cleaning method for cultural heritage materials based on atomic oxygen cold plasma. The cleaning method was applied to a reference paper material and a historical sample. Splitless Py-GC-MS was then used to assess the formation of low-molecular weight volatiles formed during the cleaning process. Results showed that furans are formed after the cleaning, suggesting that atomic oxygen induces a slight surface oxidation of the paper samples.

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Intelligence That Inspires Confidence: Agilent 6495 triple quadrupole LC/MS system

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The Agilent 6495 Triple Quadrupole LC/MS system represents a high-sensitivity, high-performance solution for targeted quantitative analysis across diverse applications, including metabolomics, lipidomics, proteomics, genomics, and regulated PFAS detection. Leveraging dual-stage iFunnel technology, the instrument achieves up to a tenfold increase in ion capture, significantly lowering detection limits while maintaining precision at submillisecond dwell times. Advanced features such as VacShield enable rapid maintenance without venting, reducing downtime by up to 92%, while Intelligent Reflex automates reinjection and fast screening workflows to enhance throughput and data reliability. The system incorporates heated hyperbolic quadrupoles, a tapered hexapole collision cell for noise reduction, and an octapole ion guide for broad m/z coverage, ensuring robust performance across small molecules, peptides, and polymers. Integrated intelligence functions provide real-time health monitoring, scheduled autotuning, and predictive maintenance, minimizing operational disruptions. Coupled with MassHunter software for streamlined acquisition, compliance with global data integrity standards, and Skyline integration for peptide and small molecule analysis, the 6495 LC/TQ delivers exceptional sensitivity, reproducibility, and workflow efficiency. Sustainability initiatives, including ACT-label certification, further position the system as an environmentally responsible choice for modern laboratories.

The habit of the stigmata of St. Francis of Assisi – commodity characterization of the fabric

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In March 2001, on the occasion of the transfer of the Habit of the Stigmata of St. Francis from the Vespucci Chapel of the Church of Ognissanti in Florence to the Sanctuary of La Verna, where the Saint received the stigmata, on the habit, already subject to restoration in 1981-82 by the Opificio delle Pietre Dure of Florence in the then "Laboratorio Arazzi e Stoffe" a conservative reconnaissance was carried out. On that occasion, accurate optical observations were made on the state of conservation, on the technique of the fabric and tailoring, on the impact of needle consolidation on the fibers, on the behavior of the dyes used for the gap, and on all those negative aspects that could have emerged from the intervention carried out with the restoration of 1982. Very mild suction operations also followed, both to check the state of decomposition of the material through the presence of microfibrils now detached from the yarn, and for any surface dust still present despite the intervention of the previous restoration following which the habit was placed in a nitrogen-tight case to limit oxidation. It was also necessary to intervene with a micro-sampling of some fibers, in order to be able to perform analyses, aimed at acquiring more information on the constituent matter (commodity and morphological aspects) and also details related to pigmentary dirt such as soil, sand, pollen still present on the dress, which could have identified probable interactions with the material and, perhaps, allow us some considerations on the life of the Seraphic.

The samples were analyzed by the two internal laboratories of the Opificio delle Pietre Dure in Florence and by the Laboratorio di Analisi Prove e Ricerche Tessili in Prato (now Brachi Testing Services) of which I was the sole shareholder. My laboratory was entrusted with the task of characterizing the fibers and yarns making up the fabric of the habit by means of optical and electron microscopy analyses, and other analyzes aimed at highlighting the commodity and morphological aspects of the fabric making up the habit.

My work and that of other colleagues has had the aim of being able to monitor the state of conservation of the dress in the future and set up a database that will support future measures.

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POSTER

Analysis of bronze artefacts from gonfienti: a comparative study of the production cycle through neutron techniques and sem-eds

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This work focuses on the study of ten metallic artefacts made of copper and copper alloys from the Etruscan site of Gonfienti, located at the edge of the Prato plain, and frequented at least since the second half of the sixth century BCE. The aim of the study is to broaden the knowledge about the metallurgical practices employed in the context under investigation. To this end, among the numerous metal artefacts found during the excavation campaigns [1] two distinct categories were selected: *raw metal fragments* and *finished artefacts*. This selection strategy made it possible to ideally *trace the entire metallurgical process*, from the extraction of copper from cupriferous ores to the casting and working of metal, to produce finished objects. The methodological approach adopted in the study of the Gonfienti artefacts is mainly based on *neutron techniques*, including Time-of-Flight Neutron Diffraction (ToF-ND), White-Beam Neutron Tomography (WB-NT) and Neutron Resonance Capture Analysis (NRCA). Neutron techniques represent the state of the art in the advanced characterization of archaeological metal artefacts, as they allow to obtain a wide range of morphological, compositional and microstructural information on their bulk in a totally non-invasive way [2][3]. The experiments were carried out at the large-scale facility "ISIS Neutron and Muon Source" in the United Kingdom. The results were integrated by SEM-EDS analyses, which provided complementary morphological and compositional data. Results indicate that the raw metal fragments are not the product of standardized technological processes but reflect a marked variability both in the nature and selection of the ore charge used for copper extraction and in the operating conditions of smelting, with significant differences in the reducing power within the reactor. The finished artefacts, on the other hand, attest to the adoption of sophisticated and complex manufacturing practices, as well as a high mastery of metallurgical techniques. Ultimately, results do not reveal any clear direct production relationship between raw metal fragments and finished artefacts. This suggest that the analysed fragments do not represent the raw material from which the examined group of finished artefacts was manufactured.In conclusion, the methodological approach adopted, which integrates neutron analysis and SEM-EDS, provided deeper insights into production and working techniques of copper and its alloys in the site of Gonfienti.

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Ink discrimination in compromised manuscript writings: a non-invasive and multi-analytical accessible method

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Reduced legibility of texts, caused by overwriting, crossing-out or erasure [1], affects the interpretation of content in historical manuscripts, whether literary works, official documents, or personal letters. These modifications often involve inks with chemical or physical properties similar to those of the original writing, making discrimination difficult; in other cases, ink traces may be nearly or entirely removed.

This research aims to characterise and discriminate inks in compromised textual parts to overcome legibility limitations and support understanding of the writing stages. After validation on laboratory samples, a non-invasive methodological approach combining accessible techniques was applied to original manuscripts preserved at the Biblioteca Nazionale Braidense (Milan) and the Biblioteca Universitaria di Pavia MiC (Pavia). This methodology focused on a multispectral method, Hypercolorimetric Multispectral Imaging (HMI) [2], with complementary traditional spectroscopic techniques, including X-ray fluorescence (XRF) and micro-Raman spectroscopies [3].

The multispectral method enabled discrimination between different inks, highlighting the writing sequence in revised marginal notes (Fig. 1a) on the Alessandro Manzoni manuscript (MANZ. 15. 0025). In particular, principal component analysis (PCA) applied to three infrared bands (760, 850 and 930 nm) highlighted underlying text and enhanced contrast between the original writing and subsequent cross-out marks (Fig. 1b). These writings were produced using metal-organic inks exhibiting different spectral reflectances, which gradually increased across the near-infrared range.

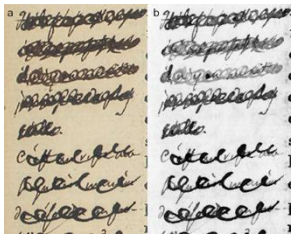

Figure 1. (a) Visible image of revised marginal notes on the Alessandro Manzoni manuscript (MANZ. 15. 0025). (b) PC1 image obtained from the PCA analysis.

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Phase-contrast X-ray Imaging for the characterization of cultural heritage materials

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X-ray imaging is a standard tool for the non-invasive inspection of the internal structure of materials. The conventional absorption contrast method provides good results for characterizing medium density samples or distinguishing materials with different attenuation power, but it leads to poor image quality when the sample is weakly absorbing, typically in materials composed of light elements. On the contrary, Phase-Contrast (PC) X-ray imaging is an effective technique for detecting low contrast details in weakly absorbing samples such as organic materials or tissues, as it provides high-quality information on micro-structural features [1].
The PITCH project (funded in the framework of PRIN2022) aims at developing, designing and characterizing a phase-contrast X-ray imaging setup with a Talbot interferometer and a liquid anode source for the study of cultural heritage (CH) materials. We present here the preliminary characterization of the setup and the first results obtained on different organic materials related to the CH field with the new laboratory system.
A selection of original fragments and possible mock-ups has been made: mummified remains, animals preserved in formalin, textile material, wood blocks and parchment are a few examples of possible CH materials that could be analyzed by our laboratory system. The preliminary analysis on mock-ups aims at characterizing these materials and understanding related issues e.g. composition, production technique, state of conservation, differences between species, degradation byproducts. The mock-ups characterization will lead to the study of real artifacts coming from museums and other cultural institutions.

Acknowledgements
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Gypsum alabaster of the statue of the Salvator Mundi made by Gabriele Brunelli (Bologna, 1615-1682): characterization and analysis

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This study presents the results of a diagnostic investigation conducted during the riele Brunelli. Traditionally described as marble, the sculpture was instead identify as being carvconservation and restoration of the 17th century statue “Santissimo Salvatore” attributed to the sculptor Gabed from gypsum alabaster ($CaSO_4 \cdot 2H_2O$) [1]. Through a multi-analytical approach, including X-Ray Powder Diffraction (XRPD), Field Emission Environmental Scanning Electron Microscopy (FE-ESEM) with Energy-Dispersive Spectroscopy (EDS) and confocal Raman Microspectrometry, the mineralogical and chemical composition of the statue was characterized in detail [2]. The analysis scientifically refuted the long-standing historical assumption that the statue was made of marble, demonstrating instead that it is composed of gypsum alabaster with minor traces of celestine (SrSO4). Moreover, the investigation identified organic amorphous residues rich in C, O and N on the altered areas, likely related to surface degradation. The results provided essential insights into the material selection and work practices of Brunelli while supporting the development of targeted conservation strategies by gaining full knowledge of the material characteristics and types of degradation affecting the artwork.

Location of the sampling points on the statue

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The lapis lazuli tabernacle of Palermo Cathedral: characterization of the materials and assessment of the risk level for its conservation

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The results of the in situ non-invasive and on sample investigations carried out to support the design of the restoration of the tabernacle of the Chapel of the Blessed Sacrament in Cathedral of Palermo (Sicily) will be illustrated.
The tabernacle, located on the left side of the transept, was ordered by Archbishop D. Martino de León y Cárdenas (1585-1655) from Cosimo Fanzago, architect and sculptor, and built to his design by Tuscan and Roman workshops [1]. This artwork is entirely decorated in lapis lazuli and polychrome marble applied to an altar with a colonnade and gilded metallic dome. The entire system is supported by a wooden structure, accessible from the cavity between the tabernacle and the back wall.
The study and survey of the pre-restoration project, coordinated by the *Soprintendenza dei Beni Culturali e ambientali di Palermo*, also included a detailed diagnostic plan, the latter funded by the Archdiocese of Palermo. The diagnostic investigation has been aimed at assessing the state of conservation, at studying the construction technique, at identifying the constituent organic and inorganic materials, and the compounds due to previous or ongoing degradation, and past altered restoration works, at detecting the entomological species causing the observed biodeteriogenic attacks.
The results have been obtained through a multi-analytical investigation, including FT-IR spectrometric analysis, to identify degradation products; Py-GC-MS and GC-MS, to characterize adhesive for the application of lapis lazuli and marble thin slabs; p-XRF analyses to recognize metal alloys; Cross-section and SEM-EDS to study metallic corrosion products and to characterize the mortar identified on the internal side of the structure; UV fluorescence imaging to localize protective and pictorial integrations; and assessment of the risk level for the wooden structure through degradation mapping, identification of any fungal species and xylophagous insects.

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Decoding Colour in Historical Violin Varnishes: Recent Analytical and Molecular Insights.

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Over the past fifteen years, investigations of historical violin coatings have advanced through the adoption of non-invasive, multi-analytical workflows. While much effort has been devoted to determining composition and stratigraphy, comparatively fewer studies have focused on the origins of colour and the optical phenomena that arise within oil–resin varnish systems. Portable external reflection FT-IR, portable XRF, synchrotron-enhanced vibrational spectroscopy and deep-ultraviolet photoluminescence imaging are used mainly for *in-situ* characterization of drying oils and natural resins, and to a lesser extent for the identification of pigments and dyes. [1,2] When greater molecular specificity is required, targeted micro-sampling combined with pyrolysis–GC-MS and related chromatographic approaches provide diagnostic fingerprints of oils, resins and colouring agents. [3] Advances in multimodal optical and X-ray imaging, including two-photon excited fluorescence, second harmonic generation microscopy and micro-computed tomography, permit three-dimensional stratigraphic reconstruction, resolving layer thicknesses and ground-coat penetration on the scale of tens of micrometres. [4] Increasingly, chemometric tools are applied to large spectral datasets, improving discrimination among materials and chromophore systems. [5] These techniques have characterized diverse colour sources, such as organic lakes (*e.g.*, madder, cochineal), inorganic pigments and oxidative chromophores. [6] Yet, a full understanding of how chemical changes in oils and resins during thermal treatment and ageing control chromophore formation and optical response is still lacking. A comprehensive, cross-methodological review is thus required. It will be the initial step of a broader doctoral project, which will deal with the explanation of these molecular mechanisms and establish relationships between chemical structure and the optical properties that determine the characteristic appearance of historical violins.

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Multi-Analytical Investigation *in situ* on the Apollo Statue from the National Archaeological Museum of Civitavecchia

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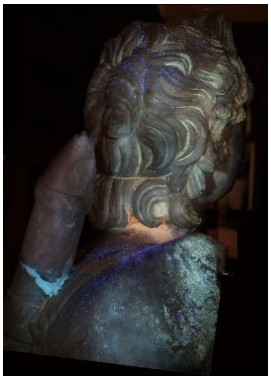
The National Archaeological Museum of Civitavecchia houses an extraordinary statue portraying the god Apollo (2nd century AD), recognized by experts as the most faithful surviving "copy" of the Colossus of Rhodes, one of the most representative works of early Hellenism.

In 2023, before the restoration of the statue, a multi-analytical investigation was carried out in situ. Ultraviolet-induced fluorescence imaging and X-ray fluorescence (XRF) spectroscopy were used to identify traces of surface treatments, restoration materials, and possible pigment residues.

UV-induced fluorescence revealed heterogeneous surface features and highlighted different materials used in a previous restoration, as confirmed by XRF.

The results guided the restoration and demonstrated the effectiveness of combining UV imaging and XRF in identifying past restoration phases and surface alterations in ancient marble sculptures, providing valuable data for conservation planning and historical interpretation.



UV-induced fluorescence on the statue

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"What Is the Colour of Water? Analytical Characterization of the Green Pigment in a Fifteenth-Century *Cosmographia*"

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Il Trattato della sfera, attributed to the Florentine Gregorio "Goro" Dati, is a mid-fifteenth-century manuscript preserved at the **Biblioteca Statale di Lucca (Italy). It is** represents an outstanding example of late medieval cosmographic illumination, where pre-Renaissance astronomy, geography, symbolism, as well as colour, intertwine to depict the known world. One of its most striking features is the depiction of seas and rivers in an unusual green hue, raising a fundamental question: *what colour is water?* Was water purposely depicted in green, or have degradation processes taken place?

A diagnostic investigation was undertaken to identify the pigments used by the illuminator and to clarify the nature of this distinctive colour. The analytical approach combined optical microscopy imaging, X-ray fluorescence (XRF), and Raman spectroscopy to characterize the manuscript's palette. Raman point analyses of the "green ocean" revealed the presence of azurite grains within the green layer. Further chromatographic–mass spectrometric analyses of a representative microsample will be performed to elucidate the pigment composition.

Preliminary findings suggest that the overall palette predominantly consists of cinnabar, lead white, azurite, and mosaic gold. However, the precise composition of the green pigment used to depict water remains unclear, showing a complex mixture of copper-based compounds. Additional analyses are underway to determine whether this hue is the result of an intentional use of different pigments in superimposed layers, or from degradation processes.

This interdisciplinary study sheds light on the material palette and technical choices of the illuminator, while offering broader insights into the perception and representation of water in medieval cartographic imagery.

A Multimodal Diagnostic Approach to a Bone Crucifix Attributed to Giovanni Angelo Montorsoli

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Giovanni Angelo Montorsoli (1507–1563), a distinguished pupil of Michelangelo, spent a decisive decade in Messina (1547–1557), where he profoundly reshaped the city's artistic landscape through major public commissions, including the celebrated Fountain of Orion (1551). His workshop in Messina became a dynamic centre for sculptural production, marked by technical innovation and refined anatomical modelling [1]. This study presents a comprehensive, multi-analytical investigation of a finely carved bone crucifix attributed to Montorsoli [2], aiming to elucidate its material composition, manufacturing techniques, structural integrity, and stylistic attributes through a suite of non-invasive scientific methods. High-resolution optical microscopy (HIROX, up to 5000× magnification) enabled an in-depth examination of surface tooling marks, micro-morphological features, and minute anatomical details, while also supporting the creation of a full 3D digital reconstruction. Complementing this external analysis, clinical computed tomography (CT) provided crucial insight into the internal structure of the object, revealing the joining system, the presence and condition of wooden nails, density variations within the bone, and potential areas of stress or past interventions. These data also helped clarify the nature of the support: the crucifix is carved from a long bone, probably a tibia, in which the morphology of the medullary canal is clearly recognizable and is composed of two carefully shaped sections internally joined with wooden pegs, displaying exceptional anatomical accuracy and technical refinement. Finally, Fourier-Transform Infrared (FTIR) spectroscopy in ATR configuration was employed to characterize the organic matrix and confirm the identification of the bone material, thereby contributing to a broader understanding of its preservation state and any surface treatments. The integration of these imaging and spectroscopic datasets provides a coherent and robust characterization of the crucifix, significantly advancing our understanding of its construction, material behavior, and state of conservation. Moreover, the converging evidence supports, on both technical and stylistic grounds, its plausible attribution to Montorsoli's workshop. This case study further demonstrates the effectiveness of a multi-technique, non-invasive analytical framework for the investigation of complex sculptural artefacts, offering new insights into Renaissance craftsmanship and informing future conservation strategies.

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Multyanalitical investigation on underwater Roman writing tablet

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This research focuses on the study of Roman writing tablets recovered from the seabed of Marausa, found within the remains of a Roman shipwreck. The tablets, preserved in extremely fragmentary condition, display extensive wooden degradation caused by prolonged submersion and aging. High-resolution photography and multispectral imaging were applied to document and analyze their surface features. Infrared reflectography revealed the distribution of an absorptive material across the tablet surfaces, highlighting areas where the wood had thinned due to deterioration and others where faint incised traces, likely corresponding to writing, became discernible. To enhance the visibility of these inscriptions, raking light photography was performed from multiple angles. The resulting shadow mapping enabled the reconstruction of surface micro-reliefs, making engraved characters perceptible despite their absence to the naked eye. A small sample of the absorptive material was removed for chemical characterization through mass spectrometry, which confirmed the presence of pine tar. This multi-analytical approach demonstrates the potential of integrated imaging and compositional analysis to recover otherwise inaccessible textual information from highly degraded underwater archaeological materials.

From left to right – Images in diffuse visible light, raking light, and IR reflectance of tablet MA3029.

This research study is part of the SCIENTIFIC COLLABORATION AGREEMENT implementing the Memorandum of Understanding dated 17.09.2021 (record no. 29/2021 of 23.09.2021, protocol no. 7766), concerning activities related to diagnostic investigations within the PSC project "Patto per il Sud" 2014–2020, titled "Excavation, recovery and restoration of the shipwreck of Contrada Bulala – Gela (CL)". The project is to be carried out in the territory of the Sicilian Region through cooperation between the University of Palermo – STEBICEF Department, and the Soprintendenza del Mare of the Regional Department of Cultural Heritage and Sicilian Identity, for the first year (03/03/2025 – 02/03/2026).

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Py-GC-MS in Archaeometry: Identifying Materials, Degradation, Restorations, and Authenticity Markers in Cultural Heritage

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Analytical pyrolysis coupled with gas chromatography–mass spectrometry (Py-GC-MS) has become a powerful tool in the molecular investigation of organic materials in artworks and archaeological artefacts. Its ability to directly analyse microsamples without chemical pre-treatment allows researchers to access the insoluble and cross-linked fractions of materials such as resins, drying oils, proteins, polysaccharides, and synthetic polymers.

Beyond identifying the original materials employed by artists and artisans, Py-GC-MS provides crucial insights into degradation products, ageing mechanisms, and residues from past restoration campaigns. With appropriate experimental setups, the technique can be combined with accelerated ageing under UV radiation and controlled temperature to reproduce natural degradation processes. These studies are fundamental to understanding how both ancient and modern materials evolve over time, helping conservators to predict their stability and design compatible preservation strategies.

The technique also supports art historians and conservators by revealing anachronistic or incompatible compounds that can indicate later interventions, restorations, or even modern falsifications. Through the characterization of materials ranging from archaeological adhesives, ambers, and lacquers to binders and coatings in paintings, Py-GC-MS contributes to reconstructing artistic practices, authenticating cultural objects, and documenting the transformation of organic matter through time.

Recent instrumental advances, including thermally assisted derivatization and evolved gas analysis (EGA-MS), have expanded its analytical potential, enabling semi-quantitative studies of complex ageing and interaction phenomena. As a minimally invasive, highly sensitive approach, Py-GC-MS bridges chemistry, conservation, and art history—offering a comprehensive tool for the preservation, interpretation, and safeguarding of cultural heritage.

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Beyond the Magic Show: Scientific Insights into a Magic Lantern Slide

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A magic lantern from the scientific collection of the Vescovile Seminary of Cremona, signed by German maker Ernst Plank (founder in 1866 of a company producing toy steam locomotives and magic lanterns), is investigated. The device dates to the last quarter of the 19th century and was used to project images onto a screen, often to narrate stories through sequences of pictures painted on glass supports [1,2]. Understanding the materials used in these objects is crucial for selecting appropriate conservation and restoration strategies. This study focuses on a painted glass slide (Figure 1), analyzed using non-invasive techniques such as multi-spectral imaging (HMI, Profilocolore srl) and spectroscopy (XRF and FTIR), as part of the activities of the restoration laboratory within the degree course in Conservation and Restoration of Cultural Heritage at the Department of Musicology and Cultural Heritage, University of Pavia.
The analyses revealed a Ca- and Si-based glass composition and, in most coloured areas, Arabic gum as binder, suggesting tempera painting. The palette includes mixed pigments: Prussian blue was used for blue areas and contributed to green, brown, and black tones. Green areas also showed yellow ochre, indicating blending. Yellow areas were mainly composed of yellow ochre, while red ones contained a lake pigment. This collaborative study highlights the integration of scientific diagnostic methods with conservation expertise in a shared educational context. Analytical results, produced by researchers, were discussed and interpreted with restorers and students, fostering a dynamic exchange of knowledge across archaeometry, conservation, and restoration.

Figure 1. Detail of the painted glass slide. Left to right: visible light photo, false-color image, UV-induced fluorescence (front and back).

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From the visible to the invisible

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The contribution we present focuses on the results of the photographic investigations conducted on the altarpiece *The Assumption of the Virgin* (1795) by Giuseppe Testa, an unpublished work preserved in the Mother Church of Carini (PA). The painting was examined during the preliminary phase of its restoration, and the diagnostic photographic analyses offered crucial insights into understanding the painter's working process, which led him to define the iconography and compositional structure of the work.

Infrared analysis allowed us to examine the painting across multiple interpretative levels: reflected infrared, false colour, and transmitted light. These techniques enabled an in-depth exploration of the different pictorial layers. The comparative reading of the data revealed numerous adjustments and revisions made during the execution phase, allowing us to reconstruct the process through which Testa arrived at the final composition.

The photographic investigations made it possible to uncover the painter's compositional choices and hesitations, enabling us to retrace his creative path up to the final rendering of the work. Thanks to these analyses, we can effectively make his thought process and decision-making "visible." It became clear that the revisions were not incidental but stemmed from a deliberate artistic intention: Testa sought to strengthen the theological message of the Assumption, engaging the viewer emotionally and transforming the image into a vehicle for the dogma.

Every aspect of the painting—light, colour, composition, and the theatrical gestures of the Apostles—contributes to the pursuit of a narrative perfection that is both visual and symbolic. The painter constructed a true "narrative architecture," in which the gestures of the hands and the postures of the bodies articulate the ascending movement and guide the viewer's gaze along the narrative trajectory.

Finally, in the lower left margin of the painting, Testa signs the work, not merely as its author but as its "inventor," underscoring his central role in the conception of the image.

POSTER

Multi-analytical characterization of archaeological glass from Lipari: integrated optical, structural and spectroscopic approaches

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The study examines a selected group of archaeological glass fragments from the necropolis of Contrada Diana (Lipari, Messina), datable between the second half of the 1st century BC and the 3rd century AD. The fragments are characterized by extensive iridescent patinas, multilayered alteration films and severe surface delamination typical of long-term burial. Beyond the challenges posed by their preservation state, the research was motivated by the need to explore the chemical–physical nature of the vitreous materials and their corrosion layers. Recent studies have shown that long-term weathering can generate highly ordered multilayered structures or even natural photonic crystals in ancient glasses [1], and that corrosion fronts may evolve into complex three-dimensional architectures detectable through micro-tomographic approaches [2]. For this study, multi-analytical approach was adopted: optical microscopy for documenting surface morphology; portable XRF for preliminary elemental characterization; Raman spectroscopy for characterizing molecular signatures of the patinas; SEM imaging for microstructural assessment; XRD for identifying amorphous and secondary phases. This approach provides a comprehensive framework for understanding the alteration mechanisms in ancient glass and supports future comparative studies on technological practices, conservation strategies and environmental drivers of degradation.

We thank European Union (Next-Generation UE), through the MUR-PNRR project SAMOTHRACE—Sicilian Micro and Nano Technology Research and Innovation Center (ECS00000022). The financial support from the European Union–NextGeneration EU PNRR IR0000020 ECCSELLENT through NRRP–M4C2, Inv. 3.1 "Development of ECCSEL-R.I. Italian facilities: user access, services and long-term sustainability" is also gratefully acknowledged.

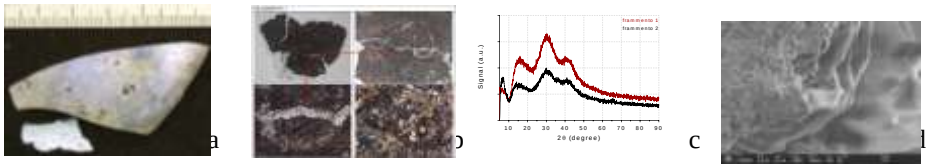

Fig. 1. Fragment of Roman glass with multilayered iridescent patina and surface delamination; b. optical microscopy observation; c. XRD pattern; d. surface morphology and microstructural analysis by SEM.

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POSTER

Multi-analytic and non-invasive diagnostics for the study of two oil paintings from a private collection

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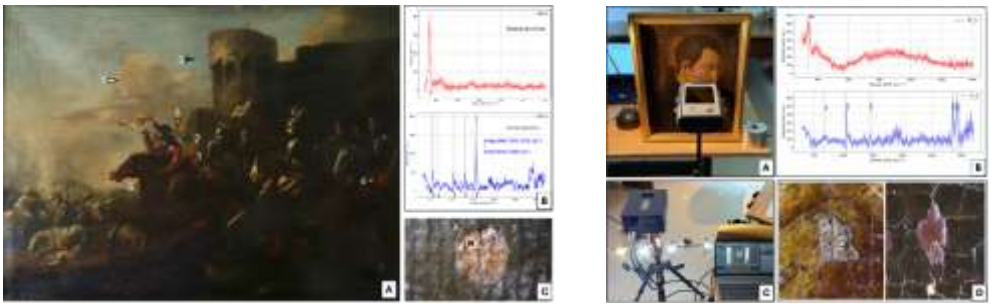
This study presents a multi-analytic investigation of two oil paintings on canvas from the Arenaprimo family collection (Messina), currently preserved by a private owner (fig. 1). The works present unresolved issues of dating, attribution, and conservation, which motivated the application of targeted diagnostic analyses to clarify their material history and current condition.
The first painting depicts a battle scene, tentatively attributed to Jacques Courtois, known as "Il Borgognone" or to artists of his school (17th-19th century). The second one shows a male portrait in profile, rendered with subdued tones and marked surface craquelure indicative of ageing and past interventions. Pigments and binders were characterized using portable Raman (Bruker Bravo) and MicroNIR spectroscopy. Hyperspectral imaging (Nireos HERA VIS–NIR) enabled reflectance analysis and pigment mapping, while IR reflectography with a modified multispectral Fujifilm X-T30 camera was used to find specific subsurface features and restoration traces. Close-up macro photography, portable microscopy (Bresser DST-1028), and 3D laser scanning provided multiscale morphological evidence of altered, retouched, or structurally deformed areas. The results highlight heterogeneous materials, localized degradation, and past interventions, supporting both attribution studies and conservation actions. Further comparative analyses with related works are in progress.
We thank European Union (Next-Generation UE), through the MUR-PNRR project SAMOTHRACE—Sicilian Micro and Nano Technology Research and Innovation Center (ECS00000022).



Painting 1 ***Painting 2***

Fig. 1 – ***Painting 1****: A. Points for Raman and MicroNIR acquisitions; B. Raman spectra; C. Detail of a conservation intervention.* ***Painting 2****: A. Acquisition setup for Raman spectroscopy on the painting using the portable Bruker-Bravo. B. Representative Raman spectra collected in two measurement points: P1 (cinnabar) and P2 (Lead white and binder). C. Hyperspectral imaging. D. Detail of the painted surface showing craquelure, surface damages and retouching.*

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Portable XRF analysis of Islamic ceramic from Southern and Western Iberia

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GC-CIGA [1] is new research project recently granted by the Portuguese Science and Technology Foundation to the University of Évora (Portugal) in collaboration with the School of Arabic Studies (CSIC-Spain) in2024. The overall goal of the project is to explore the diffusion of glaze technology in the western Iberia (Garb al-Andalus during the Islamic period),between the 9th and the 13th centuries, and to understand how Islamic social-cultural expansion, people mobility, exchange of know-how, trades, and raw material access and exploitation might have influenced this process. In this framework, the application of a multidisciplinary approach to the study of Islamic glazed ceramics combining different disciplines (i.e. archaeology, history, archaeometry and ore geology) will permit the acquisition of a complete dataset to decipher different historical dynamics. To this extent, starting from the production and diffusion of first glazed ceramic exemplars, the project GC-CIGA project will evaluate the dissemination patterns between the heartland (Southern Iberia, Cordoba for example) and the periphery, the social reasons behind the adoption of glaze ceramics, the diffusion of know-how during time, the multiplication of ceramic workshops, and the possible differentiation in raw materials procurement for glaze production in the periphery of the al-Andalus if compared to the heartland of Islamic Iberia. These data will be used to evaluate the diffusion of Islamic glazed ceramics in the Garb al-Andalus with a chronological, geographical, technological, and socio-cultural perspective.

The paper will present the results obtained by the first stage of the project that applied portable X-Ray Fluorescence Spectroscopy (pXRF) analysis of the ceramic paste of almost 500 ceramic samples including common and glazed wares recovered in different Spanish (Malaga, Seville, Cordoba, Pechina), ansd Portuguese cities (Lisbon, Coimbra, Santarém, E´vora, Mertola, Silves) with the chronology comprised between the 9th and the 13th century. Analyses were developed using a Bruker Tracer III SD portable spectrometer equipped with a rhodium anode, a SSD detector, and using a Al/Ti filter. Three repetition were recorded for each sample with a setting of 40 kV, 11 μA, and 60 s acquisition time. Overall the suitability of the method was confirmed, and preliminary data analysis suggested that different ceramic wares were produced in different places, while other were imported, suggesting technological from the heartland to the periphery of the al-Andalus.

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Forged Through Time: Archeometric Insights from 21 Bronze Coins Unearthed at Santa Maria Veterana (Triggiano, Southern Italy)

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This study examines 21 bronze coins found in the mediaeval church of the archaeological area of St. Maria Veterana in Triggiano (Apulia, Italy). Spanning various historical periods, the collection offers crucial evidence for understanding the site's occupation history and its role within local and broader systems. The research is part of the Trivianum project, led by the Pasquale Battista Foundation, which aims to study and valorize the site and, more generally, the cultural heritage of Triggiano.

A multi-analytical approach was adopted, integrating digital microscopy, Laser-Induced Breakdown Spectroscopy (LIBS), and portable X-Ray Fluorescence (pXRF) [1,2]. These complementary techniques allow for the identification of manufacturing features and corrosion patterns. The micro-destructive approach necessary to overcome surface alterations and a non-destructive analysis by pXRF enable the assessment of alloy composition. The combined results suggested new data on the technological variability of the coins, traced potential production sources, and highlighted circulation dynamics across different chronological phases of the church.

The outcomes contribute new evidence on the economic and social meaning of St. Maria Veterana church, revealing its sustained connections with regional and extra-regional spheres. By contextualizing the coins within the site's archaeological narrative, this research enhances the understanding of Triggiano's historical landscape and demonstrates the crucial role of archaeometric methods in cultural heritage valorization.

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A strange structure

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A strange structure. As far as we know when using only physical chemical techniques, dry constructions are difficult to date. Analyses are based on in-context analysis or comparisons with similar works. In the light of this only historical memory may be useful. This is the case here. Of course an archaeological excavation might be the solution. We are talking about a building and there is no historical record over the last century. The artefact is inside the "Lagoni di Mercurago" nature park on the west bank of the River Ticino near the end of Lake Maggiore. The historical richness of the area is very important. From the Celtic period to the unification of Italy. The structure is a cylinder about 3.20 meters high with a diameter of 5.20 meters. There is an 18 meters ramp of 2 meters width. What it was? The main hypotheses are here expounded and discussed.

Shooting range for artillery in the 19th to early 20th Centuries

Observation post for watching movement on the lake

Mediaeval sects

Building suited to the production of charcoal

Celtic building (tumulus?)

As correctly upheld by Archaeological Superintendence only an internal and external excavation could provide certain indication. The construction is in a private area and a research is going on at present into the property records to see whether the various transfers of ownership mention the construction. The different hypothesis are here discussed and evaluated as well as the criteria to obtain the most probable interpretation.

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Radiocarbon Dating of Persian Carpets: Assessing Contamination and Pretreatment Efficiency

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Radiocarbon dating was applied to three knotted carpets of Persian and Anatolian origin, stylistically attributed to the 15th–17th centuries and belonging to the Moshe Tabibnia Gallery (Milan). The pieces - an Ushak medallion carpet (15th century), a Kirman throne carpet (16th century), and a Palmette and cloud-band carpet from Central Persia (17th century) - presented no documented conservation history or records of past cleaning treatments, raising questions about potential contamination.
Initial analyses were performed on warp fragments subjected to the standard acid–base–acid (ABA) pretreatment. The obtained 14C ages showed inconsistency with stylistic and historical expectations, indicating the presence of exogenous carbon likely introduced during later interventions or through environmental exposure. To mitigate this, a preliminary solvent-based extraction was implemented prior to ABA, following approaches tested on contaminated textiles and parchments [1]. This additional step markedly improved agreement between 14C results and art-historical attributions, demonstrating the relevance of tailored pretreatment strategies for complex organic artifacts.
A further critical aspect concerns the chronological period of knotting of the samples, with one carpet likely falling within the so-called Stradivarius gap [2], a calibration plateau that reduces temporal resolution for late 17th–early 18th century materials. This emphasizes the need for combined stylistic, historical, and analytical evaluation when interpreting radiocarbon data from artworks of this period.
The study confirms that solvent-assisted pretreatments can effectively enhance the reliability of 14C dating in highly processed fibers and underscores the importance of collaborative approaches between scientific laboratories and conservation institutions.

Work carried out in collaboration with the Moshe Tabibnia Gallery, Milan.

Sampling from one of the studied carpets

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Analysis of patinas on ceramic vessels from Vado Ligure (Late Bronze age)

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Following the identification of numerous sites along the Tyrrhenian central coast interpreted as centres dedicated to salt production through *briquetage*, characterised by the presence of thousands of fragments of coarse-ware pottery (the so-called “reddish jars”), it was decided to review the archaeological material coming from old excavations carried out along the western Ligurian coast [1]. Among these contexts, the site of Vado Ligure - Piazza San Giovanni Battista (SV) stands out as it yielded a substantial amount of fragments of “reddish jars”. The examined sample consists of approximately 70 kg of material that survived a selection carried out during the excavation.
A few specimens with encrustations in a particular colour range were isolated. These patinas, which are absent from contemporary Ligurian ceramic production, were analysed using protocols already developed for a similar case study [2, 3]. Piro to sampling, the encrustations were classified, on an autoptic basis, into four types according to colour, thickness, and grain size. Different types of patinas can be present on the same sherd in a micro-stratigraphic sequence.
Type 4, black, can clearly be attributed to carbonised organic material; to better understand their nature, some GC analysis was performed. The interpretation of the other types (1, white; 2, beige; 3, red to purple) is more problematic: to assess their composition, we performed FT-IR, XRD and SEM-EDS analysis. The Type 2 patinas, mainly composed of clay minerals, are attributable to the burial soil; the Type 3 encrustations, richer in iron oxides, perhaps can be correlated with the “salt-colours” recorded on pottery from several salt-making sites.
The archaeometric approach proposed in this study may help to define the functional purpose of those sites that have yielded abundant ceramic fragments, but for which only limited stratigraphic data are available.

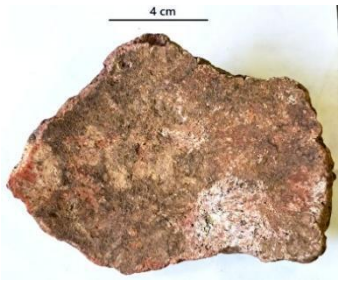

Fig. A sequence of beige, red and white incrustations on the inner surface of a pottery sherd from Vado.

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Assessing the preservation of medieval waterlogged wood: the case of the Łekno wooden road (Poland)

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The discovery of a medieval wooden road in Łekno (Greater Poland Voivodeship) in 2023, awarded as the Polish Most Important Archaeological Discovery of the Year, has drawn significant interdisciplinary attention. The 15th-century structure was uncovered during preparatory works for a new road, which posed a serious threat to the archaeological remains. The need for protection led to a joint intervention involving archaeologists, conservators, and civil engineers, aiming to safeguard the site through preventive conservation and scientific documentation. This initiative serves as a case study for balancing heritage preservation with infrastructure development.

This study presents the investigation and chemical characterization of wooden samples excavated from the medieval road and an adjacent butcher's shop in Łekno. The road structure comprises four distinct stratigraphic layers containing recurring botanical taxa, allowing comparison of degradation patterns among construction levels and wood species.

To evaluate the preservation state and chemical alterations, a multi-analytical approach was applied, combining analytical pyrolysis (Py-GC–MS, EGA–MS) and infrared spectroscopy (FTIR).

These complementary techniques provided an overview of the chemical composition and degree of degradation of the excavated wood.

Preliminary observations indicate variable preservation across the stratigraphy, with lower layers generally better conserved than upper ones. The results underscore the interaction between burial environment, wood composition, and degradation mechanisms. Overall, the study enhances understanding of waterlogged medieval wood preservation and provides a framework for in situ conservation of archaeological wooden structures threatened by modern development.

Figure 1: Excavated wooden butcher shop in Łekno (Poland)

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[1] J.J. Lucejko, et. al., 2015, Applied Spectroscopy Reviews, https://doi.org/10.1080/05704928.2015.1046181 medieval wood preservation and provides a framework

Chert Selection and Hominin Behaviour at Loreto (Early Middle Pleistocene, Basilicata, Italy): Insights from Petrographic and Morphometric Analyses

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This study examines the lithic assemblage from Layer A of the Early Middle Pleistocene site of Loreto (Venosa Basin, Southern Italy) through a combined petrographic and size-based approach [1, 2]. A total of 415 artifacts were analyzed to investigate raw material supply strategies, technological choices, and hominin behavior. The assemblage is dominated by chert, mainly silicified calcarenites and calcilutites, while limestone artifacts represent a minor component. Comparisons with geological samples from the nearby site of Notarchirico [3] and with reference materials from the SiLiBA lithotheque indicate that most cherts derive from formations of the Southern Apennines and were likely collected from secondary fluvial deposits outside the site. Artifact size and the scarcity of early-stage knapping products suggest the introduction of already-selected and partially reduced materials. Technological patterns, including intensive core exploitation, frequent retouching, and tool rejuvenation, point to deliberate resource management and anticipation of needs. These strategies reflect broader behavioral changes occurring during the Early Middle Pleistocene, marked by increased mobility, foresight, and more structured lithic reduction sequences. Overall, the Loreto assemblage highlights a selective approach to raw material use and a technological organization indicative of evolving cognitive and adaptive capacities.

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Amber Ornaments from the Lakeside Sites of Piediluco. Archaeometric Analysis and Archaeological Considerations

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Over the past decade, surveys and excavations by Sapienza University of Rome in the Piediluco basin have led to the discovery of several amber ornaments.
A truncated, flattened pyramidal bead comes from Paduli, but it is not indicative of a specific period: beads of this type are documented from the Late Bronze Age onward.
A spherical button and a multi-holed plate come from Ara Marina (Podere Colle D'Agnano). The first can be dated to the end of the Late Bronze Age. The latter can be interpreted as a spacer bead, a type of artefact that became widespread in the Late Bronze Age and the Iron Age.
The analysis of evolved gases in conjunction with mass spectrometry (EGA-MS) and Fourier-transform infrared spectroscopy (FT-IR) has shed light on the chemical composition of the amber samples and allowed us to trace their geographic origin. The signals recorded in the mass spectrum can indeed be attributed to diterpenoid compounds and bicyclic pyrolysis products of a poly-labdanoid structured polymeric material such as succinates, gedanites, and gedano-succinates, all characteristic ambers from the Baltic region.
These results fit well within the context of the archaeometric studies of Italian prehistoric amber. It has indeed been highlighted that during the Final Bronze Age, there was an almost exclusive use of amber sourced from the Baltic region in Italy. During this period, there is a significant demographic development of the lakeside sites in the Piediluco basin. In this context, other exotic artifacts should be noted, such as natron glass materials and ivory from Paduli, as well as the Nuragic-Cypriot keimelia found in the bronze deposits of the Piediluco area. Such data confirm the importance of the Apennine lake basin in the network of macroregional exchanges and may allow us to identify the actors involved in the management of trade and goods: these were likely the warrior elites, as suggested by the long spears and short swords found in the bronze deposits of Piediluco.

Machine and deep learning for classification of XRF spectra of orichalcum ingots

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In recent years, machine learning and deep learning approaches have significantly enhanced the ability to extract meaningful information from spectroscopic data, expanding the analytical potential of spectroscopic techniques themselves. In the field of cultural heritage analysis, non-invasive and portable methods are widely employed, yet they often exhibit lower sensitivity. Among these, X-ray fluorescence (XRF) spectroscopy remains one of the most commonly used techniques, although it is generally semi-quantitative and less sensitive to trace elements. This study focuses on the spectral datasets acquired from orichalcum ingots recovered in Gela, previously analyzed using ICP-OES and ICP-MS for accurate chemical characterization [1]. The aims were twofold: first, to evaluate the feasibility of achieving comparable classification of the ingots using XRF data processed through machine learning-based methods; second, to explore deep learning approaches for the homogenization of XRF datasets, with the goal of making measurements obtained under different instrumental configurations directly comparable. Both the ingots in their intact form and powder samples obtained from micro-sampling were analyzed under varying instrumental settings to determine the most effective conditions for classification performance. A dedicated data-cleaning workflow was developed, and several clustering-based classification strategies were tested. The results demonstrate that the groups obtained from the XRF data processing closely align with those identified from ICP analyses, while preliminary deep learning experiments show promising potential for reducing dataset variability. Overall, the study highlights how machine learning and deep learning can enhance the interpretative power of portable spectroscopic techniques in archaeometric investigations.

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Exploring medieval subsistence strategies in a Mediterranean mining district: The case study of Montieri castle (Tuscany, Italy)

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Medieval castles played a central role in European history, and extensive research has focused on the development of fortified sites in the Mediterranean area between the 10th and 14th centuries. Yet studies specifically addressing how these castles controlled mining resources—and more broadly how mining communities engaged with their environments—remain scarce, especially in Italy. This contribution aims to address this gap by presenting a multidisciplinary investigation focused on Montieri, a key medieval mining castle located in the Colline Metallifere district (Tuscany). Between the late 12th and 13th centuries, Montieri experienced an economic peak due to the intensive exploitation of its rich silver, copper, and lead veins, consequently making the control of its mines a point of contention between the Bishop of Volterra and the Commune of Siena. To reconstruct the lifeways of Montieri's inhabitants during this peak, we combined archaeological, bioarchaeological, and palaeopathological data, focusing on the individuals buried in the funerary area of the rural rectory of the Canonica di San Niccolò. This cemetery likely originated around a privileged burial, possibly that of a hermitic figure, which served as a focal point for numerous subsequent burials. We performed stable carbon (□13C) and nitrogen (□15N) isotope analysis on 56 human and 15 faunal skeletal remains to assess dietary habits and subsistence practices of Montieri's population. Furthermore, radiocarbon dating was performed on 5 human skeletal samples to refine a chronological framework for the use of the funerary area. The isotopic data revealed distinct dietary patterns across Montieri population, possibly suggesting differential access to resources among social strata, while radiocarbon dating places the cemetery's use mainly within Montieri's economic peak [1]. Our findings provided insights on the interplay between subsistence strategies and socio-economic dynamics of medieval Montieri, underscoring the informative potential of organic remains in addressing knowledge gaps about past societies.

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The organic content of potteries found in Pani Loriga (Sardinia) based on multistrategic approaches

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The characterization of organic materials plays a crucial role in archaeological research, deepening our understanding of various aspects of ancient daily life, from the relationships between food, society, and culture to craft specialization, knowledge exchange, and economic development [1].
This contribution presents an overview of the analysis of organic residues in pottery from the Pani Loriga site (Sardinia, Italy), using a combination of different sample pretreatments along with chromatographic and mass-spectrometric techniques (GC–MS and HPLC–MS/MS).
Figure 1 illustrates the workflow of the study. First, samples are clustered according to shape and hypothesized function (1, 2). They then are analysed to characterise of lipids, sugars, and small organic compounds (3) to refine clustering based on molecular profiles. Selected samples are subjected to untargeted proteomics (4, 5) to identify protein content, followed by targeted proteomics (6) for an in-depth characterization of vessel contents.
GC–MS revealed chemical fingerprints dominated by lipids, sugars, and resin derivatives, while proteomic analyses provided molecular and biological specificity, even when protein recovery was minimal.

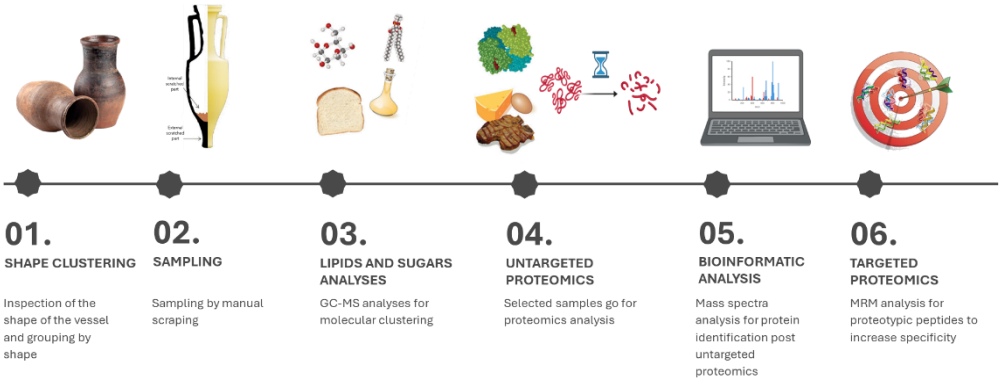

Figure 1. Analysis worklow

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Living Matter and Instability: Material Choices in Arte Povera Between Poetics, Transformation Over Time, and Conservation

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The aim of this research is to investigate how the intrinsic instability of the materials employed by Arte Povera artists affects both the visual perception of the work and, above all, the related conservation strategies. Arte Povera introduces a new paradigm based on organic, humble, or industrial materials, conceived as active agents in the definition of the artwork. The work is "alive" because the matter is alive: it transforms, shifts, decays, and responds to the temporal condition of organic materials, which - like human existence - are characterized by finitude and transience. The intrinsic instability of these materials is an intentional component of the poetics, often challenging traditional principles of conservation and the very idea of musealization.

This contribution examines three case studies to illustrate the complexity of this relationship: the installations of Jannis Kounellis, where coal, wool, lead, and iron create material systems in constant transformation; the works of Giuseppe Penone, in which bark, leaves, and vegetal skin make transformation an integral part of the artwork's meaning; and Michelangelo Pistoletto's Venus of the Rags, which raises questions about the replacement of perishable materials without betraying the conceptual identity of the work. The comparative analysis of these case studies shows how each material choice demands specific conservation responses.

Through a historical-artistic approach integrated with knowledge of the physical characteristics of the materials and with contemporary art criticism, this contribution highlights the tensions between artistic intention, natural degradation, and museum practices. It emphasizes how the interaction between art criticism and materials science has become essential to preserving not only the physical form but also the conceptual and processual dimension of Arte Povera.

Emerging from this analysis is the need for flexible conservation models capable of respecting the evolving nature of the artwork without compromising its critical legibility, the artist's thought, intention, and poetics.

Visually, the poster will present an iconic layout that gives space to images of the works, technical analysis of the materials, and the principal "countermeasures" and concrete conservation actions that may be adopted to preserve and mitigate the deterioration of such artworks.

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Monitoring the Conservation of the Bronze Statue of Apollo through Electrochemical Diagnostics

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This study examines the conservation monitoring of the bronze statue Apollo SCB_2022_Z153, which was discovered in 2022 at the sanctuary of San Casciano dei Bagni in Tuscany, alongside many other bronze artefacts [1-2]. After the excavation, the statue received stabilisation treatments to facilitate safe handling and to prevent further degradation.
Electrochemical diagnostics, including linear sweep voltammetry (LSV), were performed at three stages: before treatment, immediately after applying a corrosion inhibitor and protective coating, and after display in three temporary exhibitions [3-4]. SEM-EDS analyses complemented the study, providing alloy characterisation and identifying elements influencing corrosion processes.
The results revealed varied behaviours across different surface zones of the statue, indicating different responses to treatment and environmental exposure. These findings highlight the significance of conducting zone-specific, multi-stage electrochemical monitoring to assess treatment effectiveness and inform adaptive conservation strategies. The study illustrates how incorporating non-destructive electrochemical diagnostics into conservation practices can aid in the long-term preservation of archaeological bronzes.

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Microclimatic conditions in the King's Apartment, Royal Palace of Turin

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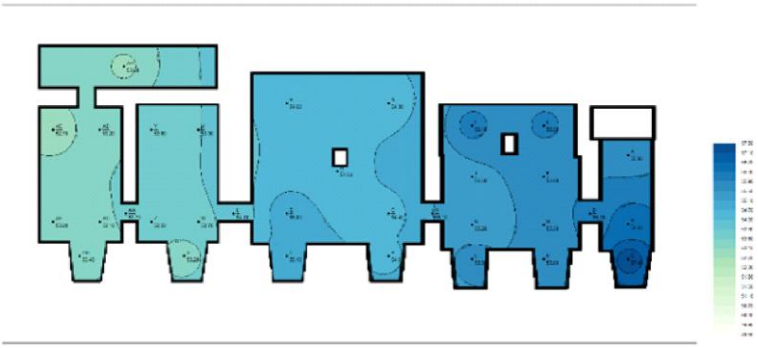
The conservation of works of art depends strictly on the microclimatic conditions of the surrounding environment [1]. This study, carried out in the framework of CHANGES project, concerns the analysis of the microclimatic conditions in the King's Apartment in the Royal Palace of Turin (Italy). The King's Apartment is located on the ground floor of the Royal Palace and consists of five interconnected rooms overlooking the royal square.
A monitoring campaign was performed from May 2024 to October 2025 with the aim to individuate the microclimatic conditions of the Apartment. During the first 13 months the Apartment was closed to the public, allowing the study of unperturbed microclimatic conditions, while in the following months the Apartment was included in the visitor route, making it possible to assess the microclimatic disturbances caused by the presence of visitors.
The measurement activity was organized in two main phases: a) intensive manual measures on six specific days in different seasons during the entire measurement period, and b) the continuous monitoring in twenty-one sites located in the rooms at different heights, and two sites outside the Apartment. The measured quantities were temperature and relative humidity while specific humidity, dew point temperature and dew point spread were computed.
The analysis consisted in the study of the temporal series, the computation of the delay time between indoor and outdoor conditions and the application of standards and statistical indexes [2]. The main results permitted to detect the historical climate, and to individuate some critical conditions in the Apartment. The study gave information about the microclimatic conditions of the Apartment and, moreover, provided some general suggestions and improvements? about the application of the standards and the use of the statistical indexes.



Relative humidity measured with manual thermo-hygrometers at 1 m from the ground on January 21st, 2025

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The restoration of the mosaic floor of room 29 in the Roman Villa of Palazzi di Casignana (RC) – Calabria Italy

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This study is focused on the conservative treatment of the room number 29 of the Roman Villa in Palazzi di Casignana (Reggio Calabria - Italy) [1]. It is a small thermal room with an irregular octagonal plan, decorated with musive and parietal surfaces severely compromised by three-dimensional gaps and deficiencies. The intervention is aimed at restoring readability and fruitional dignity to the room, through methodologies and experimental materials for the conservation of the original artifact and the enhancement of the entire site.
The project was based on a multidisciplinary approach, the restoration was preceded by the historical conservative analysis and the diagnostic investigations for the characterization of raw materials and alterations. The operational phases included cleaning, consolidation and reintegration, with particular attention to the compatibility and recognizability of the interventions. A key element was the experimentation of a three-dimensional, reversible and distinct prosthetic methodology, capable of mediating between material authenticity and perceptual needs. The integration was carried out with innovative synthetic materials, distinguishable by infrared surveys, in synergy with non-invasive thermographic analyses, essential to map the areas of intervention and to guarantee the future traceability of the additions. The project, also supported by interactive digital tools, aimed to overcome traditional approaches, proposing a replicable operating model. Experience has demonstrated the value of the synergy between historical techniques and scientific innovation, offering ideas for the improvement of supplementary strategies applicable to the conservation of the archaeological mosaic heritage.

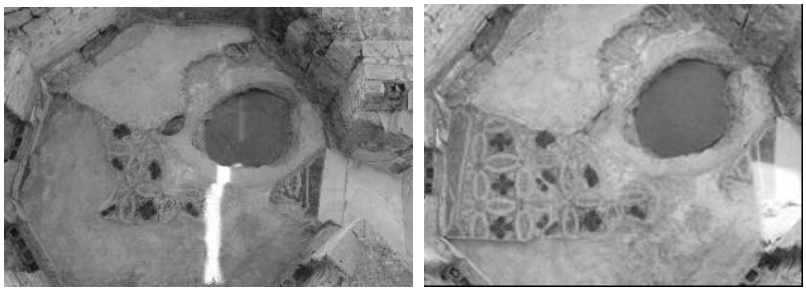

Figure. General photo of the room 29 before (left) and after (right) the restoration intervention.

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Essential-oil-loaded mesoporous silica nanoparticles as long-lasting biocidal nanocarrier system for stone conservation: case studies from the Fountain of the Cloister of S. Maria di Gesù (Palermo) and the Castle of Sagunto (Valencia)

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Biodeteriogens are among the main factors responsible for the deterioration of stone materials exposed to outdoor environments. In this study, a long-lasting biocidal nanocarrier system was developed combining mesoporous silica nanoparticles [1] and the essential oil mixture BioTersus® [2,3]. The system was characterised using FT-IR, Raman, SEM and TEM analyses, which confirmed the loading and stability of the system. The performance of the system over time was evaluated in situ [4] at two case-study sites: the monumental fountain in the cloister of Santa Maria di Gesù (Palermo) [5] and Sagunto Castle (Valencia) [6]. Both sites are affected by extensive biological patinas consisting of layers of biofilm that almost completely cover the stone surfaces. The main biodeteriogens responsible for this deterioration are mosses, crustose lichens, algae, bacteria and ruderal plants, which contribute to colour alteration, surface disintegration, encrustation and the formation of stains on the substrate. The operating protocol included: (1) Identification of biodeteriogens; (2) application of biocide compresses with paper pulp and BioTersus® for 72 hours; (3) Removal of compresses and new sampling to assess the reduction in microbial load; (4) Application of the MSN-based controlled release system; (5) Control swabs for biological analysis after a period of time. At the Fountain of the Cloister of Santa Maria di Gesù (Palermo), microbiological monitoring was carried out six months after treatment, and a further assessment is planned one year after the application of the controlled-release system. At the Sagunto Castle site (Valencia), the first control campaign was conducted one month after treatment, and a subsequent monitoring phase is planned after three months. After six months, ATP tests and culture analyses performed at the Fountain of the Cloister of Santa Maria di Gesù (Palermo) showed a significant reduction in microbial vitality compared to the reference area where the controlled-release system was not applied. At the Sagunto Castle site (Valencia), preliminary results from microbiological analyses and colorimetric measurements confirmed the trends observed at the Sicilian site, highlighting a comparable decrease in biological activity and only minimal color variations on the treated stone surfaces. These results, obtained through targeted monitoring, demonstrate that controlled-release mesoporous systems loaded with essential oils can effectively limit biological recolonisation while reducing both treatment frequency thanks to their preventive action and the toxicity of interventions during restoration activities, benefiting both the environment and the operator. Supported by reproducible protocols, this approach offers a sustainable and innovative alternative to conventional broad-spectrum biocides.

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A sustainable approach for the removal of undesired organic layers on marble artifacts

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Cleaning represents one of the most delicate interventions in restoration. As an irreversible operation, it requires careful and thorough theoretical and methodological consideration. Choosing the right cleaning system is a crucial step that contributes to the success and durability of the restoration itself. In recent years, increasing attention to environmental and operators' health has guided research toward alternative solutions to the often harsh or polluting traditional chemical-physical methods, promoting the application of biotechnologies in the conservation of Cultural Heritage [1]. This research has explored the potential of biotechnological protocols es as eco-sustainable technique for the selective removal of organic layers from stone surfaces [2,3]. To evaluate the efficacy and efficiency of the enzymatic method compared to traditional approaches, cleaning assays were carried out on naturally and artificially aged marble samples; preliminarly a layer of proteic (casein, egg, animal glue) or lipidic (linseed oil, beeswax) substances was stratified on selected marble samples. Morphological and chromatic variations were evaluated using a portable digital microscope, a Wood's lamp, and a colorimeter—non-invasive diagnostic techniques used to detect the surface appearance of the samples during experimentation.

The comparative analysis of the cleaning methods performed onto specimen surface (marble specimens *ad hoc* assembled) highlighted that enzymatic treatments showed better performance in the removal linseed oil, animal glue, and casein layers. Concerning the artwork (Amato family crest) as showed in Figure 1, an evident removal of the undesired layer has been achieved by enzymatic method (B) comparing it to the pre-treatment condition (A), in full compliance with conservative restoration protocols. In these case, microscopy and ultraviolet light observations, and colorimetric analysis revealed a high capacity in removing undesired layers. In conclusion, the results indicate that biocleaning represents an intervention methodology able of combining technical efficacy, environmental and operator safety, full compatible with stone artifacts surface, offering a solution consistent with the ethical and scientific principles that guide contemporary conservation. The results of this case-study may contribute to the understanding and assessment of applied biotechnologies in conservation and could serve as a basis for further research aimed at optimizing the enzymatic formula and defining standard operating protocols. From a broader perspective, the integration of biocleaning into restoration interventions could foster a methodological evolution toward more sustainable practices, consolidating the role of applied science in Cultural Heritage preservation.

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Preliminary insights from a multidisciplinary assessment of marine–coastal impacts on ancient watchtowers in Calabria (Southern Italy)

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Calabria's coastal watchtowers, built during the Angevin period, became key defensive elements under the Viceroyalty of Charles V. As part of a wider network that included castles and fortified settlements, these structures originally 130 towers were counted roughly, and around 70 still stand today, although many are currently underused and in a condition of abandonment.

This research uses modern technologies to systematically document and evaluate the coastal watchtowers, offering new approaches for their conservation and sustainable enhancement. A digital map created with QGIS includes data on the towers' condition, restoration history, and construction materials. These information layers are integrated with thematic environmental datasets, such as coastal erosion, lithology, landslide and seismic susceptibility, to better understand the external factors influencing the towers structures.

The study focuses on five specific watchtowers: Saracena (Palmi, RC), Ruggero (Bagnara, RC), Cavallaro (Marina di Gioiosa Ionica, RC), La Rocchetta (Briatico, VV), and Marrana (Ricadi, VV). Field observations allowed to identify the building materials, such as local stones, mortars, and bricks, as well as several degradation patterns, including salt efflorescence, alveolisation, flos tectorii, and biological deposits [2]. To investigate the mineralogical and petrographic characteristics, a range of analytical techniques will be applied, such as Polarized Optical Microscopy (POM), X-Ray Diffraction (XRD), X-Ray Fluorescence (XRF), Ion Chromatography (IC), and Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy (SEM-EDS).

The ultimate purpose is to integrate traditional surveys with advanced technologies, such as drone-based photogrammetry, to create accurate 3D models of the watchtowers. H-BIM and 3D GIS will provide multi-scale analysis, continuous condition monitoring, and assessment of environmental risks [3]. Augmented Reality tools will further enhance public engagement and emphasize the cultural value of these structures. Overall, the integrated approach supports their preservation and offers a replicable model for sustainable heritage valorization, improving both protection and public awareness. This study is part of a PhD project within TEACH (TEchnology Applied to Cultural Heritage) PhD course – University of Calabria (Italy). The project is co-funded by the CNR institutes: CNR-ICAR, CNR-ITM, CNR-IIT.

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Environment-induced risk assessment as a preventive conservation strategy for an effective long-term management of safety cinematographic archives

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The primary challenge faced by cinematographic archives preserving cellulose acetate motion picture films is managing the onset and evolution of Vinegar Syndrome, a chemical deterioration process where acetyl groups undergo hydrolysis, releasing acetic acid and triggering an autocatalytic chain reaction. While standards and guidelines recommend maintaining low temperature and relative humidity in storage to slow this process and ensure long-term film stability, in archives the adoption of these measures is often constrained due to limited resources. A review of the scientific literature highlighted that tools developed for the monitoring of Vinegar Syndrome have limitations. Archivists currently rely on visual inspection and on Acid Detection (AD) Strips, which change colour based on acetic acid concentration in the air within the film can. The evaluation is based on comparing the strip colour with a discrete scale affecting accurateness. Studies were conducted to objectively evaluate the Vinegar Syndrome progress by calculating the Degree of Substitution (DS), that represents the number of acetyl groups per anhydro-glucose unit in cellulose acetate polymer. As hydrolytic deacetylation advances, the DS tends to decrease. This research aims to identify an objective approach to monitor Vinegar Syndrome in cellulose acetate film archives. A relationship between microclimate storage conditions, acetic acid emission and film DS was investigated. The *Cineteca Nazionale - Centro Sperimentale di Cinematografia* (Italian National Film Archive) and the *Arquivo Nacional das Imagens em Movimento - Cinemateca Portuguesa* (Portuguese National Film Archive) were selected as case studies. Thermo-hygrometric observations collected at the two film archives over many years were used to characterize microclimate. Existing dose-response relationships and damage functions were used to estimate chemical and mechanical climate-induced risks. Then, an empirical relationship between colorimetric measurements of AD Strips and acetic acid concentrations was estimated through laboratory tests to provide an objective film hierarchical classification in real case studies. Finally, DS was derived using portable Attenuated Total Reflection (ATR) Fourier-Transform Infrared (FT-IR) spectroscopy to assess the chemical state of film support. A database including film metadata, ATR FT-IR spectra, strip measures, and additional information was structured to be used as baseline dataset to conduct analysis. It was found that no consistent relationship between acetic acid emission and DS value was identified, complicating DS's reliability as a standalone marker of Vinegar Syndrome evolution. In conclusion, this research advances current Vinegar Syndrome monitoring procedures for archival cellulose acetate film collections, aiming to improve early-warning detection. The approach was successfully tested in two cinematographic archives and applied by film archivists and conservators.

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A 3D-based Web Platform as an innovative tool to support the Management and Visualization of Multi-source Diagnostic Data

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In the field of cultural heritage conservation, handling diagnostic data is a complex task which requires the integration of heterogeneous data collected through multiple analytical/surveying techniques and processed with tools that are frequently not interoperable. For this reason, in recent years, research has placed growing emphasis on developing digital tools and platforms that enable shared and integrated data management.

Within the CHANGES (Cultural Heritage Active Innovation for Next-Generation Sustainable Society) project, a methodological workflow was developed to address these issues through a unified digital approach combining data acquisition, structuring, visualization, and sharing. The core innovation of the workflow lies in a 3D-based web platform, developed by exploiting open source technologies. This system is built on the 3DHOP framework, can support high-resolution 3D models (such as those obtained from digital metric acquisition systems, like laser scanning and multi-image photogrammetry), and is capable of integrating and visualizing diverse datasets within a unified 3D digital environment. It allows users to access diagnostic data through annotated 3D models, enabling the exploration of specific areas of interest and the retrieval of associated analytical information. This approach strengthens spatial understanding of material properties and degradation patterns while fostering multidisciplinary collaboration by linking physical evidence to analytical results and historical context. The platform relies on a JSON-driven data management system, providing a flexible and extensible framework for both data entry and visualization. Each diagnostic analysis is associated with a JSON template, defined in close collaboration with experts in the specific analysis domains, and able to synthetize the relevant information characterizing each analysis. This template consists of modular fields (text, images, tables, downloadable resources) which can be customized to adapt the data structure to the peculiar needs of the different analysis. Beyond visualization, the platform supports multiple sharing options, which, together with the remote access possibilities, enable collaborative analysis among users from different disciplines. Its modular architecture also allows for potential integration with external repositories, making the platform a centralized hub for cultural heritage scientific data. The fusion of multi-source and multi-sensor data within the platform exemplifies a data-driven approach to heritage diagnostics. By combining analytical results with spatial data in an interactive 3D environment, it enhances understanding of degradation mechanisms and supports the development of preventive conservation strategies.

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3D survey and machine learning for the archaeometric reading of a section of Siena's walls near Porta Camollia

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The walls of Siena [1] represent an ideal open-air laboratory for the study of urban fortification methods; in particular, the section close to Porta Camollia, located in the northern sector of the city walls, preserves in its structure a complex stratification of masonry techniques which document the evolution of the city's defences over the centuries. The aim of the research is to analyse the probable development and the various modifications that occurred over the centuries to this specific stretch of wall, with particular attention to the reconstruction in the 12th century, through a three-dimensional survey carried out with LiDAR technology integrated with SfM techniques [2]. The obtained point cloud was processed through geometric segmentation algorithms and supervised machine learning [3], to automatically distinguish the lithological and dimensional classes of the ashlars and bricks: the processing allowed to obtain quantitative data on the number, distribution and area occupied by the different construction elements, providing an objective basis that can help the stratigraphic and technological reading of the wall palimpsest. The results were integrated into a GIS environment for thematic mapping of the materials, with particular attention to the hypothetical restitution of the configuration obtained through the virtual reconstruction of the original layout. This work proposes a multidisciplinary methodological approach for the archaeometric interpretation of medieval fortifications, demonstrating how the combination of 3D surveying, automated data analysis, and interpretative modelling can quantitatively and verifiably restore the construction and functional memory of Siena's walls.

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The chemometric approach to understand technology of ancient ceramics: The matt painted pottery case study from the North Lucanian district (Basilicata region)

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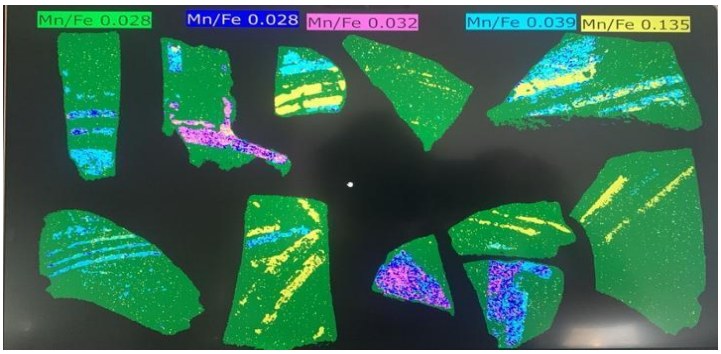
The chemometric approach combined with spectroscopic investigations (μ-XRF and μ-Raman) on ceramic fragments from the western sector of the Northern Lucanian district represent an innovative and non-destructive methodology for reconstructing the technological strategies adopted by ancient artisans in the production of the Matt-Painted ceramic (6th-5th century BC). The technological aspects were obtained from the spectroscopic imaging of red and black pigments. Using the *autophase* routine included in Bruker's M4 Tornado software, based on the PCA method, it was possible to identify compositional variations within areas characterized by the same pigment and thus determine its intraspecific variability for a robust comparison with similar decorations found on matt-painted ceramic fragments from different archaeological sites. Averaged spectra were generated for the identified *autophases* within the black and red/red-brown pigments, and the Fe/Mn enrichment factors for the ratio were estimated, considering the ceramic body. The factor was considered an index of the quality of the *black manganese technique* [1] used to produce the black pigment and was used to reconstruct the technological strategies adopted by ancient artisans in the production of this typical ceramic. The Baragiano site was set as the entry point through which the technique spread throughout the northern Lucanian district and identified as the production center where advanced technological know-how spread throughout the entire district, and probably throughout the entire Basilicata region. Besides, it is believed that the adoption of the *black manganese technique* could be related to the local availability of deposits rich in manganese. In this context, the local availability of black volcanic sand from Mount Vulture (PZ), rich in minerals as spessartine (a Mn-rich garnet), titaniferous magnetite, and hematite, may have encouraged the adoption of this technique.



Autophase identification and Fe/Mn ratio evaluation

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The Digital Supply Chain of Cultural Heritage: From Knowledge to Valorization

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This project explores a comprehensive training program designed to develop experts capable of managing the entire cultural heritage supply chain-spanning from data acquisition and conservation strategies to valorization procedures and public engagement.
Through a multidisciplinary approach combining scientific, technological, and humanistic disciplines, the program aims to equip participants with the methodological and technological skills needed to operate as “Cultural Heritage Specialists in a Digital Era”.
Key topics include the acquisition of diagnostic and archaeometric data, the creation of digital twins as unified knowledge models, and the utilization of innovative dissemination channels such as Extended Reality, storytelling, and gamification, including the results of diagnostic research aimed to disseminate the scientific culture to the general public through the valorization of culture heritage. The training emphasizes the development of competencies for applying advanced digital tools to cultural assets, enhancing their preservation, accessibility, and economic impact at local, regional and national levels. Ultimately, the program encourages professionals to innovate heritage management practices, foster community engagement, and promote sustainable cultural tourism through a holistic and technologically advanced approach to cultural heritage in the digital age.
The training program is developed within the framework of the “Patti Territoriali dell’Alta Formazione per le Imprese” initiative, funded by the Ministry of University and Research (MUR) through the DPCM of 30/07/2025, CUP H22C2400012000 (art. 14 bis del D.L. 152/2021 e ss.mm.ii.).

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The PITCH project: a laboratory-based phase-contrast X-ray imaging system for the analysis of Cultural Heritage materials

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Over the past few decades, X-ray imaging has evolved into a high-resolution, non-destructive, and non-invasive technique for radiography and tomography, effectively addressing the challenge of visualising internal structures across several applications. With the development of highly coherent synchrotron sources, non-traditional contrast methods have further expanded X-ray imaging capabilities [1]. Conventional absorption contrast is well suited for medium-density samples or for distinguishing materials with different attenuation properties, but it proves inadequate for low-Z or organic materials, which typically yield very weak contrast. Phase-Contrast (PC) X-ray imaging offers an effective solution for detecting subtle structural variations in weakly absorbing samples. This technique relies on observing interference patterns arising from spatial variations in the real part of the refractive index induced by the sample [2]. PC imaging is increasingly relevant in medical diagnostics, materials science, and Cultural Heritage (CH), where it enables high-quality visualisation of microstructural features, including those of low-density, heterogeneous, and organic components. A coherent X-ray beam is essential for phase-sensitive imaging, and such approaches are already established at synchrotron facilities [3]. Among PC techniques, X-ray Grating Interferometry (GI) provides differential phase and dark-field images alongside conventional absorption, enabling laboratory-based implementations. This opens new perspectives for CH research, from conservation to archaeology and anthropology, especially in the study of fragile or organic materials.
The PITCH project (funded under PRIN2022) aims to design, develop, and characterise a laboratory GI-PC imaging system based on a liquid-anode X-ray source, and to explore advanced acquisition strategies and reconstruction algorithms. The setup will be optimised for the analysis of a broad range of CH materials, including low-Z and organic specimens, to improve their characterisation and deepen the understanding of their specific degradation and conservation issues.

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MuLaX: A Visual and Interpretative Platform for Managing Variability in Cultural Heritage Diagnostics

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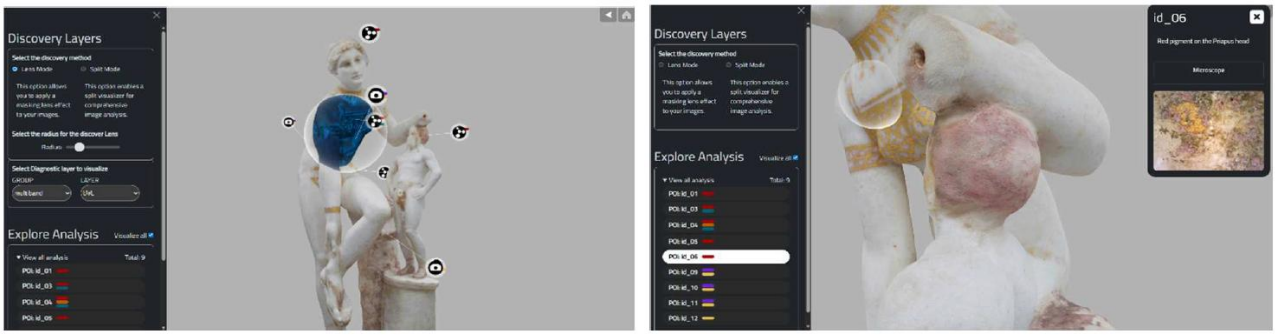
The increasing complexity of diagnostic processes in cultural heritage demands tools capable of integrating heterogeneous data sources, transparently representing reconstructive steps, and supporting informed decision-making, particularly in conservation contexts. MuLaX [1] emerges as a visual and interpretative platform designed to manage and communicate the variability inherent in colour reconstruction and, more broadly, in the layered interpretation of diagnostic data.

The tool, developed within the Horizon Europe project PERCEIVE (GA:101061157) [2] aims at fostering transparent evaluation processes, make uncertainties explicit, and stimulate professional curiosity toward alternative hypotheses. Based on the framework ATON [3] MuLaX allows conservators to explore multi-layered diagnostic data by visualizing and comparing results from diverse sources, such as multiband imaging, point analyses, and, in future updates, experimental mock-ups. Each layer can be examined independently, highlighting consistencies, gaps, and potential conflicts in interpretation.

This approach makes explicit the stratified nature of the data, enabling users to assess the reliability of each evidence layer, evaluate alternative hypotheses, and understand how different sources contribute to reconstructive decisions. By integrating these layers within a unified visual environment, MuLaX transforms complex diagnostic outputs into an interactive framework for analysis, documentation, and communication.



MuLaX interface, with lens discovery layers and spot analyses visualised

MuLaX thus sets itself as a valuable tool for addressing the complexity of colour and material reconstruction, transforming variability into a resource, and making diagnostics not merely an analytical phase but a comprehensive system supporting both decision-making and technical communication.

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Perceive Isis' Colours: Diagnostics and Communication of Ancient Polychromy

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Developed within the European Horizon project PERCEIVE (GA:101061157), the exhibition Perceive Isis' Colours addresses the challenge of communicating ancient polychromy to a nonspecialist audience without oversimplifying its analytical complexity. The aim is to highlight, through a rigorously scientific approach, the central role of non-invasive diagnostics in the study of ancient colour and to make the process linking material traces to reconstructive hypotheses both visible and understandable.

The first section, Echoes of Loss, exposes visitors to the fragility of chromatic remains and to the need for their preservation, stimulating curiosity [1] by reproducing the workflow of polychromy research applied to the statue of the Venus Anadyomene (inv. 6298), today preserved at the National Archaeological Museum of Naples. The visit begins with an immersive video introducing the theme of lost polychromy, followed by the ColourLab, conceived as an open research laboratory. ere, historical, iconographic, and archaeological sources are presented alongside the diagnostic methods employed during the scientific campaigns, such as digital microscopy, XRF and FORS spectroscopy, and multiband imaging (UVL, VIL). A 3D replica of the statue allows visitors to simulate diagnostic operations through integrated sensors that display real analytical data, illustrating how pigment traces are detected and identified. This is followed by the reconstructive phase, combining the textures extracted from marble mock-ups, recreated according to analytical results and historical sources, with a digital workflow based on 3D modelling and semi-automatic segmentation. This section demonstrates that colour reconstruction is not a merely imitative act but a critical process that integrates scientific evidence, material testing, and visual cues, that can only suggest a multiple set of hypothetical reconstructions. The path culminates in Echoes of Colours, an interactive projection-mapping installation that guides visitors through the gradual transition from fragmentary data to reconstructive hypotheses. Three objects of increasing weight, metaphorically symbolize the user's increasing responsibility in heritage object care [2]. The second section of the exhibition, The Gifts of Isis, grounded in the framework of authenticity [3], introduces a moment of re-contextualisation: through immersive environments and multisensory interaction, visitors explore how ancient colour may have been perceived within its original ritual and architectural setting, in a multiplayer experience that manages to depict life in the Temple of Isis, the original location of the Venus Anadyomene studied in Echoes of Loss.

Perceive Isis' Colours proposes a model of scientific communication in archaeometry, in which diagnostic complexity, reconstructive interpretation, and experiential re-contextualisation converge into a coherent narrative. By combining rigorous analytical transparency with immersive and multisensory engagement, the exhibition transforms colour reconstruction from a purely researchdriven outcome into a catalyst for awareness, participation, and cultural understanding.

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Hyperspectral UV-Induced Fluorescence Imaging and Multivariate Statistical Analysis for Assessing Cleaning Processes: Insights from the Ottonian Frescoes of the Collegiate Church of Sts. Pietro and Orso in Aosta

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Recent advances in hyperspectral imaging are establishing it as an increasingly adopted technology for investigating painting materials and surface treatments [1].

In this study, the hyperspectral camera was used to capture the spatial and spectral information of painted surfaces illuminated with UV (365 nm) light. This fluorescence-mode hyperspectral imaging (FL-HSI) allowed us to monitor the presence of different conservation treatments and to test two cleaning approaches on the exceptional 11th-C. cycle of Ottonian frescoes preserved in the large space between the roof and the inner ceiling of the Collegiate Church of Saints Pietro and Orso in Aosta.

The research pursued two primary objectives: (1) to assess the capability of FL-HSI to map and differentiate the heterogeneous distribution of organic conservation materials on the paintings, and (2) to develop a reproducible method for evaluating the effectiveness of cleaning interventions. A preliminary examination of laboratory mock-ups enabled identification of the UV-stimulated emission range (400–600 nm) and the fluorescence behaviour of common conservation materials such as beeswax, PVA, and Paraloid. Subsequent in situ acquisitions on two frescoes revealed highly irregular distributions of UV-induced fluorescence, confirming the presence of multiple/overlapped surface treatments. Since single-band intensity mapping was insufficient to discriminate among material classes, the workflow incorporated multivariate treatment of spectral images applied to 13-band fluorescence cubes. This approach enabled the segmentation of distinct emission sources and provided a consistent basis for pre-/post-cleaning comparison.

A dedicated metric of relative spectral change was developed to quantify the effects of the two different cleaning approaches. The evaluation accounted for both reductions and increases in fluorescence, while excluding artefact clusters linked to detector saturation. Pairwise comparisons across points of interest showed that both cleaning methods produced measurable spectral modifications in all tested areas. Moreover, in three of the four tested zones, one of the treatments produced markedly stronger modifications of the fluorescence signal.

Overall, the study demonstrates that FL-HSI combined with multivariate analysis of the data is a robust and reproducible method for documenting organic coatings and supports informed decision-making in the selection of effective cleaning treatments.

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