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CENTRO RICERCHE ENRICO FERMI

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O1 - Investigation into the use of Ulva lactuca L. extract as a new material for the green protection of archaeological metal finds

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Bio-corrosion of metal materials found in archaeological excavations prevents us from knowing the history of our cultural heritage and transmitting it, together with the finds, to future generations [1].
Reducing and/or eliminating bacterial biofilm on the metal surface, responsible for corrosion, using extracts of plant species is a way to pursue [2]. In this research, the extract of a green alga Ulva lactuca L., was tested. The target chosen for in vitro tests was Enterococcus faecalis, a Gram+ acterium, known for forming resistant biofilms on different surfaces [3]. The algae, collected in the summer season near the Dubrovnik coast, were subjected to extraction and chemical characterization. Both minimum inhibitory concentration (MIC) tests and Time-kill tests were performed to determine the antimicrobial activity. Then, two tests were conducted using copper metal samples. In test 1, the surface of the samples was previously treated with the extract and subsequently contaminated by the bacterium (preventive action). In test 2, the metal surface was contaminated by the bacterium and the extract was applied to the biofilm (curative action) [2]. In both cases, the outcome was positive: the extract strongly inhibited (90%) the development of bacterial colonies (test 1) and also strongly deteriorated the biofilm (test 2). The research objective seems to have been achieved: Ulva lactuca L extract showed an effect in both the preventive and curative treatment. This study adds an important piece regarding the cleaning and remediation in a green way, contributing to the protection of the health of the environment and of all of us.

Keywords Ulva lactuca L., Biorestoration, Green conservation, metallic materials, Cultural heritage.

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[2] Özdemir, Ç., Emanuele, L., Kotlar, M., Brailo Šćepanović, M., Scrano, L., and Bufo, SA. (2025). The Potential of Aloe vera and Opuntia ficus-indica Extracts as Biobased Agents for the Conservation of Cultural Heritage Metals. Metabolites, 15(6), 386., https://doi.org/10.3390/metabo15060386
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O2 - Ultrasonic Tomography and Augmented Reality for the Conservation and Dissemination of Cultural Heritage: The Case of the Diana the Huntress Statue

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The marble statue of Diana the Huntress (Salinas Museum, Palermo) exhibits aesthetic issues (microflora-induced darkening) and structural vulnerabilities related to the bust load supported solely by the central tree trunk. To identify internal anomalies such as fractures, voids, or degraded zones, ultrasonic tomography (UST) a non-invasive geophysical technique critical for cultural heritage diagnostics was performed.

The UST survey employed 357 measurement points and 3 transducers (1 transmitter, 2 receivers), acquiring 708 signals using the multichannel Boviar TDSA system (55 kHz frequency). Elastic wave velocity data (first-arrival times) were integrated with a 3D-scanned surface model, generating a volumetric reconstruction of the marble's mechanical properties.

Tomographic results were implemented in an Augmented Reality (AR) application via the Meta Quest 3 headset. The AR environment enables visualization of:

- Critical areas (low ultrasonic velocity, <1500 m/s) overlaid on the physical statue;
- Interactive 3D isosurfaces highlighting fractures and weak zones;
- Informational layers detailing the artwork's history and diagnostic techniques.

The average detected velocity (3000 m/s) confirms marble integrity, but critical areas (velocity <1500 m/s) were identified in the trunk, right leg, and base, indicating potential mechanical degradation. The AR representation optimized museum engagement, transforming technical data into immersive educational pathways.

The study demonstrates the efficacy of ultrasonic surveys for preventive conservation of cultural assets, while 3D augmented reality proves a valuable tool for scientific outreach by making complex geophysical data accessible to the public. The integration of UST and AR paves the way for advancements in heritage conservation, restoration, and education.

O3 - Sustainable Lime Mortars with Rice Husk Ash for the Conservation of Cultural Heritage

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Agricultural activities generate billions of tons of waste annually, with crop residues—especially from corn, wheat, and rice—representing the largest portion [1]. Adopting circular economy approaches allows the transformation of these wastes into valuable resources, reducing environmental impact and enhancing sustainability [2]. This research investigates the use of rice husk ash (RHA) in lime-based mortars for the conservation of cultural heritage. Rice husk, a by-product of the milling process, is rich in organic compounds and silica. Once burned, it yields ash that can contain up to 90% amorphous silica, making it a potential pozzolanic material. The research was structured in three phases: (1) production and characterization of RHA obtained at various combustion temperatures (500°C, 600°C, 700°C, and 800°C) through XRD, XRF, LOI, SEM- EDS, and BET analysis; (2) assessment of pozzolanic reactivity in lime pastes by means of TGA, FT- IR, and SEM-EDS investigations, with focus on portlandite consumption and C–S–H formation; (3) formulation and testing of mortars using the most reactive ashes with hydrated lime and siliceous sand, to assess their mechanical and physical performance through a complete set of analysis and tests. Results showed that RHA remains amorphous up to 700°C, with silica content above 87%. Among the samples, RHA produced at 500°C exhibited the highest pozzolanic activity, with complete $Ca(OH)_2$ consumption in 14 days. Therefore, 500°C was identified as the optimal burning temperature. Mortars incorporating 500°C RHA demonstrated promising mechanical and physical properties, comparable to those made with NHL 3.5, suggesting their suitability for restoration applications.

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[2] Muscat A. et al. (2021) - Principles, drivers and opportunities of a circular bioeconomy. Nat. Food, 2(8), 561–566.

O4 - Mediterranean technologies in a Grecian colony: The case of core-formed glass vessels in Olbia Pontica

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This study presents the first comprehensive compositional and technological analysis of core-formed glass vessels from the ancient Greek colony of Olbia Pontica (northern Black Sea region). The assemblage, predominantly blue in colour and typologically classified as amphoriskoi, oinochoai, and alabastra, is curated in two Ukrainian collections: the National Historical and Archaeological Reserve "Olbia" and the Institute of Archaeology in Kyiv. These artefacts are typologically attributed to the Mediterranean Groups (MGs), which have been associated with distinct production centres across the ancient Mediterranean. Although previous studies have attempted to trace the origin of these workshops and their raw materials, no compositional data has so far been available for core-formed glass from archaeological contexts along the Ukrainian Black Sea coast. This study addresses that gap by presenting the first analytical evidence from this region.

The application of a multi-instrumental archaeometric protocol, comprising Optical Microscopy, SEM-EDS, and FORS, enabled the detailed investigation of both material composition and technological aspect. The glasses are soda-lime-silica type, obtained through the fusion of natron and quartz-rich sands. Structural features, such as the bubbles distribution and the intentional addition of colouring and opacifying agents, provide valuable clues about production methods.

Elemental profiling, interpreted through Lü et al.[1]'s classification system, reveals that the majority of samples fall within Type II, indicating a Syro-Palestinian provenance for the silica source, while a minority cluster within Type III, consistent with Egyptian sands enriched in iron. Additionally, FORS analysis confirmed the presence of various chromophores, with cobalt ions (Co^{2+}) as the dominant colorant in most samples.

[1] Q, Lü, et al, 2021 Scientific Reports, 11

O5 - Integrated Strategies for the Conservation and Valorization of Archaeological Materials from the Sanctuary of Rossano di Vaglio (4th c. BCE – 1st c. CE, Basilicata, Italy)

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Preventive conservation, through environmental control, plays a key role in mitigating heritage deterioration and complements direct interventions. In archaeological museums where contextual information is often fragmented, a combined preventive and remedial approach is essential. This PhD project, promoted by Scuola Superiore Meridionale, investigates innovative strategies for conservation, digital management, and valorization of archaeological materials from the site of Rossano di Vaglio [1]. The first phase focused on a comprehensive survey and typological classification of the collection, leading to a multi-layered digital database where each storage unit was labeled with a QR code and georeferenced in a GIS platform, enabling integration with excavation data [2]. A central aspect of the project involved archaeometric analyses, performed at the University of Applied Sciences and Arts of Southern Switzerland. Various artifact types (bronze, plasters, stone, ceramics) were examined to detect composition and degradation products, helping to assess reactions to environmental factors and define conservation strategies. The second phase focused on microclimatic monitoring of the storage environment, with the collected data analyzed to evaluate chemical, physical, and biological risks such as soluble salt crystallization, fungal growth, and xylophagous insect activity linked to variations in temperature and relative humidity [3]. The results support the formulation of integrated management protocols that reconceptualize museum storage as a functional environment for conservation and research, enhancing environmental stability, supporting restoration workflows, and promoting digital and physical valorization of collections [4].

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[2] Istituto Centrale per la Digitalizzazione del Patrimonio Culturale. (2023). Linee guida per i processi di digitalizzazione. Piano Nazionale di Digitalizzazione del Patrimonio Culturale. Ministero della Cultura.

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O6 - The Mummified Head of the Child from Celano: A Case Study of 17th-Century Natural Mummification

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In the 1980s, the mummified head of a child in an exceptional state of preservation was discovered in Celano, Abruzzo. This finding initiated an in-depth anthropological investigation based on macroscopic, microscopic, and radiographic analyses to determine the individual's anthropological and paleopathological profile. The examinations were conducted at the Anthropology Section of the "Gabriele D'Annunzio" University of Chieti-Pescara. Anthropological analyses indicated that the mummification occurred naturally. Furthermore, the analyses confirmed the archaeological nature of the artifact, revealing that the head likely belonged to a male child approximately one year old. The age estimation was corroborated by the degree of cranial ossification, dental mineralization, and anthropometric measurements. Paleopathological examination identified signs of perimortem trauma and other indicative blunt force injuries, which were also documented radiographically. Radiographic analyses further revealed the extraordinary preservation of soft tissues and traces of internal organs. Recently, a few hair samples in perfect condition were collected and subjected to radiocarbon dating to accurately date the artifact and provide a more precise temporal context. The dating placed the artifact in the 17th century (1620–1688 CE). Dermatological analyses are currently underway on some fungal formations found on the skin of the head. The artifact is preserved and displayed at the University Museum of Chieti, in compliance with the ethical standards of the International Council of Museums (ICOM). This case study highlights the scientific value of naturally mummified remains, especially in reconstructing lifestyles and pathological conditions of a specific historical period in Abruzzo. It also serves as a foundation for future interdisciplinary research in anthropology and paleopathology.

O7 - The secrets of Etruscans craftsmanship: chemical characterization of the adhesives used for metal stripes decorations on ceramics

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Even if the Etruscan artistic styles are not as widely recognized as Greek and Roman art, they represent an artistic identity able to converse with other contemporary civilizations. A prime example, even if rarely studied, are ceramics decorated with the so called “lamelle”. This decorative technique involved applying metal-like thin stripes on the ceramic surface of the vessel, likely using an adhesive.
This study aims to clarify the handcraft technology behind these artefacts and, at the same time, by studying samples from different archaeological sites in Tuscany, observe if the production method was consistent across the region or if local practices emerged. For that aim, a set of around twenty samples were analysed through analytical pyrolysis coupled with gas chromatography/mass spectrometry (Py-GC/MS), as it already proved to be an extremely powerful analytical tool that allows us to obtain chemical information whit a low amount of sample required, only a few micrograms [1, 2]. The results obtained highlight that the materials mainly used as adhesives were birch bark tar and Pinaceae resinous material, allowing us to draw the distribution of this material and technology during this period.

[1] I. Bertelli et al., “What doesn’t meet the eye: molecular insights into adhesive technologies of Neolithic harvesting tools from Central-North Italy,” Archaeol Anthropol Sci, vol. 17, no. 8, Aug. 2025, doi: 10.1007/s12520-025-02280-w.

I. Degano, F. Modugno, I. Bonaduce, E. Ribechini, and M. P. Colombini, “Recent advances in analytical pyrolysis to investigate organic materials in heritage science,” Angewandte Chemie International Edition, vol. 57, no. 25, pp. 7313–7323, 2018.

O8 - Teeth Don’t Lie: Diet, Mobility, and Life Histories at the Sumerian site of Abu Tbeirah through a multi-isotopic approach

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This paper presents the results of a multi-isotopic study on human and animal mobility, diet, and environmental interaction at Abu Tbeirah (Dhi Qar, Southern Iraq). The site is a third-millennium BCE city in southern Mesopotamia, near ancient Ur. By applying a multi-proxy isotopic approach, which includes the use of zinc isotopes ($\delta^{66}Zn$) for the first time in this region, we explore patterns of resource use and landscape engagement in a region characterised by a dynamic ecotonal environment that includes marshland, steppe, and desert areas.

When collagen preservation is poor, such as in this case, the “non-traditional” zinc isotopes offer an unprecedented way to investigate trophic levels and dietary patterns. $\delta^{66}Zn$ coupled with carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope values of human and animal apatite in tooth enamel suggest a diet based primarily on C3 terrestrial resources, with limited evidence of freshwater resource consumption, despite the site's proximity to ancient waterways and the Persian Gulf coast.

Strontium ($^{87}Sr/^{86}Sr$, also measured on tooth enamel) and oxygen isotopes reveal variability among individuals. This possibly reflects short- to mid-range movement within the Mesopotamian alluvial plain, perhaps associated with labour mobility linked to major centres such as Ur. Additionally, differences in $\delta^{18}O$ values may also reflect paleoenvironmental changes during the late third millennium BCE, including increased evaporation.

These findings highlight the value of combining traditional and non-traditional isotope systems in archaeological contexts where collagen is absent. In this specific case, we were able to contribute directly to the debates surrounding mobility, environmental stress, and subsistence in early urban southern Mesopotamia.

O9 - When Art breathes: nanostructured plasmonic gas sensors for museum environmental monitoring

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Over the past few decades, preventive conservation of Cultural Heritage has increasingly focused on the degradation risks posed by volatile organic compounds (VOCs).[1] These molecules, released by both ageing artefacts and materials used in museum display cases, catalyze harmful chemical reactions, accelerating the deterioration of art. Gas sensing has thus emerged as a fundamental tool for environmental monitoring in museums.

To address the limitations of traditional sensing technologies, we used silver nanoparticles (AgNPs) as both the sensing element and transducer in optical gas sensors. Due to their localized surface plasmon resonance (LSPR), AgNPs exhibit excellent catalytic and sensing capabilities towards airborne pollutants, particularly when functionalized with specific receptors.[2] Among LSPR-based optical techniques, Surface Enhanced Raman Scattering (SERS) stands out as the most promising, offering chemical identification at trace level. In parallel, chemiresistors – a class of chemical sensors based on changes in electrical resistance upon analyte interaction – have also been widely employed for VOC detection in several fields, including environmental monitoring.[3] Although relying on distinct sensing principles, both technologies exploit nanometric interparticle gaps to operate effectively: for the formation of plasmonic hot-spots (in SERS) or to ensure efficient charge transport (in chemiresistors).

Efforts over the years have focused on developing sustainable and flexible platforms by integrating AgNPs into polymer brush matrices.[4] These hybrid sensing materials offer enhanced detection capabilities through tailored surface interactions, improved dispersion and stabilization of NPs.

This work presents the development and testing of an innovative hybrid substrate made of AgNPs embedded in a crosslinked polymer brush matrix of 2-hydroxyethyl methacrylate and triethylene glycol dimethacrylate (PHEMA-TREDGMA). Preliminary tests investigate its applicability as sensing layer for VOC and gas detection relevant to Cultural Heritage conservation. Notably, SERS data demonstrated great potential for the detection of acetic acid at low concentrations. Both SERS and chemoresistive sensing techniques were used to explore the PHEMA-TREDGMA hybrid potential for the possible development of future integrated strategies for museum air quality monitoring.

[1] Vergelli, Env. Poll., 2025
[2] Li, ACS Sens., 2020
[3] Khatib, ACS Nano, 2022
[4] Costantini, Chem. Eur. J., 2010

O10 - Atomic Oxygen as an Innovative Non-Contact Cleaning Method for Works of art

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The MOXY (Green Atmospheric Plasma-Generated Monoatomic Oxygen Technology for Restoration of the Works of Art) project is an international research initiative focused on developing a new, sustainable, and non-contact cleaning method for cultural heritage conservation. The project is inspired by the pioneering work of NASA scientists Bruce Banks and Sharon Miller, who in the late 1990s explored the potential of atomic oxygen (AO)—originally studied for spacecraft materials in the astronautical field—for applications in art conservation. One of their most successful results was the removal of lipstick marks from Andy Warhol's Bathtub [1]. Despite its potential, the technique was not further explored for over twenty years.
In 2022, the MOXY project advanced this idea by developing a system capable of generating and directing a controlled flow of monoatomic oxygen onto artwork surfaces. AO is highly reactive and can oxidize carbon-based contaminants, converting them into volatile products such as CO_2 and water [2]. Since it does not require physical contact or chemical solvents, it is ideal for cleaning fragile and sensitive materials. MOXY brings together universities, museums, and research centers—including Ghent, Amsterdam, Antwerp, and Pisa—and a multidisciplinary team of scientists and conservators. Current research focuses on the removal of soot, found on fire-damaged artifacts or on objects exposed to candle-lit environments, or from environmental pollution. The substrates under investigation include oil and acrylic paints, plastics, paper, and silk. Silk, in particular, presents significant conservation challenges due to its extreme fragility and tendency to degrade over time. Previous research has investigated how different dyes can influence its degradation pathways, providing a useful basis for further study. Building on this knowledge, ongoing research is now focused on evaluating the effects of atomic oxygen treatment on silk, both in the short term and after ageing. Preliminary results suggest that AO has no detectable effect right after the treatment but it may influence its long-term stability. Furthermore, in such a new and emerging field, comparison with existing cleaning methods is essential. For this purpose, parallel studies are being conducted on samples cleaned using laser technology—a well-established, non-contact method already employed in conservation practice [3]. This interdisciplinary approach aims to create a safe, effective, and adaptable cleaning tool for the protection of cultural heritage.

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[2] T. Markevicius, V. den B. K. J. et al, "Nascent oxygen innovation in art conservation: Cold atmospheric pressure plasma-generated monoatomic oxygen for non-contact cleaning of works of art," valencia: The 20th ICOM-CC Triennial Conference, 2023.

N. Brockmann, A. Sicken, and J. Krüger, "Effects of laser cleaning on the condition of different silk model samples using varying wavelengths and pulse durations," Herit Sci, vol. 12, no. 1, Dec. 2024, doi: 10.1186/s40494-024-01152-1.

O11 - Environment-induced risk assessment as a preventive conservation strategy for an effective 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 (VS), 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 scientific literature highlighted that tools developed for the monitoring of VS 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 film cans. The evaluation is based on comparing the strip colour with a discrete scale affecting accurateness. Studies were conducted to objectively evaluate the VS 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 VS in cellulose acetate film archives. A relationship between microclimate storage conditions, acetic acid emission and film DS was investigated. Thermo-hygrometric observations collected at two National Film Archives (Portugal and Italy) over many years were used to characterize storage microclimate. Existing dose-response 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 Fourier-Transform Infrared spectroscopy to assess the chemical state of film supports. 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 VS evolution. In conclusion, this research advances current VS monitoring procedures for archival cellulose acetate film collections, aiming to improve early-warning detection. The approach was successfully tested in film archives and applied by film archivists and conservators.

O12 - Stereomicroscopic assessment of CNC distribution for canvas paintings conservation

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The study of eco-sustainable, non-toxic nanostructured biopolymers for cultural heritage conservation has gained increasing attention in recent years [1]. Crystalline nanocellulose (CNC) is particularly noteworthy for its properties, including high mechanical strength and biocompatibility, which make it a promising alternative to conventional products [2]. This contribution, part of ongoing doctoral research, focuses on evaluating CNC for the consolidation of the support of canvas paintings. Among CNC's properties is its film-forming tendency [3,4], which represents both a potential risk and a benefit as it may cause localized stress but also facilitate future removability, aligning with the principle of reversibility pursued in conservation treatments. Stereomicroscopic observations were conducted on mock-ups reproducing the stratigraphy of historical oil paintings, before and after the application of various CNC formulations. The study evaluates CNC distribution patterns, surface morphology, and potential mechanical implications, and was combined with colorimetric measurements to assess visual impact. 3D surface models and Digital Elevation Models (DEMs) were generated through image stacking to analyse CNC's ability to reconnect degraded fibres and yarns.
Tests on previously lined canvases were also conducted; such conditions are representative of real-world scenarios where aged adhesives introduce variables that are often underestimated in the testing of new materials. These tests represent a rare contribution to the evaluation of CNC on complex substrates — an area still largely unexplored in the literature, yet crucial to define its real applicability limits. In conclusion, this study contributes to the characterization of innovative materials for conservation. Although data processing is still ongoing, preliminary results already reveal meaningful differences and similarities related to CNC formulation and type, offering insights for its informed use in conservation.

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O13 - Climate-induced Risk Assessment of Library Collections within Dora I WWII Bunker in Trondheim, Norway

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Short- and long-term variability in indoor microclimate conditions within conservation spaces (museums, archives, libraries) can increase the risk of cultural material deterioration. Active microclimate control systems are often used to stabilize air temperature (T) and relative humidity (RH), while massive buildings with thick walls might naturally buffer outdoor fluctuations due to high thermal inertia. Historic reinforced concrete structures like WWII bunkers, typically windowless, offer stable microclimates and protect sensitive materials from photodegradation. Often labeled as “dark heritage” WWII bunkers were long perceived only as symbols of war and occupation, leading to neglect. However, the difficulty of demolition gradually raised interest in their reuse, highlighting their social, historical, and economic value. This study presents a comprehensive microclimate analysis of a unique case: the NTNU (Norwegian University of Science and Technology) library for cellulose-based materials, housed in the Dora I WWII bunker in Trondheim, Norway (63.43° N, 10.40° E). The archive spans 3700 m² and holds approx. 5200 m³ of collections, including ancient books, journals, newspapers, and photographs. Dora I, a massive German submarine fortification with 3.5 m-thick walls, covers 16,000 m². Ten thermo-hygrometers compliant with European standards were installed, ensuring representative indoor monitoring across two floors. Time series of air temperature (T) and relative humidity (RH), continuous since 2018, are significantly longer than most studies. Statistical climatology approaches decomposed T-RH data into short-term and long-term variability, providing insights into indoor dynamics. A comprehensive risk assessment, based on dose-response functions, evaluated biological and chemical threats using both raw and filtered microclimate data. Results highlight the building’s exceptional buffering, with peak summer temperatures occurring indoors 2–2.5 months later than outdoors. No biological risk from mould or humidity-dependent insects was identified, while temperature-driven insect activity remains a concern from June to December. Chemical degradation risks persist from July to October, with slight variations linked to human activities evident in raw data. The study underscores the benefits of massive structures in preserving vulnerable materials and a useful methodological approach in combining raw and filtered microclimate data to assess climate-induced conservation risks.

O14 - Multi-analytical approach for in-depth study of hypogeal mural-painting

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This PhD project focuses on a multi-analytical study of pre-Roman mural paintings with a step-by-step diagnostic approach. Particular attention is given to Etruscan wall painting, an area of study in which scientific literature remains fragmented regarding the characterization of materials and the reconstruction of the artistic technique. Etruscan painting, primarily in the funeral context, developed from the 7th to the 3rd century BC. A comprehensive MOLAB E-RIHS analytical campaign was carried out in situ on eight painted tombs in the Monterozzi Necropolis in Tarquinia (Italy) yielding over 190 non-invasive measurements using XRF, Raman, ER-FTIR and Reflectance Vis-NIR spectroscopy. This non-invasive phase was followed by micro-sampling to analyze the paint stratigraphy using micro-VIL, Raman spectroscopy and FT-IR imaging. This study aimed to characterize painting techniques, including pigments and binders. The results confirmed the use of hematite and cinnabar for red hues, malachite for green and Egyptian blue for blue areas. Notably, azurite was detected, localized in light blue spots, for the first time in one tomb. All data were integrated into a dedicated database developed as part of this PhD project. Given the challenge of identifying Egyptian blue in situ when mixed with other pigments, experimental samples were prepared to compare the VIL responses and spectroscopic analyses at varying concentrations of Egyptian blue mixed with other pigments. Ongoing work includes the use of synchrotron-based micro-X-ray diffraction (μXRD) and micro-X-ray fluorescence (μXRF) at beamlines ID13 and ID21 of the ESRF to investigate degradation processes and clarify Etruscan manufacturing techniques. This research is conducted at ISPC-CNR, in collaboration with the National Archaeological Park of Cerveteri and Tarquinia (PACT), starting with another Ph.D., and then expanded with the collaboration of the company PEGASO s.r.l. in the ARANTH Project. Following the initial phase and results of the Molab and VIL campaigns, research was extended through an agreement between the CNR-ISPC, Archaeological Park and Pegaso s.r.l.

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O15 - Methods for vegetation management in archaeological sites: sustainability, effectiveness and conservation

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In recent years, scientific research has highlighted how vascular flora represents a concrete threat to the conservation of archaeological sites. Uncontrolled vegetation growth near or in direct contact with monuments can cause mechanical, chemical, and aesthetic damage. Current weeding methods often overlook interactions with the constituent materials of monuments and artifacts, an aspect still underexplored in scientific literature. This research project aims to fill this gap by developing practical guidelines for managing invasive plant species, considering both vegetation types and their interaction with archaeological materials. Emphasis is placed on cost-effective solutions, suitable even for resource-limited sites. The project is organized into four main phases:

- Literature review and product selection: identification of existing market solutions and analysis of scientific literature to gather data on herbicidal products and methods tested in archaeological contexts, with a focus on documented efficacy.
- Laboratory interference tests: selected weeding methods are tested on samples representing common archaeological materials, monitoring potential interactions with treated surfaces through targeted analyses.
- In situ interference tests: the same tests are conducted in a selected archaeological site that reflects typical issues. Treatments are applied and monitored to assess their effectiveness and compatibility with historical materials.
- Definition of an operational methodology: based on the collected data, a practical methodology will be developed for professionals managing archaeological areas. It will consider both the type and impact of invasive plants and treatment effects on historical substrates, aiming to support sustainable, long-term vegetation management.

The project is currently in phase two, with promising preliminary results. Potential interferences have been evaluated on an initial group of materials, including Carrara marble, travertine, yellow tuff, and brick, assessing the effects of two herbicides based on pelargonic acid and capric and caprylic acids, as well as a physical method, namely steam weeding. These tests were made possible thanks to the collaboration with agricultural companies and the support of several public and private institutions, including the Academy of Fine Arts of Naples, CREA (Council for Agricultural Research and Economics), University of Tuscia, Bio.Co.Ré. Lab, and the Archaeological Park of the Colosseum.

O16 - ADE: Enhancing XRF Spectra Interpretation with an Automated Detection Element Toolkit

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The use of portable X-ray fluorescence (pXRF) and other non-invasive spectroscopic methods is increasingly common in archaeometric research. Yet, the resulting data often remain isolated in heterogeneous formats and workflows, limiting comparability, reuse and transparent interpretation. Addressing this fragmentation is the main objective of the SAGAS (Semantic Archaeometric Graph Analysis System) project, which will explore how to capture the full complexity of archaeometric information, across diverse formats, instrumental parameters and analytical methods, within a unified, open and queryable environment. Its ambition is to foster shared readings of material heritage, with an initial focus on ceramics, by modelling relationships between individual analyses, artefacts' typologies, metadata and interpretative outcomes in a semantically rich graph.

As a first concrete outcome of SAGAS, this contribution introduces ADE (Automatic Detector Element), a Python-and-Dash web application for now qualitative, and later quantitative, analysis. This is done by enabling users to upload pXRF spectral data, and performing manual or automatic elements peak detection. Inside the ADE app spectra can be compared visually in a single, interactive dashboard, with simple controls to highlight or hide individual dataset and to annotate features of interest. Outputs, both graphical and textual, can be exported for reporting or further analysis.

By consolidating key stages of the exploratory workflow (data ingestion, feature detection, standard matching and interactive visualisation) ADE demonstrates how open-source tools can streamline the preliminary phases of archaeometric analysis. Although primarily intended for qualitative comparison, this prototype establishes a modular foundation for future enhancements, including semantic data modelling and machine-learning-driven classification. In doing so, it lays the groundwork for a collaborative infrastructure in which spectroscopic data become genuinely comparable, reusable and accessible across disciplinary boundaries.

O17 - Development of Intelligent Museum Assistants and Ethical Reuse of 3D Archaeological Reconstructions

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This integrated project explores the intersection of AI technologies and archaeological heritage, focusing on two main components: the development of intelligent museum assistants using Large Language Models (LLMs) enhanced by Retrieval-Augmented Generation (RAG), and the ethical reuse of archaeologist-generated 3D reconstructions. These two components serve different yet complementary purposes within the realm of cultural heritage, combining advanced digital technologies with archaeological research and museum education. The project explores how these technologies can create interactive and immersive museum experiences while enhancing archaeological interpretation through the use of AI-driven models and 3D virtual environments. It also highlights the importance of ethical digital practices, such as the preservation of historical accuracy and cultural sensitivity in the reuse of digital heritage assets. Through case studies such as Haghia Triada (Crete), Borg in-Nadur (Malta), and Polizzello (Sicily), the project merges AI-driven methodologies with archaeologist led modeling to create intelligent museum assistants capable of interacting with visitors in immersive, data-driven virtual environments. These reconstructions also serve as reusable digital heritage assets for training AI systems in the reconstruction of ancient environments. The integration of these digital methodologies aims to bridge the gap between traditional archaeological practices and next-generation AI technologies, ensuring ethical reuse, transparency, and cultural sensitivity.

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O18 - Debunking the Fake: An Interdisciplinary Approach to Countering Forgery or Counterfeiting in Contemporary Art

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The forgery of contemporary art poses an increasing challenge for museums, collectors, and institutions. While analytical techniques have evolved, identifying forgeries remains a complex task. [1, 2]
This research, conducted as part of a PhD in Heritage Science, proposes an operational protocol for identifying and preventing forgeries, built on the integration of scientific analysis, documentary study, digital tools, and ethical and cultural reflection. From this viewpoint, archaeometry becomes a key [3] partner in exposing deception, safeguarding the truth, and shaping the emerging role of the heritage scientist: a professional skilled in combining historical-artistic, technical, and scientific expertise in the conservation of contemporary art.
Through the analysis of real cases—also in collaboration with the Carabinieri TPC Command—the project examines the material and narrative mechanisms that drive the circulation of fakes [4, 5], emphasising the importance of scientific diagnostics in understanding and safeguarding contemporary art.
Portable, non-invasive methods are used on complex works to identify elements of material and stylistic discontinuity [6].
This information is combined with provenance research, legal assessments, and digital traceability solutions (blockchain, due diligence). Also, central to this is the recognition of technical documentation as a valuable historiographical source, capable of improving traditional historical-critical interpretation.
Forgery is regarded as a complex phenomenon: not merely fraud, but a cultural tool capable of creating alternative narratives. The aim is twofold: to enhance the capacity to detect fakes and to foster a stronger culture of legality within the contemporary art sector.

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O19 - Inside Caravaggio: Immersive Experience Models

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Cognitive neuroscience studies on vision and neural involvement during the aesthetic experience and the latest computer experiments suggest that the relationship between artist, artwork, and viewer does not end with mere observation [1, 2], but constitutes an intersubjective, embodied experience. [3] Viewing the artwork, engaging at the museum, can also become inclusive and evoke intense emotions in the viewer through the use of digital technologies, based on artistic, computational, and cognitive studies.
The case study, the digital, three-dimensional environment of Caravaggio's Adoration of the Shepherds, was created at University of Messina in collaboration with the Museum and the laboratory HuM-HI. Usable through a headset, in virtual and augmented reality, [4] it offers an immersive aesthetic experience that puts the viewer in direct contact with the work, and with the artist, and manages to involve, from a physical, sensory and emotional point of view through the 3D reconstruction, ambient soundscapes, narrative elements, and descriptive content. The digital environment is accessible in museum and non-museum settings, when in-person viewing is not possible, and for educational purposes, as it allows for the explanation of complex topics as the use of light in Caravaggio. After the design, an experiment (the results of which will be shown) was conducted on 71 students at the University of Messina to compare which mode among live viewing, VR viewing, AR viewing and a high-definition copy projected in the laboratory was more emotionally, cognitively, aesthetic and bodily engaging. [5-7]

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O20 - Digitizing to Preserve Contemporary Works of Art

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The paper deals with the study of conservation for contemporary art materials, identifying preservation solutions that adequately respect the dual historical and aesthetic significance of artworks that is increasingly challenging.

The artifacts that contemporary artists produce respond to criteria far removed from the durability of the materials employed, and often the authorship of the works produced is more attributable to ideation and design. This is the case with the recent musealization of maquettes and installation works executed mostly with rapidly deteriorating materials and techniques.

The conservation of the artifact for museum institutions is thus all the more crucial in the face of irreversible processes of material deterioration. Conservator-restorers are called upon to find new solutions, among which digitization as a form of documentation and transmission of knowledge for future generations. The intrinsic impossibility of fully restoring the work to its "time of creation" is therefore the basis of the need for scientific restoration.

Consider the case of Gianfranco Baruchello's installation Piccolo sistema, where, following the sublimation of the marker writings, a structured light scan was carried out to obtain the 3D model, and a high-resolution photographic campaign was conducted, in order to produce exhibition copies, avoiding the risk of historical forgery.

Another important example in which the acquisition of the 3D model constitutes a fundamental intervention methodology is the work carried out on Mario Fiorentino's Corviale maquette, on which a hypothesis of virtual reconstruction for the missing parts was created.

The two case studies mentioned, both from the MAXXI Collection Museum in Rome, again pose questions to the restorer regarding the conservation choices that can respond to historical and aesthetic demands: when to intervene physically on the artifact or when to rely on digital tools?

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O21 - Toward a "liquid museum." The contribution of visitors from outside the local context to the understanding, valorization, and management of cultural heritage.

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The 'liquid museum', inspired by Zygmunt Bauman, represents an evolving museum model that transcends traditional definitions of diffused museum and ecomuseums by introducing a novel relational and participatory dimension. This paradigm centers the external visitor as a participating observer, redefining their contribution to the relationship among heritage, community, and territory. The museum's 'liquidity' is expressed through four dimensions: immateriality (where the 'collection' of visions is replaced by the multiplicity of experiential possibilities), refunctionalization (integrating material heritage into daily life), fluidity (the museum's ideal extension across the entire regional territory), and vitality (heritage shared with citizens). This model uniquely values the perspectives of non-resident visitors in the co-creation and management of heritage. Examples demonstrating the visitor's historical contribution to heritage valorization will be provided, drawing from evidence in Naples. These include: The term "Spaccanapoli," absent from official toponymy, was first documented in 18th-century Dutch and German Grand Tour guidebooks. The Crater de Luz at Toledo Metro Station in Naples was originally unforeseen. Architect Oscar Tusquets conceived it by recognizing in the excavation shaft a contemporary version of Naples' historical practice of extracting subsoil materials. Data from an experimental study, conducted in Spring/Summer 2023 in Naples, will also be presented: it revealed how the extraordinary richness of Campania's heritage, extending far beyond material assets, makes the region an ideal laboratory for investigating the role of the outsider visitor in his or her experience of intangible cultural heritage. Given the increasing mass tourism, an integrated and participatory management of cultural heritage is urgently needed. The 'liquid museum,' conceived in synergy with institutions, offers an ideal model by shifting centrality from the monument to the individual — the visitor. Their propensities, tastes, and interests guide the creation of 'tailored' itineraries and paths, fostering harmony with the communities and territories they inhabit. This approach integrates conservation, communication, education, and tourism strategies into a single plan, promoting a conscious and sustainable visitor experience.

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P01 - Multi-Analytical Provenance Study of White and Polychrome Marbles from Teate Marrucinorum (Chieti, Italy)

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Ancient Romans extensively used a wide variety of ornamental stones, including both white and polychrome marbles, to produce sculptures and artifacts, as well as to decorate buildings across their vast territories. The origin of these materials reflects complex quarrying and trade networks throughout the Mediterranean. While the provenance of white marbles is commonly established by mineralogical, petrographic, and isotopic analyses [1], polychrome stones are often identified based only on qualitative macroscopic observations. This study applies a multi-analytical approach to characterize 56 marble samples from the thermal baths of Teate Marrucinorum (modern Chieti, Italy), aiming to enhance provenance determinations for both white and polychrome lithotypes. Samples were initially classified into six types based on autoptic inspection: four polychrome varieties, one grey-striped marble, and a group of white marbles. Advanced mineralogical and chemical analyses were conducted using X-ray powder diffraction (XRPD), micro-Raman spectroscopy, and X-ray fluorescence energy-dispersive spectrometry (XRF-EDS) to define crystal-chemical features and phase composition. Isotopic analyses ($\delta^{18}O$, $\delta^{13}C$) were performed on white and grey-striped marbles to further constrain their provenance. Thin sections were examined with Transmission Optical Microscopy (TOM) to assess mineralogical and textural features.
The combined dataset enabled precise identification of the four polychrome stones as Pavonazzetto antico (Marmor Phrygium), Cipollino Verde (Marmor Carystium), Portasanta (Marmor Chium), and Breccia di Settebasi (Marmor Scyreticum). The grey-striped marble was confirmed as Microasiatic Greco Scritto, while the white marbles originated from two distinct sources: Carrara, Italy (Marmor Lunense) and Marmara Island, Turkey (Marmor Proconnesium). This integrated analytical protocol demonstrates that combining qualitative macroscopic classification with detailed quantitative mineralogical, chemical, and isotopic data significantly improves provenance accuracy, offering new insights into the variety of stones selected and traded by ancient Romans.

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P02 - Archaeometric characterization of pre-Greek Daunian ceramic production: Regional variations and technological traditions in Apulian sites

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This study presents the results of an archaeometric analysis of Daunian Subgeometric ceramics, a pottery production widespread in Northern Apulia from the 7th to 4th century B.C.E. The main objective was to identify the raw materials and manufacturing techniques used by the Daunian populations before Greek influence.

The ceramic bodies and surfaces were analyzed through a multi-technique approach employing non-destructive or micro-destructive analytical methods, including LA-ICP-MS, Raman spectroscopy, PXRD and SEM-EDS [1]. This approach provided significant insights into the production technologies, raw material sources, and pigmentation techniques used by the indigenous populations of Northern Apulia during that period.

The results suggest the existence of local production at both sites—Canne della Battaglia and Ordona—considered among the most important centers for Daunian ceramic manufacturing. The compositional homogeneity observed within each site across different chronological phases indicates remarkable consistency in raw material procurement strategies over several centuries. Geometric ceramics from Canne della Battaglia are characterized, however, by more refined manufacturing compared to those from the other two phases, in line with the evident stylistic evolution in decorative motifs.

The analysis of surface treatments and pigments revealed a sophisticated understanding of local raw materials and their applications. Surface whitening treatments employed calcium sulfate-based compounds or kaolinite [2]. Red decorations were produced using local terre rosse rich in hematite as the main coloring agent [3], while black and dark brown overpaintings involved complex mixtures of iron oxides (magnetite, goethite, hematite), manganese oxides/hydroxides, and charcoal [4, 5].

These results provide valuable insights into indigenous ceramic production in Apulia prior to Greek colonization, highlighting how local artisans, while continuing to use the same locally available raw materials, refined their manufacturing processes in accordance with evolving decorative styles to reflect changing artistic trends.

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P03 - An Integrated Multidisciplinary Strategy for the Study and Conservation of the Archaeological Site of Palazzi di Casignana (Reggio Calabria, Italy)

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The monumental archaeological site of the imperial villa of Palazzi di Casignana is located along the Ionian coastal plain, just 15 km south of Locri, in province of Reggio Calabria (Italy). The original nucleus, dating to the 1st century BC, was largely obliterated by subsequent construction phases during the 3rd and 4th centuries AD—a period in which the settlement assumed the monumental configuration still appreciable today, owing to the exceptional preservation of its standing structures. This phase of construction is linked to the building of a luxurious residential district embellished with two large thermal areas, known for the richness and splendour of their decorations. Of particular value are the marble floors from Greece and Asia Minor and the mosaic floors, made with polychrome marble tiles of intrinsic iconographic value, depicting mythological images. Partially destroyed by uncontrolled urbanisation, the archaeological complex is now threatened by erosion and natural phenomena. A multidisciplinary approach is therefore proposed to plan interventions aimed at qualifying and enhancing a heritage of this nature.
Within this integrated framework, archaeometry plays a crucial role in the study and preservation of cultural heritage, as it bridges the gap between the humanities and natural sciences. Among its various applications, the provenance study of ancient marble artefacts remains a particularly debated topic within archaeology and art history.
In this study, a multi-analytical approach was applied to examine the marble tesserae from the mosaic floors of the Roman Villa at Palazzi di Casignana. Specifically, data obtained from mineralogical-petrographic analysis, XRD investiations, stable isotope measurements, and SEM-EDS analyses were combined. These results were then compared with updated reference databases of the main Mediterranean marble sources used in antiquity to determine the most likely provenance [2]. The analyses revealed significant variability and heterogeneity among the tesserae, suggesting the use of diverse marble from multiple ancient Mediterranean quarries. This diversity highlights the richness and archaeological significance of the villa complex.

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P04 - X–Rays and Musical Instruments: a way to restore and rediscover sounds

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Since Musical Heritage is defined as both the object that enables the production of music and the resulting musical experience, playing an instrument and listening to the music it produces, the primary goal of this work is to simultaneously preserve the musical instrument and its distinctive sound. This latter aspect is often overlooked by museum curators in favor of preserving the material object. Playing wind instruments entails the introduction of both air and saliva into their internal structure, which alters the moisture levels and can initiate physical and chemical processes that pose significant risks to the instrument's long-term preservation [1]. For wooden wind instruments, signs of deterioration tend to manifest at an early stage, making damage readily observable. In contrast, ivory instruments typically exhibit visible fractures only when their structural integrity has already been severely compromised.

The central challenge of this research is to utilize X-Ray imaging techniques as a starting point for the replication of wind instruments. Analysing the internal geometry provides the critical data required for the accurate reconstruction of historical musical instruments. X-Ray imaging techniques are widely employed in the field of Cultural Heritage conservation due to their ability to provide data on internal structure and preservation status without compromising the integrity of the object under examination [2]. Furthermore, Computed Tomography enables the creation of 3D models that can be thoroughly analyzed, accurately measured, virtually sectioned, and rotated from various perspectives, thereby facilitating the investigation of areas of particular interest [3].

This study enables an initial assessment of the conservation state of such instruments. In the case of wooden instruments, it allows for the evaluation of fracture severity and extent [4]. For ivory instruments, it facilitates the early detection of internal cracking, prior to its emergence on the surface. In both types, the method also reveals evidence of past restoration efforts or the presence of internal voids.

Ending goal is to perform Computed Tomography using reference markers for dimensional calibration and X-Ray attenuation, enabling the acquisition of precise morphological and structural data. These measurements are essential for the development of high-fidelity 3D-printed replicas.

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P05 - Biodeterioration of artifacts study collection stored in repositories of the National Museum of Science and Technology: risk analysis and conservation issues.

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The project aims to address biodeterioration dynamics on modern artifacts stored in museums' repositories. This category of artifacts is heterogenous, but usually represented by modern, poly-material and complex objects. Since interactions of different material result in complex management choices for conservators, from preventive measures to restorative protocols, defining new protocols is essential [1]. Relevance is also given to storage environment, as most museums' collections are stored in repositories. Biodeterioration is an ever-growing concern here, mostly because of xerophilic contaminants' spreading, stress resilient microorganisms with a wide distribution range. Museums' adaptation to climate change implies the expansion of thermo-hygrometric conditions, but its effect on biodeterioration has yet to be assessed [2]. Moreover, many repositories are being opened to public with solutions like "open storage", but increased accessibility impact on artifacts' conservation condition is still unknown [3].
Thus, this research objective is to determine biodeterioration risk at the National Museum of Science and Technology (MUST)'s repository, broadening the perspective to other cultural institutions. The aim is to obtain actionable data that can lead conservators to reasoned management choices, balancing conservation necessities, new demands of accessibility and a reduced environmental impact.
Environmental and biological monitoring campaigns will be performed in MUST's repository. Thermo-hygrometric and pollution conditions will be assessed and correlated with concentration and abundance of microorganisms present in the airborne and on cultural heritage's surfaces. Moreover in vitro tests will be conducted to assess the interaction between microorganisms and poly-material objects, improving knowledge on biodeterioration dynamics on technical-scientific artifacts.

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P06 - Mobile Image Retrieval for Cultural Heritage: A CNN-Based Approach to Museum Artifact Recognition

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Cultural heritage reflects a community's identity, values, and history. To make it more accessible and engaging, this work presents a computer vision-based system developed for the Museum of Archaeology at the University of Catania (MAUC).
The system allows visitors to identify artifacts by simply taking a photo with their smartphone, retrieving detailed information without using QR codes or physical panels. The core of the system is a Content-Based Image Retrieval (CBIR) approach that, given a query image, is able to retrieve a k of similar images in the training set. A dataset of 860 images of 30 archaeological artifacts was collected under various lighting and angles. Both hand-crafted descriptors (DAISY, SIFT, ORB) and a CNN-based model (MobileNetV3 Small) were tested, along with two retrieval methods: KDTree and Annoy.
The CNN-based method achieved 99% accuracy with fast processing (0.4s/image) and low memory usage (0.7 GB), making it ideal for mobile devices. SIFT performed well (93%) but was slower, while ORB was the most efficient but less accurate (83%).
KDTree and Annoy showed similar results, though Annoy is better suited for larger datasets. This solution offers an intuitive, fast, and scalable way to enhance museum visits, preserving the visual integrity of exhibits and enabling real-time, personalized access to cultural content.

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P07 - Ancient Goldsmithing in the Nile Valley: From Archaeometric Analysis to Experimental Archaeology

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This research is part of a PhD project investigating ancient goldworking and goldsmithing practices along the Nile Valley, primarily in Egypt, with comparative evidence from ancient Sudan. The chronological framework spans from the Egyptian Middle Kingdom and the Middle Kerma period in Upper Nubia (c. 1980–1760 BCE) to the Meroitic Kingdom, contemporaneous with the Ptolemaic Period in Egypt (332–30 BCE).

The study aims to reconstruct the entire chaîne opératoire of gold production, from extraction to finished artefact, to identify similarities and differences between Egyptian and Nubian goldsmithing traditions, to map mining areas, processing and storage sites, and exchange networks, and to develop a methodology for the study of gold jewellery integrating archaeometric analysis, ethnoarchaeological data, and experimental archaeology. The approach is interdisciplinary, combining archaeology, goldsmithing expertise, scientific analysis, and craft replication.

The jewellery examined is of Egyptian origin and housed at the Museo Egizio, Turin. The focus is on items from the New Kingdom (1550–1070 BCE), with additional consideration of funerary amulets from the Third Intermediate Period (c. 1076–723 BCE) and the Late Period (c. 722–332 BCE), in order to establish comparative ground with Nubian examples.

Within the framework of a collaboration between the Cyprus Institute of Nicosia, the University of Bari Aldo Moro, and the Museo Egizio, around 50 objects were analysed using a Hitachi XMET 8000 handheld XRF device. This enabled investigation of elemental composition, including the gold alloys of sheets and soldering materials, with specific attention to silver and copper content.

In light of previous research, this project seeks to deepen our understanding of goldsmithing technologies in the Nile Valley, highlighting their embeddedness in wider social, economic, and cultural dynamics, and the enduring connections between Egyptian and Nubian traditions.

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P08- Exploring the Informative Potential of Stable Isotope Analyses Performed on Organic Remains: The Case Study of the Medieval Mining Castle of Rocca San Silvestro (Tuscany, Italy).

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Organic archaeological remains—including osteoarchaeological, zooarchaeological, and archaeobotanical samples—are useful archives for reconstructing past human lifeways, environments, and economies. Stable isotope analysis stands out as a particularly powerful tool in this regard, offering direct insights into diet, mobility, and paleoclimate. Advanced techniques like incremental dentine analysis and compound-specific stable isotope analysis have further enhanced our ability to gain detailed insights into past populations. However, the reliability of these analyses is highly dependent on the conservation status of organic remains, as degradation and diagenesis can compromise sample integrity, making rigorous pre-treatment protocols essential.

In this contribution, we demonstrate the informative potential of isotopic analyses on organic remains through a case study from the medieval mining castle of Rocca San Silvestro (Tuscany, Italy). A comprehensive multidisciplinary approach, integrating anthropological, paleopathological, archaeobotanical, and zooarchaeological analyses, was employed to explore the health, socio-economic dynamics, and human-environment interactions within this mining community. Specifically, our study aimed to: (1) reconstruct subsistence strategies using stable carbon and nitrogen isotopes on human, faunal, and botanical remains; (2) infer mobility patterns via strontium isotope analysis of archaeobotanical remains and human and faunal enamel samples; and (3) refine the cemetery's chronology through radiocarbon dating of selected burials.

Preliminary findings suggest a mixed economy based on agriculture and animal farming. Stable carbon and nitrogen isotopic data revealed a primary reliance on C3 terrestrial resources and differential access to 15N-enriched food sources within the Rocca San Silvestro community. Strontium isotopic ratios suggest a largely local population, though sex-based limited mobility was also inferred. Radiocarbon dating confirmed that the cemetery was still in use between the 13th and 14th centuries.

Collectively, these finding provide a detailed picture of how this medieval population managed resources and adapted to their environment, demonstrating the significant potential of organic remains in filling knowledge gaps about past societies.

P09 - The searching for miniatures in photographic archive digital collections - a case study

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The current massive digitization of photographic archives is making vast amounts of previously inaccessible material available online allowing for broad access to fragile cultural artifacts that are otherwise restricted for conservation reasons. Such collections typically contain diverse subjects, with artworks appearing alongside everyday life scenes and landscapes.
This growing amount of data can be used to train machine learning models for specific computer vision tasks and develop innovative user-centered fruition strategies.
The National Photographic Cabinet of the Central Institute for Italian Cultural Heritage (ICCD) preserves a priceless heritage of more than 475.700 items divided into 65 different Funds, many of which belonged to art historians or artists.
Even if they constitute a minority, there are also several reproductions of medieval illuminated pages decorated with ornamental borders and especially illustrations that share subjects and iconography with monumental art.
Historical document and manuscript research has benefited greatly from the use of deep neural network techniques [1] for layout analysis and automatic content recognition but specific datasets [2] concerning digitized handwritten and early printed texts are always small if compared to those with natural images and don't include other artistic typologies.
The contribution presents an experiment conducted on the National Photographic Cabinet collection using a deep neural network specifically trained with an original dataset to identify manuscript pages in heterogeneous groups of images and recognize five layout elements to extract figurative miniatures [3].
After a brief analysis of the examined material, the results obtained will be exposed, highlighting the critical issues that emerged and the model strengths before concluding with the possible uses in the field of data visualization.

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P10 - An early-stage assessment of the marine coastal context on ancient watchtowers (Calabria, Southern Italy): diagnostic methodologies and enhancement strategies

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Calabria's cultural heritage features over 130 coastal watchtowers built between the Angevin and Viceregal periods (from XIII to XVI century), with only about 70 still standing today in various states of preservation [1]. To support the conservation of this heritage, a QGIS map was created to document and assess the condition of the existing coastal towers in relation to the primary environmental risks concerning coastal erosion, landslides, and earthquakes. The project centers on five historic watchtowers located in the provinces of Reggio Calabria and Vibo Valentia: respectively, Saracena (Palmi), Ruggero (Bagnara), Cavallaro (Marina di Gioiosa Jonica), La Rocchetta (Briatico) and Marrana (Ricadi). The research plans the minero-petrographic characterization of their construction materials and degradation forms, using Polarized Optical Microscopy (POM), X-Ray Powder Diffraction (XRD), X-Ray Fluorescence Spectrometry (XRF), Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS) and Ion Chromatography (IC). Moreover, an aerial photogrammetric survey will complete diagnostic data, producing 3D models integrated into an H-BIM and 3D GIS system to visualize structural materials, degradation forms, and geological risks [2]. Preliminary observations have identified the construction materials, such as local stones, mortars, and bricks, and the degradation forms, including salt efflorescence, flos tectorii, alveolization, and biological growth [3]. To enhance the tower's visibility, the final phase includes AR (Augmented Reality) content, local partnerships, and geotourism routes for sharing research findings [4].

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P11 - Reading the invisible: preventive conservation strategies without structured environmental monitoring

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Environmental control is widely recognized as a key factor in preventive conservation, especially for hygroscopic and composite materials. However, many conservation settings, such as small collections, temporary storage, or ethnographic artefacts housed in non-museum contexts, operate without structured monitoring systems or scientific support. In such conditions, the conservator's role extends beyond intervention, becoming central in establishing a sustainable, low-threshold form of environmental vigilance. This contribution presents a reflection on methods developed through professional practice, where minimal tools and qualitative observation become essential. Based on the regular use of stand-alone thermo-hygrometers, dataloggers, and visual indicators, the conservator can record key microclimatic trends and detect correlations between environmental fluctuations and material responses.

Visual inspection protocols focused on changes in surface condition, texture, gloss, or pigment cohesion are paired with systematic documentation, including photo comparisons and hand-written logs. These empirical strategies, although not instrumentally analytical, provide replicable and structured frameworks that support preventive decision-making in the absence of scientific infrastructure.

Special attention is given to materials with ritual or symbolic significance, where conservation choices must balance physical stabilization with cultural sensitivity. In these cases, preventive conservation becomes a dialogical process adaptable, reversible, and context-aware.

By highlighting the conservator's capacity to act as a microclimate observer, this paper aims to legitimize an approach based on attentiveness, consistency, and interpretive skill. It affirms that even in resource-limited contexts, preventive strategies can be both rigorous and ethical, laying the groundwork for future integration with scientific analysis when conditions allow.

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P12 - Innovative Application of Reaction Path Modelling in Cultural Heritage: Preliminary Experimental Results

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Built heritage, exposed to the atmosphere, undergoes changes known as weathering processes. Today, climate change further intensifies decay and introduces new forms of degradation [1,2]. This research proposes the use of reaction path modelling, combined with traditional diagnostic investigation, to simulate the processes involved in the weathering of cultural heritage materials. Reaction Path Modelling is a geochemical tool that utilizes specialized software to quantitatively simulate mineral formation and dissolution processes, phase composition transformations, and the distribution of chemical species within geological systems. [3]. Therefore, reaction path modelling heritage could represent a promising tool for studying the reactions involved in the interaction between stone materials and specific environmental conditions. The research plan included: i) the selection of four cultural sites in Calabria (Italy), characterized by granitoid and carbonate lithologies located in urban and non-urban environments; ii) the collection of environmental data from local monitoring stations; iii) the characterization of the lithotypes to define the solid phase for geochemical simulations. An initial simulation focused on modeling the reaction pathway of calcite dissolution at the selected site, where the ancient materials have a carbonate composition. Simulations were performed with PhreeqC software [4], using input data such as monthly CO_2 concentrations, mineralogical composition, and average historical temperatures. The output results quantified the amount of calcite dissolved as a result of geochemical interactions. Preliminary results demonstrate the applicability of reaction path modelling to weathering processes in cultural heritage and suggest its potential for predicting weathering under future environmental conditions.

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P13 - Combined 2D and 3D Imaging and Analysis of Roman Mortars from Teate Marrucinorum (Chieti, Italy)

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The archaeometric characterization of ancient geomaterials and their artificial counterparts relies on integrated mineralogical, geochemical, and textural analyses to reconstruct provenance, manufacturing techniques, and durability. Traditional 2D methods—such as analysis of polished slabs and thin sections—are used to quantify the abundance, size, shape, orientation, and distribution of aggregates, voids, and binder phases [1]. However, 3D imaging techniques further expand morphotextural information by providing volumetric data, specific surface areas, connectivity, and anisotropy [2].

This study applies a combined 2D and 3D image analysis approach to ancient mortars from the cistern the 1st–2nd century AD public thermae of Teate Marrucinorum (modern Chieti, Italy). Three horizontal core samples were extracted from the cistern walls, spanning from outer to inner layers. These semi-cylindrical specimens (15–39 cm long, 6 cm diameter) were first analyzed in the 2D domain via High-Resolution Scanner (HRS). Thin sections coaxial to the thickness were studied under Transmission Optical Microscopy (TOM) and Scanning Electron Microscopy (SEM) to investigate mineralogical and textural features at multiple scales [3]. The outermost portions of two cores were then analyzed using X-ray computed microtomography (µ-CT, EasyTom XL Ultra, RX Solutions, France).

The integration of 2D and 3D imaging allowed the characterization of mortar components, including binder matrix, aggregates, and porosity, and enabled the quantification of the cement-to-aggregate ratio, and the shape, size, and orientation of phases. Moreover, µ-CT imaging revealed internal features and anisotropy not detectable via conventional methods, enabling the detailed investigation of individual features in their full spatial context.

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P14 - Diagnostics of the state of conservation of inaccessible cultural heritage with LiDAR and UAV: the case study of the Aldobrandesca fortress of Roccalbegna – Grosseto (Italy)

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The Rocca Aldobrandesca of Roccalbegna (GR) [1] is a defensive structure built atop an outcrop of gray calcarenite known as "il Sasso," a vertical wall approximately sixty meters high overlooking the confluence of the Armancione and Albegna rivers, in the southern sector of Monte Amiata. Its unique geomorphology gave the site strong landscape and strategic value, making it ideal for controlling the surrounding valleys until the 18th century.
This study proposes a three-dimensional survey of the fortress for diagnostic purposes regarding its state of conservation. Since it is a building built on a rocky spur and therefore difficult to access, an integration of two survey methodologies was adopted: a Mobile Mapping System (MMS) based on LiDAR technology and photogrammetry from UAV (Unmanned Aerial Vehicle) [2].
The internal portions were surveyed using terrestrial LiDAR scanning, particularly suited to generating high-density point clouds in complex environments, while the external envelope was documented using aerial photogrammetry, with flights at an average distance of 5 meters and a GSD (Ground Sampling Distance) of approximately 0.7 cm/pixel. Data processing allowed the construction of a high-resolution textured model, with an estimated metric accuracy of around ±1.5 cm and a level of detail sufficient to identify alteration and material degradation phenomena.
The integration of the techniques allowed the interpretation of localized erosion, differential degradation processes, often influenced by the petrographic composition of the materials used, and biological colonization by lichens [3]. The surviving structures appear to be made almost exclusively of calcarenite, consistent with the geology of the outcrop on which the Rocca is built, and the lithological nature of these elements directly affects the mechanical response and vulnerability to alteration phenomena. The three-dimensional model provides a solid basis for future monitoring and conservation strategies, demonstrating the effectiveness of combining terrestrial and aerial surveys in documenting cultural heritage in orographically challenging contexts.

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P15 - Comparative Evaluation of Nanostructured Consolidants for Mural Paintings in Hypogeal Environments

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Underground cultural heritage sites are among the most vulnerable to environmental degradation, primarily due to their thermo-hygrometric instability and limited air circulation.
This study presents a comparative evaluation of nanostructured consolidating system applied to mural paintings in three hypogeal sites in southern Italy: the Santa Maria della Grotta complex and the Crispia Salvia hypogeum belonging to the Archeological Park Lilibeum (Marsala, Sicily), and the Chiesa of Sotterra (Paola, Calabria). The selected wall paintings were located in three hypogeal chambers, all in a precarious state of preservation. The most frequently observed forms of deterioration included efflorescence, sub-efflorescence, and saline concretions, which contributed to the disintegration of constituent layers, leading to gaps and material loss. The nanostructured system employed consisted of a hydroalcoholic solution of barium hydroxide nanoparticles, applied by brush or by spray on selected test areas until refusal. Commercial nanostructured formulations were also tested in order to compare the efficacy of the consolidation. The treatment's performance was assessed both immediately after application and after several months using three main diagnostic methods [1, 2]: the Contact Sponge Test to evaluate the consolidation of deeper layers, the Scotch Tape Test to assess paint film cohesion, and colorimetric analysis to detect surface chromatic variations. The comparison of the performance of the formulation tested in different sites confirm the potential of barium hydroxide nanoparticles as an effective and compatible consolidant for mural paintings in high-humidity, hypogeal environments.

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P16 - From Replica to Reference: Developing Analytical Protocols and Databases for Organic Materials in Roman Wall Painting

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The use of organic pigments and binders in wall paintings predates the codified fresco technique, as shown by scientific analyses of prehistoric murals from the Upper Palaeolithic, where binders like egg, blood, and animal derivatives were used. This practice continued through history and is evident even in Roman wall paintings. Even though ancient sources such as Vitruvius and Pliny the Elder primarily describe fresco, modern diagnostics have revealed frequent use of a secco (dry) and mezzofresco (lime paint) overpainting. These layers, frequently applied with lime-based or organic binders, enabled the addition of pictorial details or the use of pigments incompatible with the fresco technique. However, identifying these organic materials remains difficult due to their low concentration, specifically the binder-pigment ratio, degradation over time due to their chemical and physical properties, and the limits of current analytical techniques, with consequences for the conservation of both materials and knowledge. While non-invasive techniques frequently reveal the presence of organic materials, they offer limited specificity in their identification. Similarly, invasive approaches such as gas chromatography offer only limited success in achieving satisfactory results. In this specific context, the creation of experimental mock-ups inspired by Roman wall-painting techniques and current knowledge of them is a suitable endeavour. The production of these replicas involves the use of pigments and binders of various kinds. These samples serve as a test bed for the evaluation of analytical protocols, both invasive and non-invasive, assessing their sensitivity and accuracy. Concurrently, a useful reference database is constructed for comparison with real archaeological finds. Planned analyses include non-invasive techniques such as multispectral imaging, visible and near-infrared reflectance spectroscopy (FORS), Raman spectroscopy and Fourier transform infrared spectroscopy (FTIR). In a subsequent step, micro-samples will be taken for analysis by gas chromatography coupled to mass spectrometry (GC-MS).

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P17 - Preliminaries Micro-Raman Spectroscopy investigations on samples obtained from the swords of the Torre Galli necropolis housed at the National Archaeological Museum of Reggio Calabria (MArRC)

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This research project focuses on the diagnostic characterization of a group of 15 swords from the Torre Galli necropolis (Drapia, VV), currently housed at the National Archaeological Museum of Reggio Calabria (MArRC). The Torre Galli necropolis, excavated by Paolo Orsi in 1922–1923, comprises 334 tombs: 277 from the Iron Age (late 10th – early 9th century BCE) and 57 from the colonial period (7th–6th century BCE).The swords, of significant typological and technological interest, consist of iron blades, handles sheathed in bone or ivory, and wooden scabbards covered with bronze sheets.

The project aims at the compositional, morphological, and structural characterization of these artifacts to improve understanding of ancient manufacturing techniques, assess their conservation state, and support restoration, protection, and valorization strategies.

The focus of the project is on the use of two primary and complementary diagnostic methodologies:

- Micro-Raman Spectroscopy, performed at the Raman Spectroscopy Laboratory (Department of Physics, University of Calabria), for identifying corrosion products, crystalline phases, possible organic residues, and restoration materials;
- X-ray Microtomography, carried out at STAR, a national research infrastructure hosted at the University of Calabria, providing non-invasive 3D data on internal morphology, composition, manufacturing techniques, and preservation conditions of the objects.

The integrated analytical protocol included:

- X-ray Fluorescence (XRF) for elemental composition of metal alloys;
- Fourier-Transform Infrared Spectroscopy (FTIR) for detecting organic compounds, including traces of past conservation treatments.

In conclusion, this study has provided an initial diagnostic overview of the composition and preservation state of the Torre Galli swords. Micro-Raman analyses allowed the identification of corrosion products on both iron and bronze components, helping to better understand the degradation processes. Furthermore, XRF spectroscopy enabled the characterization of the metal alloys employed. The results offer a useful basis for future research and for developing targeted conservation strategies for the artifacts.

P18 - The colors of the Temples of Agrigento and Selinunte. Preliminary results from non-invasive diagnostic investigations.

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This work presents a preliminary study on the use of color in the ancient world—specifically in Greek Sicily between the 6th and 5th centuries BC—through a multidisciplinary approach combining archaeology and diagnostics. The study focuses on two case studies: polychrome architectural fragments from Temple F in Selinunte and the Temple of the Dioscuri in Agrigento, both preserved at the "A. Salinas" Regional Archaeological Museum in Palermo (Italy). As is well known, color played a fundamental role in the ancient world, characterizing not only sculpture and statuary but also monumental architecture—public and private, religious and civic alike. Unfortunately, due to the current state of preservation, ancient color is not always visible to the naked eye, as it often survives only in traces or has largely disappeared. To investigate these remnants, non-invasive physico-chemical diagnostic techniques—such as multispectral imaging like UV fluorescence, visible induced luminescence (VIL) and Raman spectroscopy—were employed using portable in situ instrumentation. This methodology enabled the detection of ancient traces of color and decorative motifs that are no longer visible today, including the identification of Egyptian Blue.

P19 - Non-invasive analysis by means of X-Ray Fluorescence on Kofun-period bronze arrowheads

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The Kofun period of Japan stretched from the mid-3rd to the early 7th century CE and witnessed the construction of monumental keyhole-shaped mounded tombs (kofun) over a continuous 350 years. They were built across most of the Japanese archipelago and these elite tombs shared considerable similarity in structure and composition of burial goods [1].
The Urama-chausuyama mounded tomb, located in Okayama City, Okayama Prefecture, is a keyhole-shaped mounded tomb, dated to the end of the 3rd to beginning of the 4th century CE. Its pit-style stone chamber, while heavily looted, revealed a significant amount of burial goods, including bronze mirrors, iron swords, iron arrowheads, bronze arrowheads, and iron tools. It was excavated in 1988 by Okayama University [2].
We conducted an analytical campaign aiming at characterizing the Kofun-period bronze arrowheads excavated from the Urama mounded tomb, both the metal bulk and the surface patina. We exploited a combination of non-invasive techniques including X-Ray Fluorescence, X-Ray Diffraction, X-Ray Computed Tomography and neutron beam techniques. Some of the analyses were complicated due to the presence of a thick Paraloid layer covering the arrowheads, that was applied for conservation reasons after the excavation.
We present here the analysis with portable XRF conducted at Okayama University on twenty bronze arrowheads. From the samples' characterization, we observed the presence of a high level of tin on the external patina probably correlated to cassiterite (SnO_2). From the literature we know that bronzes with high Sn content are highly corrosion resistant [3]. We observed different content of lead in the external patina probably due to the corrosion processes [4] and other elements probably correlated to the presence of soil on the samples' surface. The XRF data also brought to light the presence of mercury which may come from cinnabar used in the burial. To answer this question different mock-ups that simulate the arrowheads' condition were made. The results of these analyses will allow us to expand our knowledge on these peculiar burial goods.

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