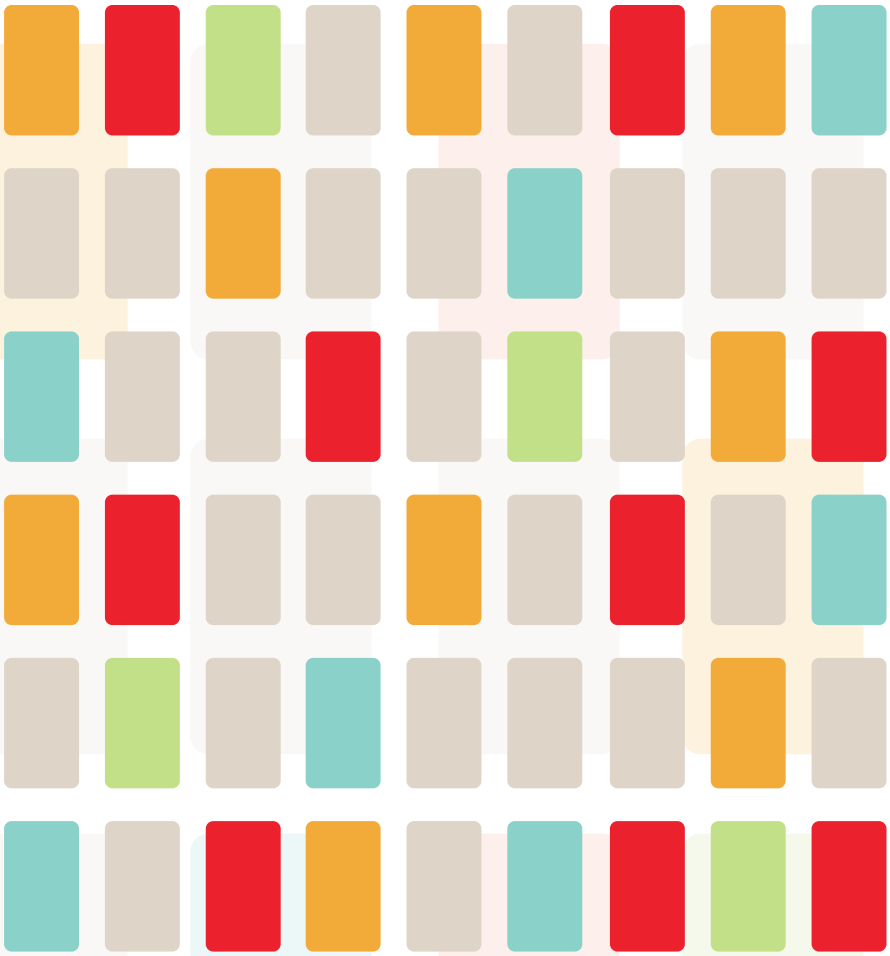
3rd Annual Conference of the Slovenian Node of the European Research Infrastructure for Heritage Science

E-RIHS Slovenia

Koper, 18–19 November 2025

Book of Abstracts



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EUROPEAN RESEARCH INFRASTRUCTURE FOR HERITAGE SCIENCE - SLOVENIA

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Introduction

Dear colleagues!

It is our great pleasure to welcome you to the 3rd Annual Conference of the Slovenian Node of the European Research Infrastructure for Heritage Science (E-RIHS.si), hosted by the University of Primorska, Faculty of Humanities. This year's conference will be held at InnoRenew CoE in Izola on November 18 and 19, 2025. It brings together researchers, conservators, curators, and professionals from various disciplines to share and exchange knowledge and contribute to shaping future of heritage science.

The programme features opening addresses and an award ceremony, a keynote lecture, oral and poster sessions, and a guided laboratory tour throughout the course of two days. It focuses on the latest analytical methods, digital transformation, materials research, conservation strategies, and participatory approaches to protecting and understanding cultural heritage.

Vania Virgili, Director General of E-RIHS ERIC, will deliver a keynote lecture highlighting the shift from the physical to the digital and discussing the role of E-RIHS in advancing heritage science.

We appreciate and thank all contributors, session chairs, reviewers, and partners who helped make this event a scientific success, as well as the organizing team for their dedication in making it a friendly and open environment for all attendees. We are thankful for the institutions that worked together to provide the collections and case studies on which many of the presentations are based on.

We encourage you to use these days to start conversations, make new partnerships, build new collaborations and think about what the next generation of services and data ecosystems in the heritage field might look like. May the conversations that start in Izola continue long after the closing remarks, making the E-RIHS.si network stronger and helping to protect, understand, and make cultural heritage more visible to the public.

We encourage you 'to boldly go where no one has gone before and, above all, don't panic.'

On behalf of the Programme Committee,

Zrinka Mileusnić
Head of the Organising Team,
E-RIHS.si 2025

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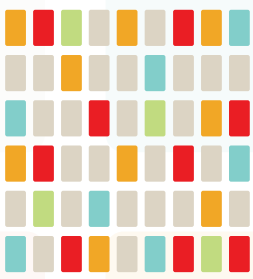

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Programme

Tuesday, 18 November 2025

Venue: University of Primorska, InnoRenew CoE, Livade 6a, Izola

09:00–10:00 Registration & Welcome

10:00–10:30 Opening Addresses

Klavdija Kutnar, Rector, University of Primorska

Aleksander Panjek, Dean, Faculty of Humanities, University of Primorska

Andreja Kutnar, Director, InnoRenew CoE, Andrej Marušič Institute, University of Primorska

Jonatan Vinkler, Director, University Library, University of Primorska

Matija Strlič, Chair of the Programme Committee, E-RIHS.si, Faculty of Chemistry and Chemical Technology, University of Ljubljana

10:30–10:45 Award and Recognition Ceremony

10:45–11:30 Keynote Lecture

From Physical to Digital: Advancing Heritage Science through E-RIHS

Vania Virgili, Director General of E-RIHS ERIC

11:30–12:00 Coffee Break

12:00–13:15 Session 1 chaired by Neža Čebron Lipovec

From the European Directive to the National Strategy: Establishing an Ecosystem for Digital Cultural Heritage in Slovenia – Alenka Kavčič Čolić, Kolar Jana

Use of Data Spaces for Humanities and Cultural Heritage Research in AID HCH project – Domen Mongus, Mitko Nikov, Mitja Žalik, Matej Brumen

Big Data or Lots and Lots of Small Data? XML in CIDOC-CRM for the (Integration) Project of Epigraphic Heritage of the Middle Ages and Early Modern Period – Gregor Pobežin, Zrinka Mileusnić

New Insights into Early Iron Age Iron Production in the SE Alpine Area: Case Studies from Cvinger near Dolenjske Toplice and Pungrt above Ig – Luka Gruškovnjak, Petra Vojaković, Jaka Burja, Barbara Šetina Batič, Agni Prijatelj, Manca Vinazza, Branko Mušič, Barbara Horn, Helena Grčman, Matija Črešnar

Preservation of the Archaeological Record and Grave Goods at the Pezdirčeva Njiva Cemetery: An Integrated Geoarchaeological, Archaeometric, and Conservation Science Approach – Agni Prijatelj, Helena Grčman, Nataša Nemeček, Lucija Grahek

13:15–14:30 Lunch & Poster Session

14:30–15:30 Session 2 chaired by Boris Kavur

Development of an Analytical Method for the Reconstruction of Historic Smells through GC-MS-O and Sensory Evaluation – Emma Paolin, Fabiana Di Gianvincenzo, Matija Strlič

Reassessing the Risk of VOC Emissions from Archival Storage Boxes – Randa Deraz, Abdelrazek Elnaggar, Matija Strlič

E-RIHS.si Multi-Analytical Approach to Heritage: Insights from the Heritage Science Lab Ljubljana – Ibrahim Elrefaey, Hend Mahgoub, Alban Paskoff, Irena Porekar Kacafura, Ana, Motnikar, Magdalena Mezeg, Pika Skerlj, Nives Slemenšek, Manca Boh, Lucija Močnik Ramovš, Martina Vuga, Jana Kolar, Matija Strlič

Documenting the Senses: The Inclusion of Smell in the Register of Intangible Cultural Heritage of Slovenia – Mojca Ramšak, Nina Dečko, Tjaša Zidarič

15:30–16:30 Poster session

Wednesday, 19 November 2025

Venue: University of Primorska, InnoRenew CoE, Livade 6a, Izola

08:30–09:00 Registration & Welcome

09:00–10:00 Session 1 chaired by Martina Blečić Kavur

Re-Reading the Building History by Merging Architectural, Technical, Historical and Ethnographic Approaches – Neža Čebron Lipovec, Irena Potočnik, Mike Burnard, Mohammad Derkivand, Andreja Kutnar

Conservation Metamorphoses of Ptuj – Simona Menoni Muršič, Vlasta Čobal Sedmak, Gorazd Gerlič, Mateja Neža Sitar

Uncovering Autochthonous Deteriogenic Biofilm and Developing Beneficial Bacteria-Based Bioformulations from Indigenous Isolates for Biocontrol and Biocleaning of the Rožanec Mithraeum Limestone Monument – Janez Kosel, Milica Ljaljević Grbić, Ivica Dimkić, Tamara Janakiev, Črtomir Tavzes, Slađana Popović, Aleksandar Knežević, Lea Legan, Klara Retko, Polonca Ropret, Nina Žbona, Nikola Unković

Between Villa Rafut and Rafut Park: Monument's Protection History – Tina Bratina

10:00–10:30 Coffee Break

10:30–11:30 Session 2 chaired by Tim Mavrič

Wooden Shingle Roofs in Slovenia: Tradition, Intangible Heritage, and Scientific Validation of Performance – Miha Humar, Boštjan Lesar

Engaging Citizens in Building a Digital Twin for Cultural Heritage in Koper – Ana Slavec, Črtomir Tavzes, Miklosz Kresz

The two Ancient Egyptian Sarcophagi in Vipava: Assessment of Heritage Value and Conservation Concerns for Site Management – Abdelrazek Elnaggar, Andrea Petrović, Darya Herman, Siniša Sekulić, Sonia Covolo Ciuch, Stefan Pemper, Tijana Marković, Eva Grmek, Jasna Fabčič, Jure Peršolja, Matejka Fajdiga, Ernesta Drole, Jan Ciglenečki

Rethinking Historical Wood Waste – Aljona Gineiko

11:30–13:00 Lunch & Poster Session

13:00–14:15 Session 3 chaired by Gregor Pobežin

Dating the Beginning of the Late Bronze Age – Boris Kavur, Martina Blečić Kavur, Andreea Dima, Oana Gaza, Maria Ilie, Cristian Manailescu

Archaeological Heritage in Motion: Interdisciplinary Approaches to Interpreting Early Medieval Identities in the Eastern Alps – Andrej Magdič

The Shipwreck of Gnalić: Revealing the Story Behind – Irena Lazar, Zrinka Mileusnić

Interactive Entry into the Ship Interiors of Lost Slovenian Vessels – Boris Beja, Žiga Ceglar, Marko Stražar, Tis Loris Lavrič

Remote Sensing Documentation for the Protection of Montenegro's Underwater Cultural Heritage – Darko Kovačević

14:15–14:30 Closing remarks: Zrinka Mileusnić, Boris Kavur

14:30–15:30 Laboratory Tour

Vania Virgili
Director General
of E-RIHS ERIC

From Physical to Digital: Advancing Heritage Science through E-RIHS

The digital transformation of heritage science is reshaping how cultural assets are analysed, preserved, and shared. The European Research Infrastructure for Heritage Science (E-RIHS, www.e-rihs.eu) spearheads this shift by integrating physical and digital access to advanced techniques and resources across Europe. Its mission is to create a cohesive environment where research infrastructures, tools, and data enable collaboration and innovation in cultural heritage. Established as a European Research Infrastructure Consortium (ERIC) in March 2025, E-RIHS integrates diverse scientific disciplines – ranging from chemistry and physics to art history and archaeology – to promote open, data-driven approaches for heritage conservation and research.

E-RIHS provides physical and virtual access to four complementary research platforms. ARCHLAB offers access to scientific archives and reference collections; FIXLAB to large-scale analytical facilities for advanced diagnostics and archaeometry; MOLAB to mobile, non-invasive instrumentation for in situ investigations; and DIGILAB, the newest platform, enables access to digital data, semantic tools, and cloud-based services. DIGILAB's architecture follows FAIR principles and the heritage digital-twin model, linking research questions, instruments, data, and knowledge through interoperable workflows.

The development of DIGILAB marks a significant evolution from physical to digital services within E-RIHS. The E-RIHS Catalogue of Services federates more than one hundred European services and collections under a unified access framework and introduces new digital services, such as ATON for 3D visualisation, Movida for data integration, and aioli.espadon for semantic annotation. Together, these tools allow researchers to conduct heritage science directly within virtual environments, promoting data reuse, transparency, and collaboration across disciplines and institutions.

E-RIHS aligns with the European Cloud for Heritage OpEn Science (ECHOES, www.echoes-eccch.eu) to build the European Collaborative Cloud for Cultural Heritage (ECCCH). This ecosystem connects infrastructures, data spaces, and open-science communities, advancing Europe's leadership in digital heritage. By bridging physical and digital access, E-RIHS fosters a sustainable, interconnected

Figure 1 ARCHLAB (Prado archives, Madrid)

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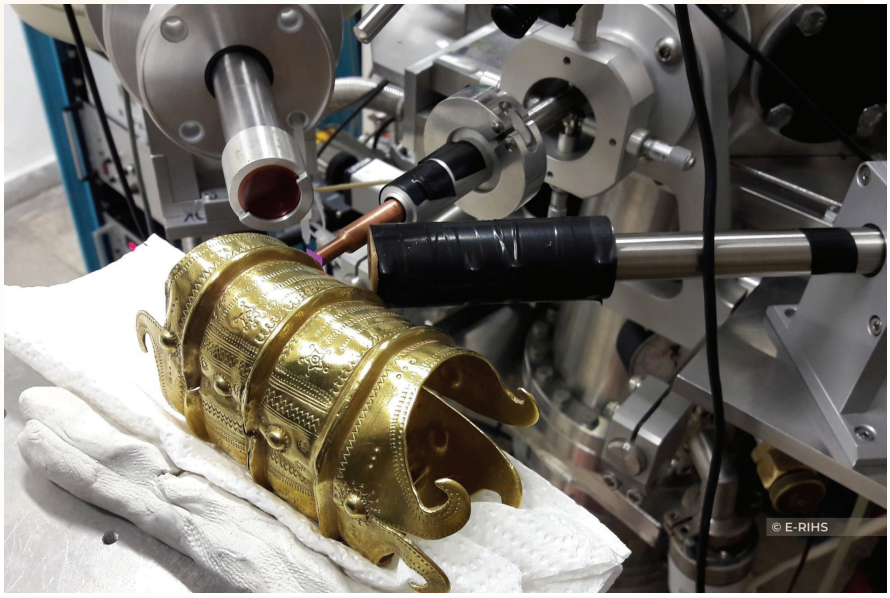

Figure 2 FIXLAB analysis (MTA Atomki, Hungary)

model for cultural-heritage science, ensuring that knowledge remains accessible, reusable, and impactful for future generations.

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From the European Directive to the National Strategy: Establishing an Ecosystem for Digital Cultural Heritage in Slovenia

The establishment of the European Data Space for Cultural Heritage is based on a European legal framework that links digital policy, culture, research, and intellectual-property protection. A key document is Directive (EU) 2019/1024 on open data and the re-use of public-sector information, which also requires cultural institutions (museums, libraries, archives) to make open data available for re-use without restrictions. The Directive introduces the concept of 'high-value datasets,' the re-use of which brings significant benefits for society, the environment, and the economy. Cultural-heritage data are included in this category. In line with the European Strategy for Data (2020) and Commission Recommendation (EU) 2021/1970 on a common European data space for cultural heritage, the European Collaborative Cloud for Cultural Heritage (ECCCH) is being developed, which by 2029 will provide secure storage, interconnection, and access to heritage data at EU level.

The National Strategy for Digital Cultural Heritage, prepared within the AID HCH project, provides the framework for these activities. It aims to establish an open, interoperable, and sustainable ecosystem that will enable the publication, long-term accessibility, and re-use of data. It emphasises the importance of adopting metadata standards and schemes and ensuring interoperability between institutions, supporting research with artificial intelligence, developing data literacy, and engaging the public. Equally important is the provision of ethical and legal frameworks to protect sensitive content and enable the responsible use of data. Alignment with European practices will allow Slovenia to strengthen the sustainable use of digital-heritage resources while increasing their scientific value and societal accessibility.

An important contribution to these goals will be DIGILAB within E-RIHS (European Research Infrastructure for Heritage Science), designed to establish research infrastructure for the creation of digital content and the development of the data space. Slovenia participates as a member of the consortium through E-RIHS.si, which since 2018 has been connecting national research and heritage institutions. A key contribution of the Slovenian node will be the development of DIGILAB, where the National and University Library (NUK) will take part in high-quality digitisation, the design of metadata schemes, the system for assigning persistent identifiers, and the creation of a portal for data access. In this way, Slovenian heritage science will be directly integrated into European research and data flows.

Acknowledgements

The research paper was elaborated within the research project no. J7-60128: AID HCH – Breakthrough in humanities and cultural heritage with artificial intelligence, funded by the Slovenian Research and Innovation Agency (ARIS).

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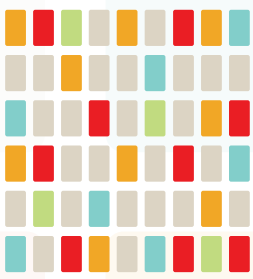

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Use of Data Spaces for Humanities and Cultural Heritage Research in the AID HCH Project

Although data spaces have become a recognised foundational technology for data sharing and the integration of distributed data sources in recent years, they still often get confused with traditional cloud systems and data centres. While the latter are mainly maintained as silos for storing and distributing data through application programming interfaces (APIs), data spaces merely hold the addresses of the APIs in a central catalogue, thus enabling access to multiple cloud systems concurrently through centralised services (Bacco et al., 2024).

In the research project 'AID HCH – Breakthrough in humanities and cultural heritage with artificial intelligence,' we address the development of a prototype data space to support the introduction of new artificial-intelligence concepts in the research of cultural heritage and the humanities. We primarily focus on developing a federated data catalogue and implementing services that will allow for simultaneously searching for data over multiple sources, fusing them, and training artificial-intelligence models that can be used for (i) studies of Slovene identity and the role of women, (ii) heritage narration, and (iii) preventive conservation.

The first stage of the development of the central data catalogue is focused on integrating spatio-temporal data that support all three targeted studies. This includes the registration of geographic maps, remote-sensing data (e.g. LiDAR), sensor data, and other documents that we geo-reference to selected spatial entities (e.g. newspapers to places), thereby creating a comprehensive picture of space and time. The observed spatial entities are then enriched with information obtained by processing individual data sources using trained artificial-intelligence models. The presented methodology has been integrated into a user-friendly node editor, as shown in Figure 1, which allows us to adapt the pipeline easily to different use cases (Lens, 2023).

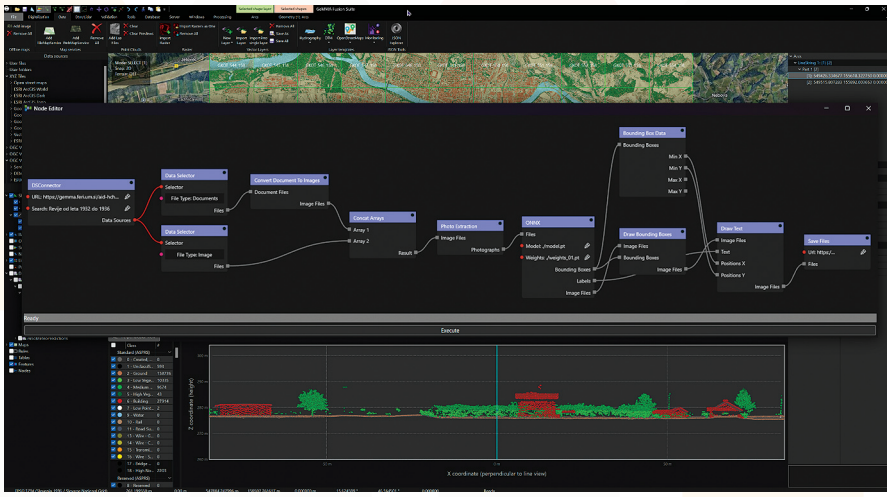

Figure 1 Graph-based pipeline for analysis of scanned documents and photographs built in a custom node editor

The validation of the presented methodology was done by investigating archived images and identifying samples that contain men, women or both, as presented in Figure 2. The preliminary results indicate that over 92% recall and precision can be achieved, thus showing the potential for upgrading the system into an actual semantic search engine.

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Figure 2 Detection of people in archived film photographs

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Big Data or Many Small Data? XML and CIDOC CRM in a Project on Medieval and Early Modern Epigraphic Heritage

Digital epigraphic projects are by no means a novelty. The Epigraphy.info platform, for instance, currently lists dozens of active initiatives. Since the emergence of the first digital epigraphic, palaeographic, and manuscript projects, scholars have grappled with a persistent challenge: how to translate more than a century and a half of established scholarly conventions – such as the Leiden standard in epigraphy – into a coherent digital format?

The research community has largely addressed this issue through the adoption and refinement of guidelines for textual encoding in XML, particularly the TEI standard (Text Encoding Initiative), which has become the foundation for the digital transcription of epigraphic texts. Within this framework, the EpiDoc subset of TEI provides a robust and well-tested schema for encoding inscriptions, and it remains the most widely accepted format for the digital transcription and interpretation of epigraphic sources.

However, a persistent limitation of the EpiDoc model is its insufficient capacity to represent event-based phenomena – those connected to the archaeological context of inscriptions and their intra- and extra-textual relationships. These relationships are essential not only for the interpretation of epigraphic material itself but also for its meaningful integration into broader historiographical or archaeological data environments. To address this challenge, several initiatives, such as the EAGLE Project, have proposed methodological frameworks for harmonising EpiDoc with the CIDOC Conceptual Reference Model (CIDOC CRM).

For medieval and early modern inscriptions, this harmonisation is not merely desirable but essential. Such inscriptions – simultaneously material and immaterial artefacts – often refer to entities that also appear in palaeographic, archival, and other historical sources. The integration of the TEI/EpiDoc and CIDOC CRM data models thus provides a coherent response to the central question of how to interlink diverse yet related datasets.

By analysing a sample epigraphic record encoded in both the EpiDoc and CIDOC CRM frameworks, this paper demonstrates how an inscription can be described, concluding with a discussion of why both perspectives are indispensable for a comprehensive understanding of epigraphic heritage.

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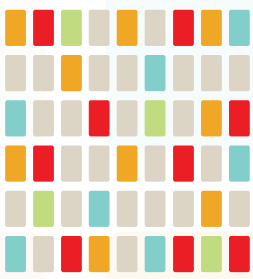

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New Insights into Early Iron Age Iron Production in the SE Alpine area: Case Studies from Cvinger near Dolenjske Toplice and Pungrt above Ig

Iron metallurgy undoubtedly played an important role in the wide range of changes that occurred in the Early Iron Age, far beyond the Eastern Hallstatt Area. A key to its better understanding are interdisciplinary studies, which offer new data and can significantly supplement our previous knowledge about smelting of iron ore as well as smithing of iron objects.

The prehistoric complex of Cvinger near Dolenjske Toplice occupies a strategic position between the regions of Dolenjska and Bela krajina. It has yielded important finds for understanding the Late Hallstatt period (6th–4th century BC) and contains the largest known iron-smelting area in the region. Interdisciplinary research campaigns at Cvinger have combined modern remote sensing techniques, such as airborne laser scanning, multimethod geophysical surveys and geochemical mapping, with established archaeological methods. The results have provided new insights into the entire complex, including the chronological refinement of the iron-smelting area.

At the Pungrt Hillfort–an early urban settlement in central Slovenia inhabited from the 8th/7th century BC to the 2nd century AD – the abundant macro-remains of iron slag, found primarily in secondary refuse contexts, provide clear evidence that iron metallurgy played a significant role in the settlement's economy. However, only an integrated geoarchaeological approach allows reliable identification of the primary locations of metallurgical production within the site. Scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS)

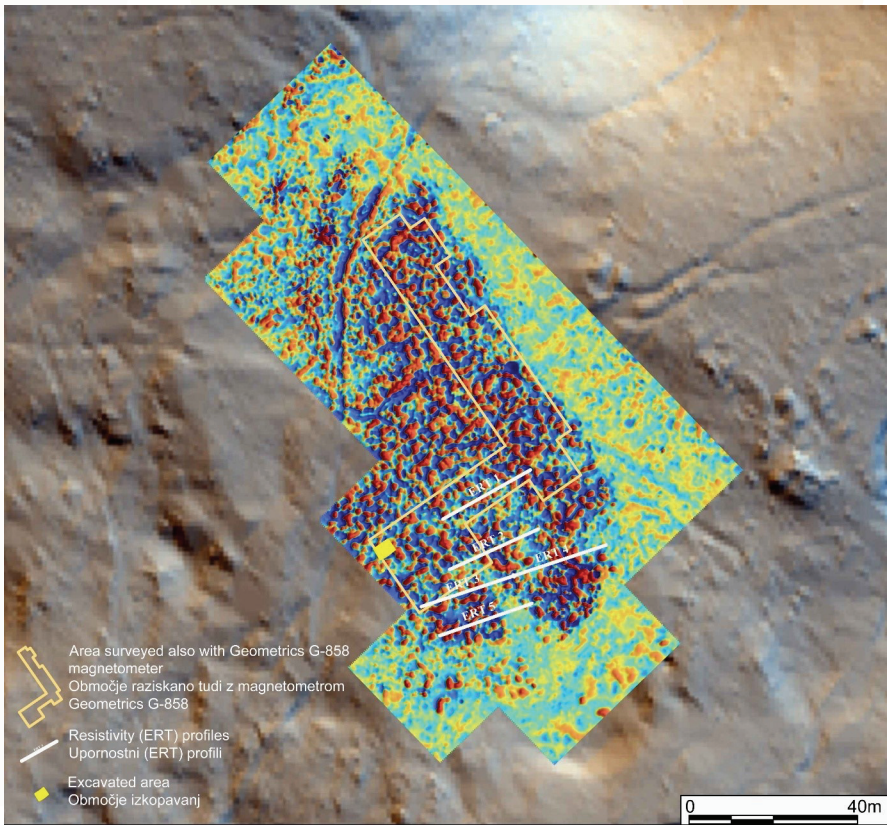

Figure 1 Branževec iron ore smelting site below the Cvinger hillfort near Dolenjske Toplice: Results of the magnetic prospection (figure by: B. Mušič; see Mušič & Orengo, 1998, and Črešnar et al., 2020)

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examination of the iron-working debris (hammerscale and slag) provided what is believed to be the earliest clear evidence for the use of flux in iron welding during the Early Iron Age. In addition, the full range of micro-refuse discovered allows us to infer that the blacksmith was probably involved in the entire chaîne opératoire, from ore procurement and processing to the final shaping of the iron objects.

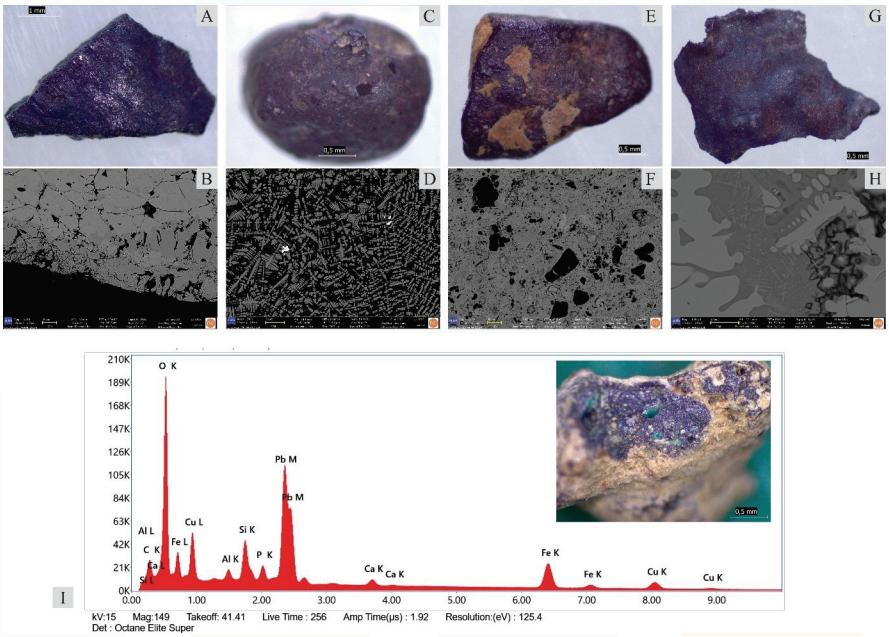

Figure 2 Pungrt hillfort. SEM-EDS analysis of micro-refuse from Building 24 in IIb2 phase. Flake hammerscale (A) photograph and (B) SEM image showing hammerscale with various ferrous oxides. Spheroid hammerscale (C) photograph and (D) SEM image showing dendritic microstructure typical for solidification. Miscellaneous hammerscale (E) photograph and (F) SEM image showing hammerscale, different ferrous oxides with flux. Slag (G) photograph and (H) SEM image showing solidification microstructure of slag. (I) Photograph of slag and EDS spectra showing presence of Pb and Cu, typical for copper smelting (figure by L. Gruškovnjak, J. Burja & B. Šetina Batič; see Gruškovnjak et al., 2025).

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Preservation of the Archaeological Record and Grave Goods at the Pezdirčeva Njiva Cemetery: An Integrated Geoarchaeological, Archaeometric, and Conservation Science Approach

Pezdirčeva njiva is an extensive Iron Age cemetery located on the terminus of Kučar's western backslope. In use from the Late Hallstatt into the La Tène period (late 5th–2nd centuries BC), it contains both burial mounds and flat graves, with skeletal burials predominating and a smaller number of cremations. A total of 183 graves, excavated between 2017–2021, were preserved exclusively within the site's B horizons. Archaeometric analyses of bronze and iron artefacts from Late Dolenjska Hallstatt and Vinica type graves revealed the counter intuitive result that metal objects were, overall, better preserved in the older graves.

In this study, we examine how the interplay of natural and anthropogenic processes over time shaped the stratigraphic record at the site. We also aim to explain the preservation of grave goods at Pezdirčeva njiva within the broader context of the site's palaeoenvironment and soil development. Drawing on three integrated datasets-the site's soil stratigraphy, the geochemical and micromorphological properties of the soils, and a geomorphic analysis of slope processes-we developed two theoretical models: the first reconstructs site specific soil development throughout the Holocene, and the second explains the transformation and preservation of the archaeological record and artefacts.

The soil stratigraphy at the cemetery indicates that the degradation of the archaeological record and artefacts in the Late Hallstatt period graves, driven by bioturbation, eluviation-illuviation, and redox processes, accelerated only after agricultural fields were established over the burial site and the burial mounds had eroded from the surface. These processes began to affect the Late Hallstatt record significantly later than they did in the flat Vinica type graves, which have been continuously exposed to them since the La Tène period. Consequently, the archaeological record of the Vinica type graves is considerably more degraded, and the artefacts within them are more poorly preserved. The model therefore offers a plausible explanation for the apparent paradox that the younger flat Vinica type graves, together with their grave goods and the overlying buried soils, are less well preserved than the Late Hallstatt period buried soils and graves with artefacts beneath the burial mounds.

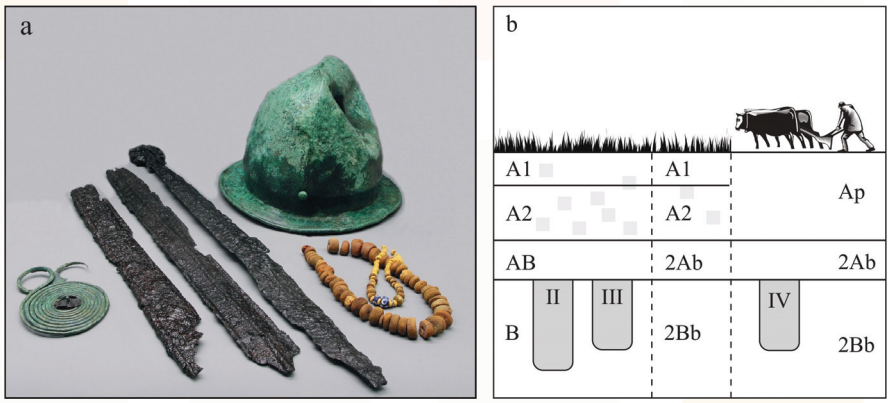

Figure 1 Grave goods and the archaeological record from Pezdirčeva njiva: (a) bronze, iron, amber, and glass artefacts from Dolenjska and Vinica-type graves at Pezdirčeva njiva (photo: N. Nemeček); (b) pedostratigraphic contexts at the site: Late Hallstatt-period burial mounds (left and middle columns) and flat Vinica-type graves (right column).

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Lecture

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Development of an Analytical Method for the Reconstruction of Historic Smells through GC-MS-O and Sensory Evaluation

Volatile organic compounds (VOCs) released by heritage objects not only reveal their material composition and state of preservation but also constitute their characteristic scents. In recent years, the study of heritage smells has attracted growing attention, highlighting their value in interpreting history and expanding cultural engagement (Bembibre, Barratt, Vera, & Strlič, 2017).

To characterise the olfactory profile of historical materials, both chemical and olfactory information are essential. These are obtained through gas chromatography coupled with mass spectrometry and olfactory detection (GC-MS-O), complemented by sensory analysis by a panel of trained assessors (Paolin et al., 2025). Our research aims to study and reconstruct historical smells by correlating chemical data with olfactory descriptors.

The reconstruction process begins with an assessment of the olfactory relevance of identified compounds calculated using odour activity values (OAVs), i.e., the ratios between compound concentrations and their odour detection thresholds. This ensures that only relevant odorants are considered. These results are compared with the odorants detected as 'strong' during GC-O analysis and their corresponding compounds. These are then cross-validated and aligned with the olfactory descriptors defined through sensory panel evaluations. Once the correspondence between chemical and sensory descriptors is established, the key compounds and their OAVs are used to develop the reconstructed mixtures.

As a case study, we examined the headspace of a historic perfume from the 1940s. The reconstruction process begins with a minimal set of five key compounds and is progressively expanded. GC-MS-O analysis identified 15 principal odorants, including linalool, linalool oxide, p-cymene, eucalyptol, and camphor, which contribute to its floral and fresh character. Each stage of the reconstruction was validated through panel assessments and GC-MS analysis to ensure both sensory and compositional similarity to the original sample.

This methodology provides a robust framework for the preservation and reconstruction of heritage scents, offering museums and cultural institutions new opportunities to present olfactory heritage and enhancing visitor immersion and engagement.

Acknowledgements

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Reassessing the Risk of VOC Emissions from Archival Storage Boxes

The long-term preservation of paper-based heritage collections depends not only on environmental control but also on the chemical safety of storage materials. Volatile organic compounds (VOCs), particularly acetic acid, emitted from archival boxes are often cited as a preservation risk (Menart, de Bruin, & Strlič, 2014), yet their actual impact under realistic conditions remains poorly quantified.

In this study, we assessed VOC emissions from archival storage materials including polypropylene, coated and uncoated cardboards, recycled and speciality papers, naturally aged and lignin-based boards. Emissions were analysed using thermal desorption-gas chromatography-mass spectrometry (TD-GC-MS) and ion chromatography (IC). Paper and metal Oddy tests were applied to assess potential preservation risks, while equilibrium acetic and formic acid concentrations in boxes were modelled at room temperature using measured emission rates and realistic air-exchange rates (Novak, Grau-Bové, De Stefani, Kraševec, & Strlič, 2024; Ramalho, Dupont, Egasse, & Lattuati-Derieux, 2009).

Results showed that polypropylene and archival-quality cardboards primarily emitted inert hydrocarbons with low levels of organic acids, yielding neutral or even preservative outcomes in Oddy tests. Conversely, aged lignin-based and coated cardboards released higher levels of volatile acids and showed more severe Oddy test responses. Yet, equilibrium modelling demonstrated that even the highest-emitting materials did not generate acid concentrations exceeding the 100 ppb threshold generally regarded as harmful for paper. Importantly, elevated concentrations measured in practice are more attributable to emissions from the stored paper itself rather than from the enclosures.

These findings indicate that accelerated Oddy tests overestimate the risks posed by packaging materials. Room-temperature emission assessments combined with ventilation modelling provide a more reliable framework for evaluating preservation risk. Archival box suitability should therefore be judged primarily on mechanical stability and humidity-buffering performance rather than VOC emissions. Overall, VOCs from box materials-including acetic and formic acids-are not a significant concern under typical storage conditions, supporting a more evidence-based approach to preventive conservation (Deraz, Di Gianvincenzo, Malešič, Kralj Cigić, Elnaggar, & Strlič, 2025).

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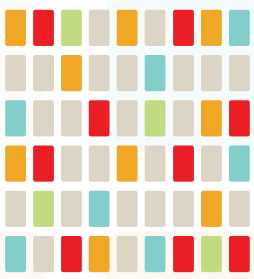

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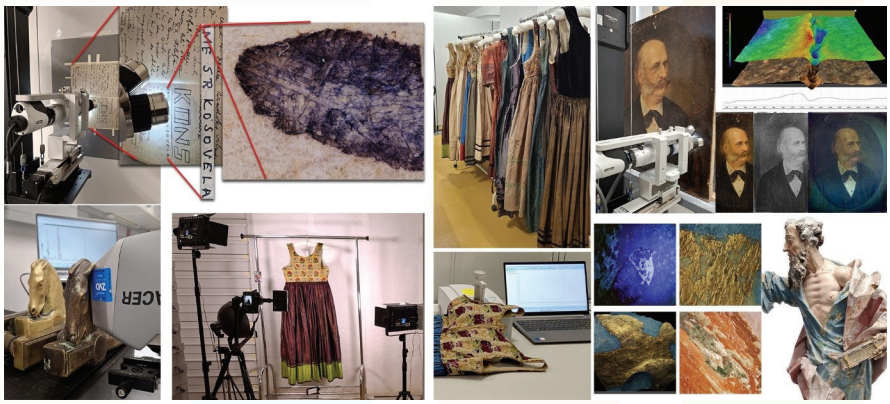
E-RIHS.si Multi-Analytical Approach to Heritage: Insights from the Heritage Science Lab Ljubljana

The European Research Infrastructure for Heritage Science (E-RIHS) provides state-of-the-art facilities, advanced methodologies, and interdisciplinary expertise for the heritage science community. Within its Slovenian national node, E-RIHS.si, the Heritage Science Laboratory Ljubljana (HSLL) plays an active role with a particular research focus on heritage collections, visualisation, and digitisation. This abstract highlights the utilisation of E-RIHS.si services and network-building for collaborative research between Slovenian academic and heritage institutions. Recent examples of this collaborative research include HSLL's extensive investigations into textile heritage, linked with an ongoing doctoral research project. Non-destructive and in situ multi-analytical surveys using technical imaging, FTIR spectroscopy, microscopy, and XRF were carried out on textile collections from the Slovene Ethnographic Museum and the Maribor Regional Museum. These analyses enabled the identification of fibres, mordanting, weighting, and dyeing techniques, adding a new layer of information to museum collections. This multi-analytical approach has significantly advanced our understanding of textile degradation mechanisms and informed conservation strategies.

Beyond textiles, investigations into diverse heritage objects have been conducted through E-RIHS.si access projects for high-resolution imaging, scientific documentation, material characterisation, training, and education. At the National Museum of Slovenia, FTIR spectroscopy and digital microscopy identified a casein plastic inlay in a Baroque chair. At the National and University Library (NUK), a comprehensive, multi-faceted investigation was conducted on a selection of manuscripts by the renowned Slovenian poet Srečko Kosovel. The study integrated advanced analytical techniques including multispectral and hyperspectral imaging, near-IR and FTIR spectroscopy. This was complemented by high-resolution photographic documentation and ultra-high-resolution digital microscopy, utilising automated image stitching to create a single gigapixel-scale representation for micro-scale analysis. This integrated approach, supported by data-analysis tools, allowed for the detailed examination of material composition, ink formulation, and the micro-topography of the substrate, providing unprecedented insight into the work's creation and preservation state.

Additionally, at NUK, XRF analysis was applied to three historical metal door handles. One is suspected to be a later copy, and elemental analysis is expected to help identify any compositional differences that could support their classification. At the Posavje Museum Brežice, XRF and FTIR analyses were used to investigate the composition of a historical Baroque sled and to explore the pigment palette used on the walls of the Knights' Hall in the castle. At the Academy of Fine Arts and Design of the University of Ljubljana, technical documentation, sci-



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entific imaging, and microscopic analysis have been applied to paintings, sculptures, and historical artefacts.

A core element of our work is the production and management of high-quality imaging and analytical data, forming the foundation for research, documentation, and heritage preservation. The integration of digital imaging, spectroscopy, and data processing not only facilitates object-level analysis but also supports broader efforts in digitisation, comparative studies, and long-term digital preservation. These datasets are compiled into rich digital corpora and delivered to heritage institutions as comprehensive technical reports, raw source files, and, in some cases, scientific publications.

Through in-depth studies of diverse heritage materials, this collaborative research demonstrates the versatility, reach, and impact of the E-RIHS.si network. It shows how a coordinated national infrastructure can effectively support academic research, cross-institutional collaboration, and heritage conservation.

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Documenting the Senses: The Inclusion of Smell in the Register of Intangible Cultural Heritage of Slovenia

In the preservation of intangible cultural heritage, the importance of multisensory documentation is increasingly recognised, yet the olfactory dimension remains significantly under-represented in official heritage registers. This study explores the role of smell in the Register of Intangible Cultural Heritage of Slovenia, filling a critical gap in contemporary register practice that traditionally privileges visual and auditory elements over other sensory experiences (Dečko, Zidarič, & Ramšak, in press).

In this research, a comprehensive analysis of the Register of Intangible Cultural Heritage of Slovenia was conducted, in which all registered entries were systematically analysed for explicit and implicit references to olfactory elements. The methodology included a qualitative content analysis of the register entries, structured interviews with heritage bearers, and a comparative assessment of current register protocols. Data collection focused on identifying patterns of odour-related content across different heritage categories and assessing the discrepancy between the entries in the register and the experiences of heritage bearers. The analysis revealed that fewer than 4% of the registered entries explicitly mention odour, representing a significant under-representation of the olfactory elements of cultural heritage. However, in-depth interviews with heritage bearers showed that odour is afforded much greater importance in different heritage areas. Four main categories of smells emerged: food aromas that serve as quality indicators of traditional culinary practices; plant and animal scents associated with agricultural and pastoral traditions; medicinal scents associated with healing practices; and characteristic craft smells that characterise artisanal production processes. Heritage bearers consistently emphasised smell as a key indicator of the quality of traditional practices, underlined the central role of olfactory memories in the transmission of traditions between generations, and reported the regular inclusion of smell-based elements in public heritage presentations and educational activities.

These findings reveal a significant gap in the Register of Intangible Cultural Heritage of Slovenia and demonstrate a discrepancy between the lived experiences of cultural heritage and the entries in the register. This suggests that current

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registration practices do not capture the essential sensory dimensions of cultural heritage. The research shows that olfactory elements are more than peripheral features-they serve as fundamental markers of authenticity, quality-control mechanisms, and powerful means of preserving cultural memory.

This study demonstrates the importance of systematically integrating multisensory approaches into the Register of Intangible Cultural Heritage of Slovenia. It recommends the introduction of specific protocols for assessing the sense of smell in the register's entries; the development of standardised terminology for describing olfactory characteristics; and the creation of a systematic framework for recording subjective sensory experiences of heritage bearers. These improvements would significantly increase the authenticity and completeness of register entries and ensure that future generations have a comprehensive understanding of traditional practices. The results also have far-reaching implications for international heritage registers and suggest that multisensory approaches are an essential evolution of heritage recording methods rather than optional extensions.

Acknowledgements

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Re-Reading the Building's History by Merging Architectural, Technical, Historical, and Ethnographic Approaches

Interdisciplinarity is fundamental in the field of conservation, bridging heritage science and heritage studies. A particularly enriching approach is the integration of ethnographic research, oral history, architectural analysis, technical investigations, and archival sources, offering new insights into a building's history and its significance. In this context, we present a case study of the Servite Monastery in Koper/Capodistria, Slovenia, which exemplifies the potential of interdisciplinary and transdisciplinary methods. Over 15 years of research have uncovered the site's historical layers, enhancing our understanding of its complex past, particularly in a region marked by contested historical narratives.

The study employed a range of methods: architectural analysis; historical imagery (early 20th-century photographs); ethnographic research based on 'group memory talks' and the 'photo-voice' method; and participatory citizen-science approaches via an online memory book. These methods provided a comprehensive understanding of the site, with a focus on its recent history, often neglected in traditional significance assessments that prioritise its monastic period. Recent research into the material qualities of the complex investigated discarded timber elements and their potential for reuse.

Our findings highlight the tangible (spaces, material qualities) and intangible (functions, affective dimensions) attributes of the site, particularly its role as a maternity hospital. The transdisciplinary approach has proven essential in fostering an inclusive and sustainable appreciation of the site, offering a broader, more nuanced interpretation of its value for both the local community and heritage-conservation practice. The environmental benefits from long-term reuse of the discarded timber elements add another dimension to the site's societal value.

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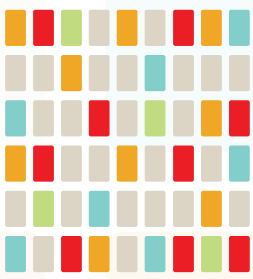

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Conservation Metamorphoses of Ptuj

We illuminate conservation approaches through three key revitalisation projects undertaken in the past decade in the preservation of Ptuj's heritage, which have proved decisive in the revival of the historic city centre. Ptuj is one of the oldest- but also one of the most vulnerable-monumental environments in Slovenia, where conservation work poses a considerable challenge. It is therefore essential to emphasise the continuous presence of the monument-protection service and the interdisciplinary teamwork of conservators, in which close collaboration with architects is crucial. Through three large-scale and demanding projects, we present distinct problems, approaches, and solutions that have revitalised these historically important areas from ambient, scenographic, architectural, and urban perspectives.

The former officers' pavilion at Vičava 1, built in the Art Nouveau style between 1903 and 1905, is an example of renovation in which the conservation regime- beyond the basic goal of rehabilitation and revitalisation of the building for business use (Technology Park) – required that the building, in as intact a state as possible, continue to shape the wider setting of the cultural monument of national importance. At the same time, it had to maintain characteristic views towards the castle and from the castle. These principles guided the planning of conservation interventions in the building and its surroundings.

By contrast, the long-decaying buildings of the so-called Old Glass Workshops provide an example of the comprehensive renovation of a quarter of bourgeois architecture that developed from the 15th century onwards. Revitalisation of the area – together with the associated streets and Vraz Square – created conditions for creative, cultural, and event activities (Youth Cultural Centre). The conservation baseline was set as the conservation-restoration of all valued elements, in order to preserve the quarter's heritage potential despite the collapse of essential parts of the area. Conservators preserved the historical character of the quarter and directed contemporary architectural interpolations so that new interventions harmonise with the historic urban fabric.

The renovation of the Ptuj city marketplace illustrates a conservation approach to redesigning and redefining an open urban public space in the heart of the city. The starting point for the scheme was analysis and interpretation of historical sources and of the appearance of this area along the former riverbed of the Grajena.

Interpreting Ptuj's historical urban image is also vital for local residents, as such presentations of the past help establish an authentic sense of identity with the city inherited from former inhabitants. With effective cooperation, a shared interdisciplinary vocabulary, responsiveness to the wishes and needs of the local community, and – above all – mutual respect, projects of this kind present conservators with the challenge and responsibility of transmitting to posterity the enduring message of place through high-quality, modern renovation.

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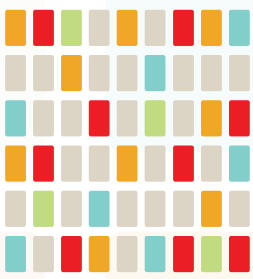

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Uncovering Autochthonous Deteriogenic Biofilm and Developing Beneficial Bacteria-Based Bioformulations from Indigenous Isolates for Biocontrol and Biocleaning of the Rožanec Mithraeum Limestone Monument

The conservation of the Rožanec Mithraeum limestone monument in Slovenia demands an integrated understanding of the fungal and bacterial communities driving surface alteration and deterioration. High-throughput mycobiome sequencing (metagenomic) combined with light, FTIR, and Raman microscopy identified the epilithic lichen Gyalecta jenensis and its carotenoid-rich photobiont Trentepohlia aurea as the source of the salmon-hued biofilm on the monument. Biopitting – the principal deterioration symptom – was attributed to endolithic thalli and ascomata of Verrucaria sp., whose oxalic-acid secretion dissolves carbonate substrates. FUNGuild analysis further confirmed a high relative abundance of lichenised and symbiotrophic fungi as key deteriogens.

In the next step, the monument's indigenous bacterial community – isolated and identified during the initial metagenomic phase – was analysed as a basis for developing a synergistic bacterial consortium with the potential to be reintroduced for biocontrol and biocleaning treatment of the same Mithraeum monument. Parallel 16S rRNA gene metabarcoding revealed that Proteobacteria, Actinobacteriota, and Cyanobacteria dominate the indigenous bacterial community, while culturable isolates were chiefly Bacillus and Paenibacillus. Enzymatic profiling highlighted Bacillus mycoides MIT8.7 and Paenibacillus amylolyticus/taichungensis/tylopili/tundrae MIT8.18 as potent producers of amylase and protease, with subsidiary lipase, cellulase, mannanase, and xylanase activities essential for biocleaning.

Plate-growth inhibition assays (PGI%) pinpointed Bacillus velezensis MIT7.8 and Pseudomonas chlororaphis subsp. aurantiaca MIT4.11 as the most effective antagonists against seven autochthonous biodeteriogenic fungi. Additionally, full cultures of Streptomyces anulatus 1–3 TSA and Streptomyces sp. 11-11MM matched the efficacy of commercial biocides (0.3% Preventol RI80, 100% Keim, 100% BFA) without inducing changes in surface roughness (Rq, Ra) over three months on locally sourced limestone models.

By elucidating indigenous bacteria capable of targeted biocontrol and biocleaning, this study lays the groundwork for an eco-friendly, in situ bacterial consortium. Such a formulation promises an effective alternative to traditional chemical biocides for the long-term preservation of stone cultural heritage.

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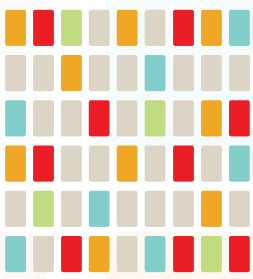

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Between Villa Rafut and Rafut Park: Monument's Protection History

The central theme of my bachelor's thesis was an analysis of Villa Rafut (1909–1914) in Pristava near Nova Gorica – designed by the architect Anton Laščak (Antonio Lasciac) – in relation to the accompanying park, within the context of heritage protection. Villa Rafut is widely recognised in international academic literature as an example of the direct transfer of architectural stylistic innovations. Laščak's international renown stems from his pioneering contributions to Neo-Islamic – more specifically Neo-Mamluk – style, which emerged in Egypt at the turn of the twentieth century.

Following nationalisation, the villa was designated to house the district Hygienic Institute, while the area encompassing the park was recognised as a natural heritage site of national significance. Significant changes took place only in 2003, when the villa was formally recognised as heritage and incorporated into the park complex. Since then, the villa and park have constituted a single cultural monument of local importance, representing garden-architectural heritage.

Figure 1 Villa Rafut (https://www.rafutskipark.si/sl/zgodovina/)

Figure 2 Portrait of Anton Laščak, c. 1906–1908 (ERPAC – Servizio Musei e Archivi Storici, Fototeca Musei Provinciali di Gorizia; in Kovšca, 2017)

The current decree reveals inconsistent and fragmented protection of the two parts of the monument complex, as evidenced by the naming of the monument unit as 'Rafut Park with the villa.' The unit's unusual name not only indicates the consequences of past functional separation but also points to possible echoes of unjustified neglect of the monument's historical, artistic, and architectural values in representational strategies currently discussed in the context of the monument's revitalisation.

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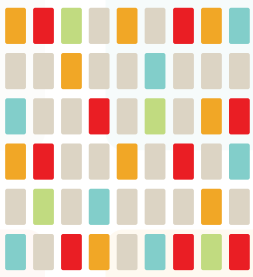

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Wooden Single Roofs in Slovenia: Tradition, Intangible Heritage, and Scientific Validation of Performance

Wood has been a traditional roofing material in Europe and beyond, with widespread use on significant buildings during the 17th century. Today, wooden roofing persists mainly on huts and houses in Alpine regions, where it represents both tangible and intangible cultural heritage. Despite its high cost, wooden roofing remains valued for its durability in harsh mountain climates, particularly in Slovenia. The most common roofing elements are split wooden shingles made from spruce (Picea abies) and occasionally larch (Larix decidua). Several traditional beliefs regarding the harvesting time, preparation, and performance of wooden shingles continue to circulate but lack scientific validation.

This study combined historical review, field surveys, documentation of the shingles production, laboratory experiments, and a citizen science approach. Laboratory and field tests were performed to evaluate the moisture performance of split and sawn shingles. Moisture monitoring was established on several roofs in Trenta Valley and in the Ljubljana test field. In parallel, a citizen science project was launched to document the distribution, condition, and typology of wooden roofs across Slovenia. Citizens contributed photographs and data on existing shingle roofs in various Alpine regions, including southern Carinthia, Trenta, the Gornjesavska Valley, and Velika Planina.

Experimental testing demonstrated no significant superiority of split shingles over sawn shingles in terms of moisture performance. The citizen science initiative provided extensive documentation of existing shingle roofs, enabling the mapping of their distribution and identifying regional practices in shingle application and maintenance.

The findings challenge long-held traditional beliefs about the superior durability of split shingles, emphasising the need for evidence-based approaches in preserving wooden roofing practices. At the same time, citizen participation has proven effective in recording the cultural and architectural significance of wooden roofs in Slovenia, contributing to both heritage preservation and scientific research. The combination of experimental testing and public engagement provides a framework for sustaining traditional Alpine architecture while safeguarding associated intangible heritage.

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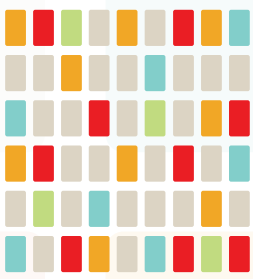

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Engaging Citizens in Building a Digital Twin for Cultural Heritage in Koper

The MonuPED project tackles the complex challenge of establishing Positive Energy Districts (PEDs) within monument-protected areas (MPAs), where energy-transition goals often conflict with cultural-heritage preservation. This citizen-science initiative, led by the Institute for the Protection of Cultural Heritage of Slovenia (ZVKDS) in collaboration with InnoRenew CoE, focuses on the historic centre of Koper – a densely built urban area with many protected buildings. These protections pose barriers to energy-efficient renovations, such as thermal insulation or solar-panel installation.

To address this, the project will actively engage citizens in data collection, enriching existing datasets with first-hand information about their buildings. This data will support the development of agent-based models that simulate stakeholder behaviour and help identify solutions that balance heritage conservation with sustainable energy practices. The project will use snowball sampling to recruit participants, beginning with interviews and progressing to focus groups and co-creation workshops. These activities will foster dialogue, raise awareness, and empower citizens to become co-creators of change.

The initiative also promotes open science, with a data-management plan aligned with FAIR principles and a commitment to ethical data handling. Educational materials and outreach activities will ensure broad public engagement, while results will be shared with policymakers across sectors – science, culture, energy, and urban development.

Ultimately, the project aims to catalyse a community-led urban transformation in Koper, serving as a model for similar initiatives across Slovenia and Europe. By integrating citizen input into research and planning, the project demonstrates how grassroots participation can drive innovation, improve energy efficiency, and preserve cultural heritage in the face of climate change.

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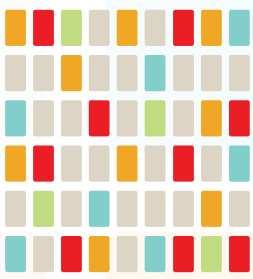

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The two Ancient Egyptian Sarcophagi in Vipava: Assessment of Heritage Value and Conservation Concerns for Site Management

The Egyptian heritage in Slovenia is scattered across national and regional institutions, which poses a particular challenge for its preservation, management and interpretation. Among the most significant examples are two sarcophagi from the Old Kingdom in Giza, which were originally created as resting places for the high-ranking officials Iun-Min and Ra-wer. They were discovered in the tombs of the courtiers at the end of the 4th/beginning of the 5th Dynasty of Ancient Egypt near the Pyramid of Khafre. Anton Lavrin, one of the most important Austrian Slovenian consuls and collectors, brought these sarcophagi to Slovenia, where they were converted into family tombs in his hometown of Vipava and are now privately owned. When they were opened in 1987, it was discovered that the sarcophagus of Iun-Min contained the remains of Lavrin's parents, while the sarcophagus of Ra-wer contained a small lead coffin with the exhumed remains of his son Albert.

Today, the sarcophagi are located in a public cemetery which, although accessible, is highly vulnerable to environmental exposure and vandalism. Although a protective roof was erected in the 1990s, the sarcophagi are exposed to rain, frost, wind, temperature fluctuations and accelerated decay due to their open location. The site is also endangered by uncontrolled public access, a common problem in Slovenian cemeteries.

Figure 1 Location of the ancient egyptian sarcophagi in Vipava (photo: Abdelrazek Elnaggar)

Through intensive archival research, on-site consultations and an on-site risk assessment, this study addresses key questions: How can the conservation and presentation of the Vipava sarcophagi be systematically managed in the context of the museological and conservation framework? What gaps still exist in the understanding of their reinterpretation and use in out-contextual settings? How can sustainable management strategies be developed to create a balance between

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conservation, public engagement and community involvement? And most importantly, how can diverse stakeholders contribute to a long-term management plan that ensures both preservation and relevance to contemporary audiences? The study emphasises the need for a collaborative approach engaging the researchers, tomb owners, local authorities and communities, which could also consider formal recognition and possible inclusion on the National Heritage List. This will also contribute to a better understanding of the ways in which diplomatic, scientific and social networks have influenced the dissemination, study and recontextualisation of Egyptian antiquities in Slovenia.

Figure 2 Fieldwork with students from the Faculty of Humanities, University of Primorska, within the Heritage Science course (Photo: Abdelrazek Elnaggar)

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Rethinking Historical Wood Waste

As restoration and conservation projects increasingly prioritise sustainability, the reuse and recycling of historical building materials are gaining attention. This study contributes to previous research (Fico, Rizzo, Malinconico, & Esposito Corcione, 2024) by exploring the suitability of historical wood waste as a 3D-printing material, addressing both heritage preservation and circular-economy goals. The research investigates how a 100-year-old wooden platband, found in a waste container, can be replicated from historical wood waste. To better understand the environmental impact of fabricating a platband replica from wood waste, the duration, energy consumption, and cost of the processes applied were documented and analysed.

The research was conducted in several stages. First, the historical platband was cleaned of paint and dust to prepare it for digital modelling. Sawdust for filament extrusion was prepared from non-conditioned pine beams and oak parquet of the same age as the platband. Polylactic acid (PLA) was chosen as a binder for the composite filament (Mosomi, Olanrewaju, & Adeosun, 2024). The study then proceeded with 3D printing using the fabricated filament. The final stage will involve outdoor moisture-content and biodegradability testing to evaluate the climate resistance of the printed replicas.

Preliminary results indicate that historical, non-conditioned wood waste combined with PLA can be extruded into a filament suitable for 3D printing. High-accuracy photogrammetry captured the structure and surface features of the historical artefact with precision, which were then transferred to the 3D-printed replica.

The digital-to-print route for the wood-waste/PLA composite required substantially more time, energy, and hands-on labour than producing a replica from new wood in a workshop. This shows that process optimisation remains an important goal for future work.

The method presented constitutes a sustainable conservation approach that aims for zero waste while respecting the value of historical artefacts, particularly when original materials are in poor condition. This technology has clear potential for multidisciplinary application.

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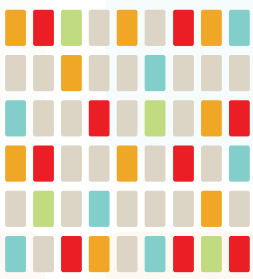

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Dating the Beginning of the Late Bronze Age

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As part of the FHŠ and IFIN-HH collaboration project, we performed a series of AMS datings of samples from the late 15th and early 14th centuries BC at the 1 MV Tandetron of the Department of Applied Nuclear Physics. The aim of the project was to date the oldest cremation graves in eastern Slovenia from the Završč cemetery and to synchronize the chronology of the beginning of the Late Bronze Age with the wider cultural area ranging from the Carpathian Basin to northern Italy. Based on the previous results of datings of various sites in the region, new datings and comparisons of the results, we demonstrated that the Urnfield Culture in Central-Eastern Europe begins around 1,420±20 BC.

As part of the project, we dated charcoal samples and samples of cremated bones from the same contexts. In the past experiments in controled environemnts clearly demonstrated that exchange of carbon between bone apatite carbonate and CO_2 in the combustion gases depend on both temperature and CO_2 concentrations. Hence CO_2 derived from woods from the cremation fires is likely substituted into the bone bio-apatite fraction explaining the remarkable similarity of σ13C values of cremated bones. Our assumption was that in open pyres the concentration of CO_2 was lover and that the age discrepamcy between the results could be explained with the old wood effect.

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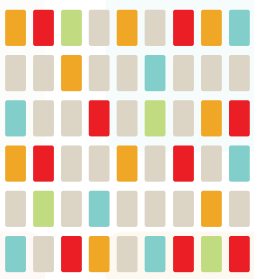

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Archaeological Heritage in Motion: Interdisciplinary Approaches to Interpreting Early Medieval Identities in the Eastern Alps

Community identities in the early Middle Ages have long been a defining theme in Slovenian historiography and archaeology, but the dominant narrative-shaped in the late eighteenth and nineteenth centuries-projected modern ethnic concepts deep into the past (Magdič, 2024). Drawing on social theory (Habermas; Bourdieu; Laurajane Smith), this paper shows how recent interdisciplinary research on migration, regional settlement patterns, and political organisation, based on computer models and archaeometric analyses of material culture, repositions early medieval settlers as dynamic communities rather than fixed ethnic groups, thus moving beyond traditional frameworks.

We combine critical discourse analysis of historiographical and archaeological texts (Magdič, 2024) with advanced spatial and computational approaches and archaeometric techniques. The use of machine-learning tools such as time-series clustering and emerging hot-spot analyses (Štular et al., 2022) and the results of petrographic investigation of pottery (Fazioli, 2024) are linked with the results of regional historical geolinguistic research (Magdič, 2022) to interpret patterns of movement, cultural interaction, and the formation of identities.

Our results show that nineteenth- and early twentieth-century scholarship entrenched nationalistic assumptions, while current interdisciplinary work reveals more complex pathways. Machine-learning analyses point to at least two waves of migration between c. 500 and c. 700 AD in the Eastern Alps that created complex community identities. Petrography shows a clear shift in ceramic technology from carbonate-rich late antique fabrics to gneiss-rich and grog-rich wares in the early Middle Ages, indicating both technological innovations and new community practices. Data on regional communities and dialect boundaries further illustrate the interplay of complex identity landscapes.

By integrating historiographical criticism, digital archaeology, linguistics, ceramic petrography, and social theory, we move beyond the nationalist narrative of the nineteenth century and develop a multi-scalar interpretation of early medieval communities. This approach considers material culture as habitus and identity practice and emphasises the need for closer collaboration with the natural and computer sciences to test hypotheses about mobility, provenance, and interaction. Interdisciplinarity combined with community-oriented theory thus enables a more nuanced and deeper understanding of archaeological heritage and its identity narratives.

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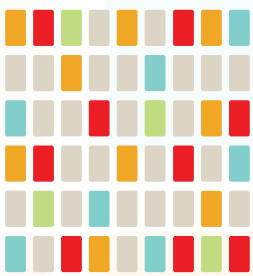

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The Shipwreck of Gnalić: Revealing the Story Behind

At first glance, the interpretation of the ship's contents and history seemed straightforward; however, only a detailed, interdisciplinary investigation of diverse sources – including scientific analyses of the glass materials – revealed the true story of the vessel and its cargo.

Within the international project The Heritage of the Serenissima under the Culture 2000 programme, a multidisciplinary team undertook one of the first comprehensive studies of the Gnalić wreck and its finds, building on the rescue campaigns carried out since the 1960s and subsequent archival research. The ship – identified as the Gagliana grossa, lost in 1583 – sank a few miles south of Biograd (Croatia), carrying a rich, mixed cargo.

Although the vessel transported a wide array of commodities – ceramics, metalwares, textiles, and raw materials – the predominant component of the cargo was glass. Thousands of glass items were recovered, including Italian tableware, drinking vessels, window-glass 'crowns,' mirror plates, and an intriguing set of objects with Eastern characteristics. Drawing on archaeometric analyses alongside archival evidence, recent work re-examines trade mechanisms, supply chains, and consumption patterns in the Eastern Adriatic during the late sixteenth century.

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Interactive Entry into the Interiors of lost Slovenian Ships

The paper examines the sculptural legacy of Stojan Batič, created for Slovenian ships of the Splošna plovba company, which remains largely inaccessible to the public. With his sculptures and reliefs, Batič adorned the ships Trbovlje (1960), Bela Krajina (1961), Ljubljana (II) (1964), Ljutomer (1965), Kras (1967), Postojna (1967), Portorož (I) (1968), and Portorož (II) (1986). In his works for ship interiors, he interpreted themes of community, mining life, the national liberation struggle, music, national history, the relationship between mother and child, Greek mythology, and dance.In the selected works created in the late 1950s and early 1960s, two of the artist's characteristic features are particularly evident in his interpretation of various stories and motifs, many of which relate to the places after which the ships were named. These are the perforated relief, which in its enlarged form serves as a visual complement to architecture, and his distinctive treatment of the sculptural surface, composed of geometric planes that resemble a network, honeycomb, or raster structure supporting narrative elements. The experimental part includes three-dimensional animations based on archival black-and-white photographs of ship interiors from Ljubljana and Portorož. The proportions of the spaces were determined using Batič's artworks as a reference. The reconstruction

Figure 1 Archive photographs of the ship's saloon with the relief of Batič (Splošna plovba Archive)

Figure 2 Final render of the reconstructed lounge with completed materials, lighting and post-processing (Marko Stražar)

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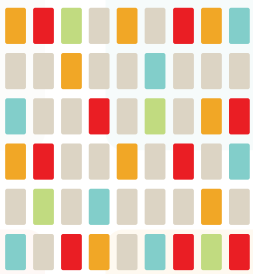

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aimed to present to the viewer the spaces once experienced by Slovenian sailors and visitors, which no longer exist today. The result of this research and creative process is a set of three-dimensional reconstructions of ship interiors that can be experienced through virtual reality technology as well as in the form of a two-dimensional video walkthrough.

Acknowledgements

Jerneja Batič, Duška Žitko, Splošna plovba, Mednarodni grafični likovni center.

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Remote Sensing Documentation for the Protection of Montenegro's Underwater Cultural Heritage

Montenegro's underwater cultural sites remain incompletely documented, limiting their legal protection, research, and long-term conservation. The 'Underwater Cultural Landscapes of Montenegro,' initiated by the Center of Archaeology, University of Montenegro, responds to this challenge by applying advanced remote-sensing technologies and interdisciplinary methods to support state institutions in the legal declaration of protection, and monitoring of these cultural resources, which are often invisible to decision-makers. The project integrates Multi Beam Echo Sounder and Side-Scan Sonar surveys with targeted underwater photogrammetry to produce high-resolution 2D and 3D datasets suitable for metric analysis, condition assessment, and monitoring. Built on inter-institutional cooperation and technical capacity developed through prior EU co-funded projects, the methodology prioritizes in-situ, non-intrusive documentation in accordance with the UNESCO 2001 Convention. Survey outputs are consolidated within a Geographic Information System database, ensuring standardized metadata and cross-sectoral access. Integration of the dataset into Montenegro's Spatial Plan until 2040 establishes a basis for including underwater cultural heritage in maritime spatial planning processes. Beyond regulatory aims, the project translates scientific outputs into public outreach campaigns, strengthening institutional capacities and supporting sustainable cultural tourism. Grounded in established acoustic-mapping and metric photogrammetry practices, the project delivers operational datasets and governance tools for accountable management of Montenegro's underwater cultural landscapes.

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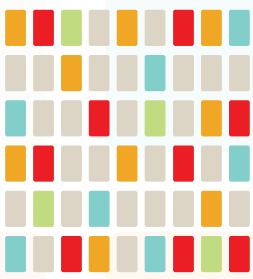

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A Vibrational Spectroscopic Study of a Medieval Sword from the Collection of the National Museum of Slovenia

A late-medieval longsword (inv. no. N40037) from the arms and armour collection of the National Museum of Slovenia represents a fine example of the fourteenth-century German blade-making tradition, most likely produced in Passau or a related workshop. In addition to typological and stylistic study, scientific analyses were undertaken to investigate its state of preservation and possible past conservation-restoration treatments (Lazar, 2023).

Two micro-samples were taken from the metal surface and analysed using Fourier-transform infrared spectroscopy (FTIR) and Raman spectroscopy. The aim was to identify organic and inorganic components present on the surface and to clarify both historical conservation-restoration procedures and current corrosion processes.

Results revealed the presence of natural resin, probably of triterpenoid origin, mixed with oil, most likely applied as a protective coating. Protein bands indicated the use of animal glue, presumably as a binder or coating component. Corrosion products identified included oxalates-linked to biological activity or organic decomposition-and chukanovite ($Fe_2(OH)_2CO_3$), which forms under low-oxygen conditions in the presence of carbon dioxide. Raman spectroscopy confirmed the presence of iron oxide (Fe_2O_3) and revealed variations in vibrational bands across spectra from different particles, suggesting differences in crystalline phases, impurities, or degrees of degradation. These heterogeneities provide valuable insights into the sword's exposure to diverse microenvironments and potential historical interventions.

Additional detection of silicates points to environmental contamination, while further protein signals confirm the presence of organic residues from protective layers. The findings strongly support the conclusion that the sword underwent restoration in the early twentieth century, employing methods typical of that period, such as resin- and glue-based coatings.

Overall, the analyses demonstrate the coexistence of historical conservation layers with active corrosion processes. The identification of Fe_2O_3, chukanovite, and oxalates illustrates both the persistence of degradation and the long-term influence of environmental conditions. These results provide an essential basis for planning future stabilisation and conservation-restoration strategies tailored to the sword's current material condition.

Acknowledgements

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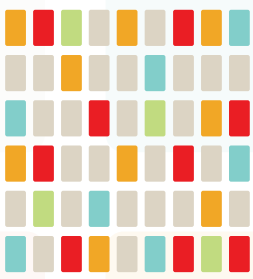

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Research on the Easel Painting *Emavs* by Ivan Grohar: Material Characterization

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During conservation-restoration, the paint layer's response to non-polar solvents and heat revealed that the 131-year-old painting Emavs, by Slovenian painter Ivan Grohar (1867–1911), could not have been painted using the traditional oil technique attributed to it. As there are no detailed studies of Grohar's painting technique, and everything indicates the presence of wax in the paint, we decided to conduct a material analysis of the painting.

We examined the painting's surface non-invasively using a portable X-ray fluorescence spectrometer (XRF) and Raman spectrometers (RS). The elemental and material composition (pigments and fillers) of selected areas of the painting was determined. Using optical microscopy, we identified the layers present in cross-sections of the samples (ground and paint layers). We analysed their material composition (binders, pigments, fillers, and degradation products) using Fourier transform infrared (FTIR) and Raman spectroscopy (RS). The results confirmed the presence of wax and oil in the paint and ground layers. To determine the exact types of binders present we examined one sample using gas chromatography coupled with mass spectrometry (GC-MS). The palmitic-to-stearic acid ratio (P/S) revealed that the identified fatty acid esters are characteristic of natural drying oils, suggesting linseed oil was used. The presence of wax was visible on the chromatogram, but we could not determine its type. Using a portable FTIR spectrometer with the reflection technique, we further examined the surface of the painting and confirmed the presence of wax at all examined locations. In addition to the characteristic doublet bands in the methylene group vibration regions, we detected a carbonyl group vibration band, which indicates the presence of natural wax. However, this band could also be due to linseed oil, making it difficult to determine the exact type of wax.

The use of various methods revealed the Emavs painting's materials and technique, although the type of wax remains unclear. These findings alert conservators to the possibility of encountering the wax-oil technique in Grohar's works. This technique requires a different approach to conservation and restoration than that used for paintings created using the traditional oil technique. For art historians, the findings offer an interesting topic for researching a previously overlooked and relatively unknown painting technique in the 19th and the 20th Century Slovenian easel painting.

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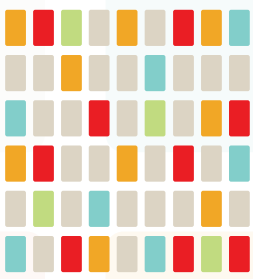

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A Multi-Analytical Study of an Unrestored Floating Component from Slavko Tihec's Kinetic Object Vertikale

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Slavko Tihec is one of the most important sculptors of the second half of the 20th century in Slovenia. Since the late 1960s, Tihec incorporated movement into his sculptures, blending abstract art with physical laws in his unique works known as Aquamobiles. These kinetic sculptures, powered by water or electricity, represented a major innovation in 20th-century Slovenian art and remain key pieces in the national modern art collection.

The kinetic object Vertikale represents an important piece of the collection at the Museum of Modern Art (Slovenia). It consists of four parts: 21 floating components, a basin with an electric pump and pipes, a basin cover, and water. Although much of the object was restored in the past, it is currently in poor condition and requires further restoration and conservation.

Moreover, since the original material composition of the floating components remains unknown, this study focuses on analysing an unrestored component that has not previously undergone any treatment. We present a non-invasive and non-destructive multi-analytical approach to determine the material composition of this component. The study combines 3D scanning, X-ray radiography, Raman spectroscopy (using a portable Raman spectrometer), infrared spectroscopy (using a portable reflection FTIR spectrometer), hyperspectral imaging (HSI), and X-ray computed microtomography. X-ray radiography and computed microtomography revealed the internal structure and the presence of compartments. Raman spectroscopy, HSI, and FTIR identified the presence and distribution of pigments and materials such as titanium dioxide (rutile), polyester/alkyd resin, nitrocellulose, and aragonite. The latter indicates limescale deposits. These findings will inform the development of an optimal restoration procedure for the Vertikale kinetic object.

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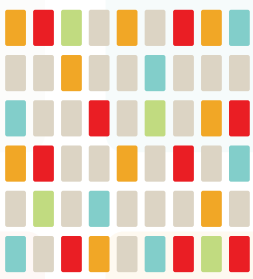

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Use of X-Ray Computed Tomography for Heritage Conservation

X-ray computed microtomography (XCT) is one of the most powerful non-destructive visualisation techniques for the full-field examination of an object, as it is able to provide morphological and physical information about the internal structure of the examined sample. In addition, XCT data allows the extraction of a very precise surface model of the specimen, more accurate than the surface model captured by handheld scanners, and the technique is already well established in the field of cultural heritage preservation. The wide variety of sizes and composition that characterise archaeological finds and artefacts requires specific expertise in tomographic systems. Two main objectives have been achieved in recent years: to enable conservators to carry out examinations using this powerful method and to make CT equipment available to museums and conservation centres. In recent years, our research group has been able to carry out high-resolution XCT on both small objects (voxel size of a few micrometres) and large objects (up to 0.5 m in size). We will report on our experiences with XCT diagnostics of cultural artefacts and present a number of case studies.

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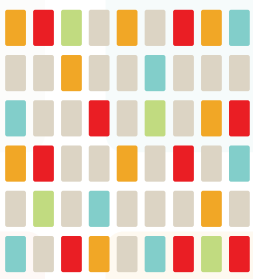

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Project: Degraded Environments – Revitalising Cultural Spaces through Art

The Project Degraded Environments and Their Revitalisation into Cultural Spaces through Art emerged from the ever-present question of the relationship with the environment. We focussed on the possibility of preserving the cultural traces of time and developing ideas on how spaces whose original function has changed or withered over time can be refilled with content so that they are left to decay. The project was multidisciplinary in nature and combined content from fields that are otherwise rarely encountered, e.g. cultural heritage from an educational perspective, industrial archaeology, digital technology, textile technology, etc. When searching for sites, we started from the database of functionally degraded areas (FDO; http://crp.gis.si/bf_map). However, we did not want to diminish the individual views of the participants. They were able to focus their project on the environment in their neighbourhood and the specific problems associated with it. This led to different aspects, effects and consequences of degraded areas (ecological, social, etc.). The project involved 12 lecturers from different faculties of the University of Ljubljana, the Slovenian National Institute of Civil Engineering, the National Museum of Slovenia and the Museum of Modern and Contemporary Art Metelkova, as well as 33 participants. In intensive interaction between participants and mentors, draft concepts for projects were developed. Part of the project also served to develop research skills. Depending on the type of degraded site, different aspects and research methods had to be applied. As it turned out, the project included knowledge that is often insufficiently integrated into the pedagogical process and therefore remains alien to the young population. At the same time, these problems have a significant impact on future generations, so it is advisable to develop their skills so that they themselves are able to make certain creative changes and contribute directly to the revitalisation of their environment. The project Degraded Environments and Their Revitalisation into a Cultural Space with Art was carried out under the auspices of the UL umbrella project for a sustainable society – ULTRA, Lifelong Learning and Micro-Credentials Pilot Group.

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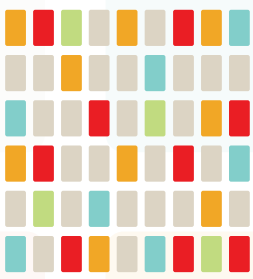

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Analyses Reveal a Rare Wall-Painting Technique on an Ancient Building in Celje

In 2018, an ancient building containing thousands of fragments of wall paintings was discovered under the Muzejski trg in Celje. Since then, the paintings have been conserved (some of the walls are in situ, while the ceiling is in the IPCH Restoration Centre). As part of the regular process, samples of the paintings were taken to analyse the materials. Particular attention was paid to the painting technique and the possible use of organic binders, as the surface of the paintings appeared unusual to the trained eye: the background was smooth and shiny, while the figures and ornaments were painted in relief over the surface and had a matt appearance.

Cross-sections of the paint layers showed that the background paint had penetrated the intonaco plaster layers, indicating that the surface plaster layer was still wet when the background paint was applied. Other paint layers were applied to the previously dried background, indicating the use of the secco painting technique. Therefore, particular attention was paid to the possible presence of an organic binder. Initial analyses were carried out using FTIR spectroscopy, which identified the carbonyl band in the bulk samples. Further analyses of extracted samples and cotton swabs from surface cleaning tests revealed spectra similar to beeswax, as well as features typical of free fatty acids.

As the FTIR results are not selective, GC-MS was used to identify the paint binder in more details. The results confirmed the presence of fatty acids and long-chain organic compounds typical of both linseed oil and beeswax, suggesting a mixture of both as binders. This confirmed that the antique wall paintings from the ancient building from Muzejski trg in Celje were painted using the encaustic technique.

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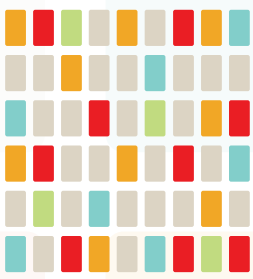

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Reading a Historical Dress: Analysis and Decomposition as the Basis for a Virtual Reconstruction

Analysing historical garments offers valuable insights into past material culture, social norms, and craft practices. This study focuses on a two-piece silk dress from the second half of the nineteenth century held in the clothing heritage collection of the Maribor Regional Museum and applies the methodological framework of the book The Dress Detective (Mida & Kim, 2015) to examine its material, construction, and cultural significance. The dress, which consists of a bustle-supported skirt and a fitted jacket with a princess line, is an example of the fashionable silhouette of the 1870s–1880s, with its extremely narrow waist, rich embellishments, and intricate details such as lace, pleats, and fabric-covered buttons. Made from natural fibres (probably silk, cotton, linen) and sewn both by hand and with early machine stitches, the dress reflects the transitional tailoring techniques of the period.

The analysis revealed functional solutions, including a concealed pocket, as well as non-traditional design features, such as an unusual bust dart (beneath the decorative gathered band in the bust area). At the same time, signs of wear, alterations, and damage/deterioration were documented, testifying to the active use of the dress and later adaptations. Beyond its aesthetic qualities, the dress conveys ideals of femininity, social status, and physical discipline that characterised late nineteenth-century fashion. By dissecting the dress into its structural and material components, the study demonstrates how object-based analysis provides essential data for virtual reconstruction and enables the preservation of its technical and cultural information beyond the physical boundaries of the textile. This work thus emphasises the potential of systematic analysis of garments to serve not only as a research method in the history of dress, but also as a basis for the development of digital strategies for documenting and preserving textile heritage for future generations.

Acknowledgements

The authors would like to thank the Maribor Regional Museum for access to the studied garments.

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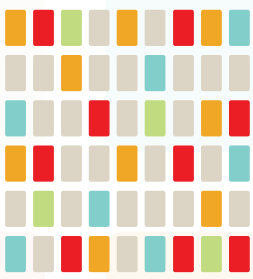

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Recent Archaeometric Research Using Ion-Beam Methods at the Jožef Stefan Institute

At the Tandetron accelerator of the Jožef Stefan Institute, proton-induced X-ray emission (PIXE) and proton-induced gamma-ray emission (PIGE) have recently been used for the analysis of archaeological glass and metals. For glass, we carried out three series of measurements on prehistoric material-glass beads from Novo Mesto, Ig near Ljubljana, and Ljubljana (SAZU courtyard), together with several other sites – with the aim of identifying glass types and exploring relationships between sites.

Beads from Ig near Ljubljana comprise glass manufactured using natron-based alkalis, in line with the dominant types circulating in the Late Iron Age and, later, the Roman period. Beads from Novo Mesto – mostly dated to the Early Iron Age – are also mainly natron-based, although a few are made using wood-ash alkalis with a prominent potassium fraction, characteristic of Late Bronze Age glass from northern Italy following the introduction of wood-ash fluxes. Among beads from the SAZU courtyard and other Late Bronze Age sites we identified alkalis derived from wood ash and halophytic plants, as well as natron. Several beads exhibited elevated boron and lithium concentrations, consistent with raw-material associations to thermal springs in Asia Minor.

A second assemblage – Late Antique and medieval glass – includes finds from the Capuchin Garden in Koper (Capodistria), whose results have been published (Šmit & Milavec, 2025). Part of this glass is natron-based and exhibits a high degree of recycling, a typical feature of Late Antique glass of Egyptian and Levantine origin. Other samples are unrecycled, indicating their increasing role in later glass markets. The medieval glass, made using halophyte ash, corresponds compositionally to glasses circulating across the eastern Mediterranean from the eleventh century onwards. We also analysed Byzantine glass from Morava and Braničevo (Serbia), which comprises natron-based material, glass made with halophytic-plant ash, and glass using mineral-alkali sources in Asia Minor (Balvanović et al., 2025).

Among metal objects, we analysed a series of the earliest Hungarian silver coins held at the National Museum of Slovenia (Šmit & Šemrov, 2025). We distinguished lower-quality silver issues in the twelfth century, whereas the Mongol invasion in

Figure 1 Analysis of Tinning on Armour from Hrušica

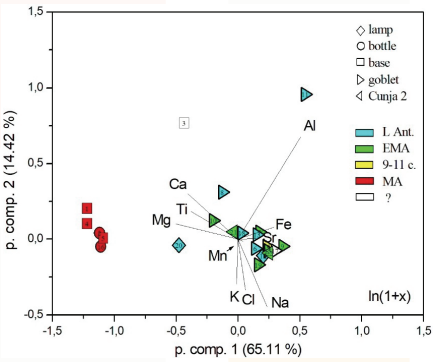

Figure 2 Distribution of Glass from Koper into Groups Using Principal Component Analysis (PCA) (after Šmit & Milavec, 2025)

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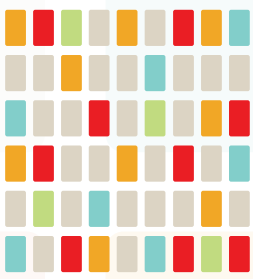

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the mid-thirteenth century did not affect metal quality. We also analysed Bronze Age bronze samples collected during field surveys in Hungary (detailed study ongoing). A preliminary analysis of Late Roman armour from Hrušica showed that its silver-like appearance was achieved by tinning.

Collaborators: Roman Balvanović, Matija Črešnar, Janka Istenič, Kaja Lipoglavšek, Tina Milavec, Tjaša Mržljak, Gábor Sánta, Andrej Šemrov, Brina Škvor Jernejčič, Petra Vojakovič.

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From Frescoes to the Cloud: A Digital Twin of the Church of the Holy Trinity for Monitoring and Documenting Conservation-Restoration Processe

Hrastovlje is among the most important cultural and historical monuments in Slovenia. At the center of the village stands fortified the Romanesque-Gothic Church of the Holy Trinity, built in the 12th century, whose interior is adorned with frescoes by Janez of Kastav dating to around 1490. Due to its artistic, historical, and symbolic significance, the church has been declared a monument of national importance and is included on UNESCO's tentative list of World Heritage Sites.

The documentation of conservation-restoration interventions is essential for the preservation of cultural heritage, as it ensures traceability of the work carried out, enables comparisons of conditions over time, and guarantees transparency in the methods and materials used. It provides a foundation for future research and interventions while strengthening accountability toward heritage. With the integration of modern digital tools such as 3D scanning and digital twins, documentation is becoming increasingly accessible, comprehensive, and valuable for both professionals and the wider public.

The virtual 3D model was created using a combination of scanning and modeling, enabling an accurate digital reproduction of the physical object or space. Textures derived from orthophoto images were applied to the base model, ensuring high visual fidelity and a realistic representation of surfaces. The resulting digital twin was integrated into the company's cloud system, allowing easy access and interaction. The model supports data entry, element mapping, and information storage, with all data georeferenced to maintain precise spatial correlation. Since the conservation-restoration process is currently in the preparatory phase, the entered data reflects the pre-intervention condition. As the restoration work progresses, the data at the same locations will be updated or supplemented. In this way, the digital model provides a comprehensive overview of activities throughout the monument's maintenance process. Its digital format also enables data migration between different systems, facilitating use and analysis in a wide range of other applications.

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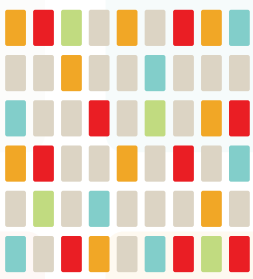

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Lime-Gypsum Renders Reinforced with Mineralised Hemp Fibres for Sustainable Renovation

Biofibres have been used in construction for centuries, but their renewed use today is increasingly driven by sustainability principles and the demand for low-carbon building materials. Hemp fibres are particularly attractive because they can improve thermal and acoustic insulation as well as the mechanical properties of renders (Özodabaş, 2023). However, their natural ignitability and high water absorption remain a challenge. Therefore, this research focuses on the development of low-carbon lime-gypsum renders reinforced with mineralised hemp fibres using traditional technology, as the lime-gypsum binder is not only a low-temperature material but is also considered the highest-quality binder for stucco decoration (Válek et al., 2020).

The study investigates two main aspects: (i) the effect of hemp-fibre length on the mechanical performance of lime-gypsum renders and (ii) the role of mineralisation in improving fire resistance. In addition, waste gypsum is combined with quicklime to avoid the need for calcination to obtain an air binder (hemihydrate) (Golež, Pogačnik, & Mladenović, 2018). This approach reduces the need for natural gypsum and contributes to waste reduction. It aligns with the circular economy and the principles of the New European Bauhaus, which emphasise sustainability, aesthetics, and integration (Rojas et al., 2019).

Lime-gypsum binders were produced by mixing calcium quicklime (CL 90-Q) with various proportions (5–50 wt%) of waste gypsum. The phase composition of the samples was characterised using X-ray powder diffraction (XRD), thermogravimetric and differential thermal analysis (TG/DTA), and microstructural analysis by scanning electron microscopy coupled with energy-dispersive spectroscopy (SEM/EDS). Renders were reinforced with hemp fibres of different lengths (0.5, 2, and 10 mm), and compressive strength was determined after 28 days. Mineralisation treatments were carried out to improve fire resistance and reduce the water absorption of the fibres. Water-absorption tests were also performed.

This research demonstrates the potential of combining biofibres, carbonate-based flame retardants, and industrial by-products to produce sustainable, low-carbon building materials with improved mechanical performance, increased fire safety, and reduced environmental impact.

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Evaluation of Calcium-Based Consolidants for Wall Paintings on Dolomitic Lime Renders

Wall paintings on dolomitic lime renders face specific conservation challenges due to the fragile nature of the substrate. Unlike widely studied calcium lime, dolomitic lime mortars contain several magnesium phases (e.g., brucite and magnesium hydroxide carbonates), which can affect durability. Historically used in Italy, France, Germany, Austria, the UK, and Slovenia (especially in Baroque wall paintings), dolomitic mortars are prone to shrinkage, microcracking, efflorescence, and pigment alteration due to their high water retention and uneven carbonation. Conservation of wall paintings executed on dolomitic substrates presents further challenges, as many inorganic consolidation treatments are chemically incompatible with high magnesium content, limiting effective intervention options. Recent developments in material science have focused on carbonate-based consolidants, which penetrate well and improve substrate strength. This study evaluates the effectiveness of three such consolidants: Calcium acetoacetate (CFW), Nanorestore (NR), and NanoLaq (NL) – used individually and in combinations. Their complementary chemistry was tested on model wall painting samples (using red ochre and azurite on dolomitic lime render, lime secco technique). Applications included single treatments and combinations (e.g., CFW + NR CFW+ NL, etc.).

Samples were analysed over time (30, 90 days) using different analythical techniques. Non-invasive methods included surface hardness testing, ultrasonic velocity measurements and micro-invasive method as the drilling resistance measurement system (DRMS) to measure penetration depth and increase in mechanical properties after the consolidation.

Spectrophotometry was used to monitor colour changes after the application of consolidant. On site study has been also performed. The results show that the colours are slightly darker after consolidation with CFW and the combination of CFW and NL. In contrast, consolidation with NR and the combination of CFW and NR results in slightly lighter areas (white spots), while there is no significant colour change after treatment with NL. The measurements of surface hardness show that in most cases the values are higher compared to the untreated substrate. Similarly, DRMS measurements show increased values for CFW and NL alone, as well as for the combination of CFW with NR. The results contribute to better understanding of dolomitic lime interaction with carbonate-based consolidants and sustainable practices in preservation of wall paintings.

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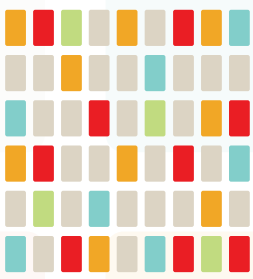

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Inside Ancient Osor (Cres Island, Croatia)

Ancient Osor, situated on the isthmus between Cres and Lošinj, was one of the most significant centres in the Kvarner region and an important maritime hub of the northern Adriatic. Its role in intercultural networks during the last millennium BCE is reflected in ancient written sources that associate the site with both mythological traditions and the circulation of essential metals.

As part of the international research project Osor beyond the Myth (N6-0292), new investigations were conducted using a multidisciplinary approach. In addition to geoarchaeological, geophysical, and underwater investigations, detailed analyses of material culture from settlements, graves, and underwater contexts were carried out. Archaeometallurgical, bioarchaeological, and anthropological studies were complemented by chemical and isotopic analyses (amber, tin, strontium, aDNA).

Most of the material culture originates from necropolises located both within and outside the urban area. The value of the items, particularly jewellery and clothing, indicates both local production and imports from various regions. Earlier interpretations had demonstrated extensive Alpine, Pannonian, and Mediterranean connections; the new data provide more detailed insights into these networks.

The results address key gaps, providing new insights into the provenance of raw materials, Osor's role in economic networks, and aspects of the population's health and diet. For the first time, they offer a clear understanding of the society and lifestyle of the period, while highlighting Osor's strategic significance in the maritime and cultural networks of the northern Adriatic during the last millennium BCE.

Figure 1 Osor (photo: Hrvoje Serdar)

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A Historical Apothecary Cabinet: Towards Understanding the Composition of the Powdered Contents

The National Museum of Slovenia houses a walnut apothecary travelling cabinet with wrought-iron fittings, dated to the 17th or 18th century. The cabinet contains fourteen compartments of varying shapes, a concealed drawer, several original metal and one ceramic container, and fourteen paper bags containing visually different powdered materials. To better understand the nature and composition of these powders, nine representative samples were analyzed in collaboration between the Faculty of Chemistry and Chemical Technology, University of Ljubljana, and the National Museum of Slovenia.

A multi-analytical approach was applied to provide a comprehensive characterization of the samples. Handheld X-ray fluorescence (XRF) was used to determine elemental composition, while Fourier-transform infrared spectroscopy with attenuated total reflectance (FTIR-ATR) provided information on the presence of functional groups. And additionally, headspace solid-phase microextraction coupled with gas chromatography and mass spectrometry (SPME-GC-MS) was used to investigate the potential presence of volatile organic compounds.

The analyses consistently indicated that the powders are inorganic in nature. Tin was identified as the dominant element, with additional occurrences of calcium, iron, and traces of lead. No organic functional groups were detected with FTIR-ATR, and SPME-GC-MS did not reveal volatile organic compounds. These results suggest that powders cannot be associated with organic pharmaceutical ingredients.

Although the absence of organic compounds limits direct insight into historical formulations, the results provide a clearer picture of the material content of the box, support informed conservation decisions, and illustrate the benefits of interdisciplinary collaboration in advancing the study of pharmaceutical heritage.

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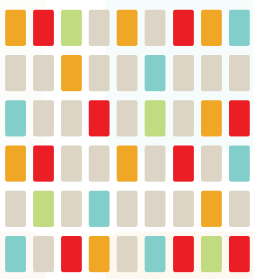

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Investigating the Composition of Early Medieval Silver Coins: The Case of Sceattas

The elemental composition of a previously unanalysed group of of series D, E and X sceattas from the numismatic collection of the De Nederlandsche Bank was investigated using portable X-ray fluorescence (pXRF). These small silver coins appear in the archaeological record from roughly c. 680–750 CE and are believed to have been used to facilitate long-distance trade among the emporia of northwestern Europe (op den Velde & Klaassen 2004). This study focused on sceattas from the Low Countries.

A total of 183 sceattas were analysed. These included those from the Remmerden hoard, of which 135 were Series D sceattas and 5 belonged to the primary Series E. Additionally, 43 Series X sceattas were also included. The elemental compositions of the obverse and reverse face of each sceatta were measured. The coins were not cleaned or polished prior to analysis. Analyses were performed with a Bruker Tracer 5g portable XRF spectrometer. To obtain quantitative data (in %wt) of the relevant elements the 'Precious Metals 2' factory calibration was used.

This study was the first time such a large sample of Series D sceattas was available for analysis. The results indicated the potential of two separate groupings, the 'higher-Au-lower-Cu' and 'lower-Au-higher-Cu' groups within the series. While the differences were not sufficient to declare the groups as entirely distinct, likely due to them having been intermixed, this is still an interesting finding. For the primary Series E varieties their respective Au/Ag ratios revealed significant differences between them. Series X displayed the most variability in its composition. The finest coins contained over 90% silver, followed by groups containing 70–90% and 50–60% silver. Finally, five of the coins were found to have been made of pure copper.

The discovery of two potentially distinct compositional groups of Series D sceattas was only possible due to the large sample size of available, which highlights the potential of large-scale compositional studies. The data suggests Series X sceattas were partly recycled from other series, with added base metals to extend silver supplies. Further non-pXRF analyses are needed to confirm these complex minting practices.

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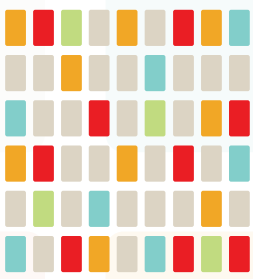

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