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EUROPEAN RESEARCH INFRASTRUCTURE
FOR HERITAGE SCIENCE - SLOVENIA

1st E-RIHS.SI Conference
22nd November 2023

Book of Abstracts



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E-RIHS Slovenia

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Introduction

Introducing the Inaugural E-RIHS Slovenia - Annual Conference

Heritage science is the interdisciplinary domain of scientific study of cultural and natural heritage. Heritage science draws on diverse humanities, sciences, and engineering disciplines. It focuses on enhancing the understanding, care, and sustainable use of heritage so it can enrich people's lives, both today and in the future. Heritage science is an umbrella term encompassing all forms of scientific enquiry into human works and the combined works of nature and humans, of value to people¹.

In line with the mission of the European Research Infrastructure for Heritage Science², E-RIHS Slovenia³ encourages collaboration among researchers and professionals across diverse fields, including social science and humanities, and science, technology, engineering, and mathematics. Its primary goal is to cultivate a cross-disciplinary culture of research through provision of access to cutting-edge research infrastructures. E-RIHS Slovenia plays a crucial role in the promotion of Slovenian heritage science and its global engagement.

Building upon the collaborations and progress achieved within the E-RIHS research infrastructure, we are delighted to introduce the inaugural E-RIHS Slovenia conference as an annual event. This initiative is designed to convene researchers and experts from across the country, encouraging discussions on cutting-edge science, facilities, and projects in the domain of heritage science and related fields.

It will serve as a forum to present and review recent advances and ongoing research in the field of heritage science with a wide range of participants, including students, researchers, conservators, engineers, practitioners, entrepreneurs, and policy makers. They will have the opportunity to exchange ideas, present research findings, and explore innovative strategies and new technologies in their fields. The conference will actively promote the vision and goals of E-RIHS Slovenia and pave the way for potential future collaborations.

Attendees also will have the opportunity to become familiar the extensive services and resources that E-RIHS (i.e. particularly its Slovenian node) provides to researchers, institutions, and organizations, from cutting-edge technology and laboratories to expertise, in addition to identifying needs and/or filling the gaps in

¹ https://en.wikipedia.org/wiki/Heritage_science

² <https://www.e-rihs.eu/>

³ <https://www.e-rihs.si/>

the infrastructure for future development. By working in harmony, we can amplify the impact of our efforts in preserving and understanding our cultural heritage.

Networking is at the heart of this event. Attendees will have ample opportunities to engage with peers, mentors, experts, and institutions in the field of heritage science and related fields. These connections have the potential to lead to future collaborations, research projects, and a stronger, more interconnected heritage science community in Slovenia.

Moreover, the participation of junior researchers and students from diverse disciplines has been one of the core aims of the event. We believe that by providing them with a platform to present their work and engage with experts, we will ignite their passion for heritage science research and foster a deeper awareness for our cultural heritage.

This year, the conference takes place in Ljubljana, Slovenia on November 22, 2023. It is a one-day event hosted at the University of Ljubljana (Great Senate Hall / Zbornična dvorana). The conference aims to showcase the diversity of projects and research conducted within Slovenian institutions in the past year. Its programme includes 18 talks, 13 posters, and one plenary talk. We extend our gratitude to the Steering Committee of E-RIHS for their valuable advice, guidance, and contributions. We hope you that your experience of inaugural conference will be an enjoyable and rewarding experience, inspiring your engagement in heritage science and joining us again in the coming years.

Sincerely Yours,

The Organizing Committee

Conference Programme

09:00 – 09:10	Opening Address / Introduction Matija Strlič
09:10 – 09:50	Plenary Talk: Heritage Science Austria (AT-HSI) Network <u>Klaudia Hradil</u> , Maria Bianca D'Anna, Martina Griesser, Sabine Ladstätter, Katja Sterflinger
Session 1: Chaired by Tamara Leskovar	
09:50 – 10:10	Digitalization and Environmental Aspects of Built Structures on Republic Square - Research and Innovative Approaches <u>Katja Žagar</u> , Katja Malovrh Rebec, Anja Lešek, Jože Hafner
10:10 – 10:30	Virtual Free Form Modelling of CH Objects Rok Hafner
10:30 – 10:50	Analysing the Enigma M4 Cipher Machine Using Microtomography <u>Miha Hren</u> , Lidija Korat, Andrej Gaspari
10:50 – 11:10	Coffee Break
Session 2: Chaired by Klara Retko	
11:10 – 11:30	Floor Construction Technologies and Maintenance Strategies in Prehistoric Households: Integrating Micromorphological and Geochemical Evidence at the Pungrt Hillfort, Slovenia <u>Agni Prijatelj</u> , Luka Gruškovnjak, Petra Vojaković, Karen Milek, Matej Dolenc, Helena Grčman, Matija Črešnar
11:30 – 11:50	Reconstructing Activities in Archaeological Household Contexts Using Micro-Refuse Analysis: A Case Study from the Pungrt Hillfort, Slovenia <u>Luka Gruškovnjak</u> , Agni Prijatelj, Petra Vojaković, Jaka Burja, Barbara Šetina Batič, Borut Toškan, Tjaša Tolar, Rok Brajkovič, Helena Grčman, Matija Črešnar
11:50 – 12:10	A Short Overview of the Interdisciplinary Research on Late Prehistoric Pottery <u>Manca Vinazza</u> , Lidija Korat, Paola Korošec, Doris Potočnik, Petros Chatzimpaloglou, Aleš Šoster, Matej Dolenc, Nastja Rogan Šmuc
12:10 – 12:30	Aptamers for the Analysis of Proteinous Organic Residuals Found Within Ceramic Vessels <u>Janez Kosel</u> and Polonca Ropret

12:30 – 12:50	The Fast and the Furious, the Use of XRF in Archaeology <u>Boris Kavur</u> and Martina Blečić Kavur
12:50 – 13:50	Lunch Break
	Session 3: Chaired by Boštjan Lesar
13:50 – 14:10	Lifecycle Assessment as a Green Heritage Science Tool <u>Abdelrazek Elnaggar</u> and Matija Strlič
14:10 – 14:30	Treatments Preventing Acidic Degradation of Cellulose-Based Paper Artefacts <u>Matej Bračič</u> , Jasna Malešič, Mihael Brunčko, Doris Bračič, Tamilselvan Mohan
14:30 – 14:50	Combining Different Spectroscopic Techniques for the Investigation of Inks: From Mock-Ups to Historical Samples <u>Klara Retko</u> , Lea Legan, Maša Kavčič, Ekaterina Parnak, Jasna Malešič, Polonca Ropret
14:50 – 15:10	Evaluation of Ageing Behaviour of Some Historical Maps Containing Green and Blue Pigments: An Example of E-RIHS Access <u>Jasna Malešič</u> , Klara Retko, Kristina Mervič, Martin Šala
15:10 – 15:30	Machine Learning for Dating of Historic Paper <u>Floriana Coppola</u> , Jernej Markelj, Jasna Malešič, Matija Strlič
15:30 – 15:50	Coffee Break
	Session 4: Chaired by Jasna Malešič
15:50 – 16:10	Heritage Living Labs - Participatory and Inclusive Approaches in HE <u>Zrinka Mileusnić</u> , Neža Čebren Lipovec, Irena Lazar
16:10 – 16:30	Revitalizing the Heritage of Underground Architectures and Impact on Society (Sitarjevec Mine, Slovenia) <u>Mateja Golež</u> and Rok Vežočnik
16:30 – 16:50	Assessment of Structural Properties of a Wooden Mosque in Bužim, Bosnia <u>Boštjan Lesar</u> , Miha Humar, Redzo Hasanagic, Hasan Talić, Davor Kržišnik
16:50 – 17:10	Seismic Risk Assessment of Architectural Heritage Building Stock Managed by the Ministry of Justice and Used by the Judicial Authorities <u>Meta Kržan</u> and Marjana Lutman



17:10 – 17:30

**Multianalytical Approach to the Study of the Triptych
from the Church of St. Dominic in Izola**

Lea Legan, Klara Retko, Maša Kavčič, Jakub Sandak, Saša
Dolinšek, Polonca Ropret

17:30 – 17:40

Closing address

Zrinka Mileusnić



Plenary Talk

Heritage Science Austria (AT-HSI) Network

**Klaudia Hradil¹, Maria Bianca D'Anna², Martina Griesser³, Sabine Ladstätter²,
Katja Sterflinger⁴**

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Heritage science is the multidisciplinary study of cultural heritage that provides access to art, cultural assets, natural resources, and intangible heritage through documentation, interpretation, and preservation. Its infrastructures and expertise are crucial for the understanding and preservation of cultural heritage. I will introduce the Heritage Science Austria (AT-HSI) network, an initiative that creates a network of Austrian institutions through interaction between museums, galleries, archives, universities, research institutes, and professionals. HSI-AT was founded in 2018 to overcome knowledge fragmentation and establish a national network of scientists that can coordinate European projects. HSI-AT connects researchers working in the field of heritage science in Austria from the natural sciences, technology and the humanities and improves the documentation and preservation of Austria's heritage, promotes best practices, knowledge exchange and centralized access to facilities. In addition, HSI-AT supports the FAIR principles (Findable, Accessible, Interoperable, and Reusable) in the handling of research data in Heritage Science.



Speaker Presentation Abstracts

Session 1: Chaired by Tamara Leskover

Digitalization and Environmental Aspects of Built Structures on Republic Square - Research and Innovative Approaches

Katja Žagar, Katja Malovrh Rebec, Anja Lešek, Jože Hafner

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In the framework of the Year of Edvard Ravnikar, the Slovenian National Building and Civil Engineering Institute (ZAG) took part in an exhibition about Republic Square. A large part of the exhibition was devoted to the history of the square, presenting the development of the concepts for the square and the TR3 tower. From the first competition to the realization of the square, there have been numerous changes. Memories of past events were brought back to life, mainly through the collection and study of archive material. The contribution of our team was also inspired by the past but focused on the present and the future of this remarkable cultural and historical space, as to preserve and use it, it must be properly maintained.

In the planning phase of the TR3 tower, considerable attention was paid to the operational energy efficiency of the building. A solar analysis was carried out, and the façade's design was adapted accordingly. The analysis was repeated by our team using modern computer-enabled calculations. The impact of shading elements on energy consumption was examined by considering different scenarios, including the renovation option. Compared to the windows available at the time the tower was built, modern windows are much more energy efficient. Next, the complete annual energy consumption and environmental footprint of the tower were reviewed. A comparison between the environmental footprint caused by building operation and the footprint made by the materials integrated into the building was made. While the choice of building materials is important, the TR3 tower has a much greater impact on the environmental footprints during its lifetime operational phase. That is why new solutions to reduce energy consumption and preserve the heritage values of the tower need to be explored.

Many different historical plans of the TR3 tower are currently stored in different archives. Finding plans that have been implemented is a time-consuming process,

mainly due to the lengthy design process and the large number of design variations in the past. To solve the issue, HBIM (heritage building information modelling) was established to organize various building data, including data about cultural value. The HBIM model is a digital three-dimensional representation of a historical building in which three-dimensional representation of building elements is upgraded by different semantic information. The HBIM of TR3 tower was made based on point clouds, a set of points in a three-dimensional coordinate system, representing the visible surfaces. In addition to point cloud, historical plans were also used to create a geometrically and semantically accurate model. With the appropriate incorporation of additional information about the building, including the possible integration of real-time sensor data, the model could serve as a monitoring tool for the tower, contributing to a better management of the heritage in the future. Further on, digital technologies were used by our team to show conceptual designs of the square. Animated and annotated schematic models of the square were created with open-source software and displayed on a hologram. It is our observation that innovative technologies mentioned can encourage interest in cultural heritage among the general public, which would contribute to a more general understanding of its importance.



Virtual Free Form Modelling of CH Objects

Rok Hafner

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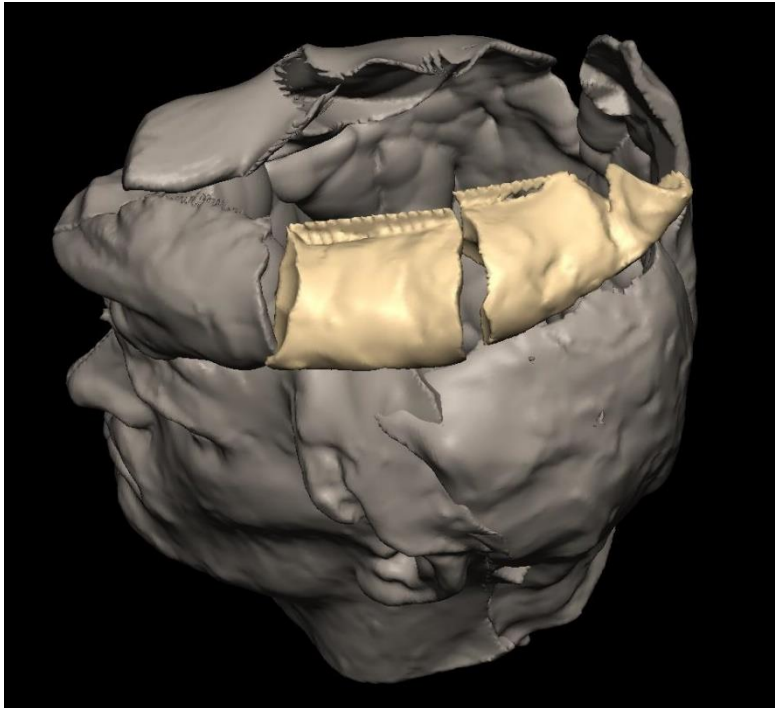
The horizon of the use of 3D images in the cultural heritage field is broadening by each day. At the Restoration Centre of the Institute for Protection of Cultural Heritage of Slovenia (IPCHS) we carry out a virtual restoration. In that field, free organic forms are predominant and are not suitable for classic CAD software. Haptics allows to achieve compelling solutions using the realistic sense of touch. It is a digitalization of classical sculptural techniques. We have already completed numerous of projects where haptics has been used to transform virtual material.

Fragmented Venus with erots was found at the archaeological site "vojarna" in Osijek. In order to improve interpretation, the individual fragments were placed in space in relation to each other based on the proportional lengths of the individual body parts and limbs. In this way it was possible to locate artefact's parts for each fragment. Even better visualization was achieved by modelling of the main missing links between the individual fragments, distinguished from the textured original by their colour. The corners of the chapel of Goričane Mansion were historically supported by atlantes of related physiognomies in various counterpost. Only one original has survived. To restore the original impression, copies of the other three atlantes were made. A 3D model of the single original was manipulated to correspond to the neighbouring statues into the forms of the archival photographs. The remodelled 3D models of the copies were used to machine the copy supports on CNC machines into rigid PU foam. The statue of Hostage by sculptor Boris Kalin from Draga near Begunje in Gorenjska was targeted by collectors of non-ferrous metals. It was found in fragments on a euro pallet sold to a company that buys such materials. The captured 3D models of the fragments of the still-identified essential parts of the statue were used for remodelling, while the rest of the torso was at the same time sculpted in a classic. That way we have managed to preserve at least part of the sculptor Boris Kalin's hand and, by comparison, the approximate original size. The singing boys on the façade of the Maribor Drama Theatre were exposed to the weather damaged. In particular, the protruding parts of their limbs and their attributes. The missing parts were re-constructed, the areas with the real geometric forms, the sims and the semicircular base were corrected. The allegories in front of the National Museum were made sandstone of poor quality during the monarchy, and soon began to deteriorate, which led to their removal



from site. Decades ago, the first polyester copias were made. With 3D images compared, it was found that the layouts of the first copias did not match those of the originals. The new copias in rigid PU foam have the corrected surface structure and the right contrapost.

The next step of the use of this technology would be the development of green materials in which to produce 3D models of the copy carriers prepared that way.



Analysing the Enigma M4 Cipher Machine Using Microtomography

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Enigma is one of the most famous cipher machines used by the German military during World War II to transmit messages. The number of devices that survived the war unscathed is relatively small, and in recent decades these devices have been discovered in prime locations, such as sunken German submarines or hideouts on land. The naval version of the Enigma, which was discovered between 1984 and 1986 in the wreckage of the German minesweeper R 15 on the seabed along the Istrian coast, also originates from this era. The machine underwent a conservation process, and at the same time the rotors of the device were scanned with microtomography to obtain information about the model, composition, and configuration of the machine's rotors.

Microtomography (microCT) is a non-destructive microscopic technique that uses X-rays to create 3D images of objects. In the case of the scanned Enigma machine, this process allowed us to examine the internal state of the device (rotors and electronics) without further damaging it. Specifically, the Enigma rotors were in extremely poor condition, having been subject to corrosion for several decades (Figure 1a). The resulting 3D images revealed intricate details of the machine's construction, including the exact positions of various components and materials that were offset from their factory position (Figure 1b).

One of the findings of the microtomography examination was the discovery in which positions the rotors were located when the ship sank. The external position of the additional gamma rotor (P) indicates that the Enigma was not set up in a way that allowed it to exchange messages with the M3 model, which corresponds to code keys from the last two months of the war. The serial numbers of the rotors of the Enigma machine were also examined, and it was discovered to be a naval model M4 machine with the serial number M 15648 (Figure 1c). In addition to the above, the examinations also showed that the machine was made using a variety of materials such as brass, steel and bakelite (early type of plastic).

Overall, microtomographic examination of the Enigma machine provided valuable insight into the internal condition and model identification of this iconic device. By studying the interior of the machine, the position of the rotors and the identification



of the Enigma model, we obtained additional information about the presence of this device on the R 15 minesweeper toward the end of World War II.

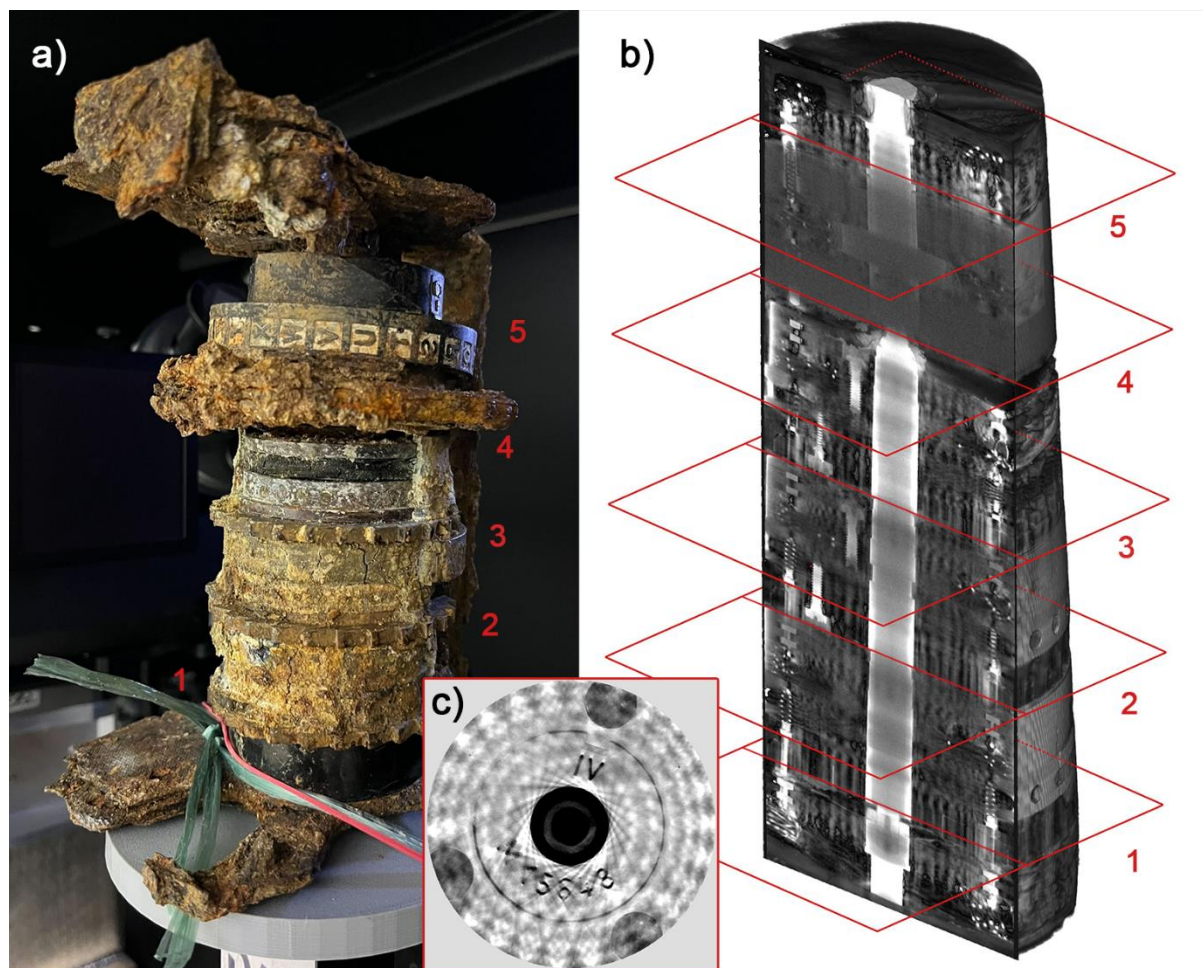


Figure 1. (a) Rotors of the Enigma machine, placed on the support of the microCT device, (b) cross-section of the microtomographic image along the middle axis of the reels, with marked areas where the cross-sections with serial numbers of the rotors were located, (c) an example of a cross-section labeled 1 with visible serial number of the rotor. (© Miha Hren).

Session 2: Chaired by Klara Retko

Floor Construction Technologies and Maintenance Strategies in Prehistoric Households: Integrating Micromorphological and Geochemical Evidence at the Pungrt Hillfort, Slovenia

Agni Prijatelj^{1,2}, Luka Gruškovnjak², Petra Vojakovič^{2,3}, Karen Milek⁴, Matej Dolenec⁵, Helena Grčman¹, Matija Črešnar²

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The structured use of space in the European Iron Age hillforts remains elusive, despite extensive research over the years. The constraints of the prevalent small-scale excavations are compounded by research focusing primarily on hillforts in their landscape context, their varying fortification systems, their settlement phases and chronologies, and their distinct material culture.

In the ongoing research project, *The proto-urban hillfort of Pungrt above Ig: from 10 hectares to 10 microns* (2021–2024), select areas of the Pungrt hillfort are all examined at the micro-contextual level. The site is the first Slovenian Iron Age hilltop settlement with a documented proto-urban design. With 8,800 m² of the settlement's interior uncovered, it is also the place of the largest excavation of any hillfort site in Slovenia. During the development-led rescue excavation (2020–2021), a systematic geoarchaeological sampling programme was undertaken at the site: some 200 intact micromorphology blocks and 1,850 bulk samples from various floor sequences and open area surfaces were collected across the best-preserved areas of the settlement. In this ongoing research, we examine them at the micro-contextual level by integrating high resolution approaches, including micromorphology, microrefuse and (micro-)geochemical analyses, and Bayesian modelling of an extensive set of radiocarbon dates. Our aim is to reconstruct distinct architectural and technological knowledge utilised in the construction, maintenance and rebuilding of multi-phase buildings, open spaces and multi-phase



fortification system at the site. We also examine the functionality of the individual buildings and related outdoor areas, various discard practices and human-animal interactions.

Here, we present a distinct set of floor construction technologies and maintenance strategies associated with the Late Hallstatt Building 21. Constructed on the lowermost terrace next to a 2m-wide gravel road along the inner face of the stone rampart, the timber structure had stone foundations, internal partition walls, and several hearths and ceramic vessels, built into floor surfaces. The stratigraphic sequence in the building consisted of a series of interchanging floors and dark, homogenous layers. Our micromorphological and geochemical analyses have revealed the nature of these floor materials and accumulated occupation residues, their precise depositional pathways and micro-contextual associations.

Throughout the building's life-cycle, two main types of constructed floors were used: clay-rich floors made from the local, decalcified subsoils, and clay-lime floor plasters. The latter provide the first evidence of the mastery of the lime technology during the Hallstatt period in Slovenia. Micromorphological and XRD analyses indicate that local dolomite and limestone were burnt to produce quicklime, which was then mixed with mineral subsoils in a dry slaking technique to produce clay-lime floor plasters.

In addition to longer-term cycles associated with these two floor types, the microstratigraphic sequence in Building 21 contained records of various floor maintenance practices. These involved the periodic replastering of floor surfaces with finishing coatings that were significantly thinner (1–3 mm) than the floors (3–10 cm) and consisted of either mineral- or organic-based materials. Both types of coating have been identified for the first time in a prehistoric settlement in Slovenia. The organic-based coatings consisted of a mixture of animal dung, chaff and mineral subsoil material. The use of animal dung as a construction material is significant, as it suggests that the material was intertwined with the dwelling at the Pungrt hillfort.

In its final phase, Building 21 changed from a dwelling into a stable. The housing of domestic animals within the structure resulted in the organic-rich, highly phosphatised, trampled deposit. This stable floor consisted mainly of animal dung and fodder, with fragments of the stabling crusts preserved locally.

The results of the integrated micro-contextual analyses of floor sequence from Building 21 provide information on different architectural choices, floor construction technologies, and maintenance practices. They also offer insights into various social practices, human-animal relations, and multiple temporalities associated with the building's life cycle. As such, they allow us to address previously

under-explored themes within the hillfort research, most notably the issues of the structured use of space, ecological relations, distinct discard and sanitation practices, and overall community sustainability.



Figure 1. A microstratigraphic sequence from Building 21: clay-lime floor plaster (white arrow) underlying a series of alternating mineral-based floor coatings and beaten floors (black arrow).

Reconstructing Activities in Archaeological Household Contexts Using Micro-Refuse Analysis: A Case Study from the Pungrt Hillfort, Slovenia

Luka Gruškovnjak¹, Agni Prijatelj^{1,2}, Petra Vojakovič^{1,3}, Jaka Burja⁴, Barbara Šetina Batič⁴, Borut Toškan⁵, Tjaša Tolar⁵, Rok Brajkovič⁶, Helena Grčman², Matija Črešnar¹

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Due to the development-led excavation in 2020 and 2021, the previously little-known hillfort of Pungrt above Ig, located near the Slovenian capital of Ljubljana, has become one of Slovenia's most important Early Iron Age sites. Namely, the most extensive excavation (8,800 m²) of any hillfort settlement in Slovenia was accompanied by an extensive geoarchaeological sampling of various floor sequences and open area surfaces across the best-preserved areas of the site. The two sampling strategies employed at the select buildings included a vertical micromorphological sampling in exposed sections and a horizontal sampling in a grid for micro-refuse and geochemical analyses. In this paper, we examine the insights into recurring daily activities and the structured use of space provided mainly by micro-artefacts analyses and demonstrate that such a thorough understanding of space could never be garnered through the excavation data alone.

The ongoing laboratory analysis of micro-artefact assemblages – undertaken within a research project funded by the Slovenian Research and Innovation Agency – is one of the integral components of the first high-resolution geoarchaeological study of any hillfort site in Slovenia. Micro-artefact identification and characterisation involve several different analytical techniques, including petrography, metallography and SEM-EDS, which are coupled with zooarchaeological and paleobotanical analyses of bone and plant micro-refuse. The distributions of identified types of material are analysed in a Geographic Information System (GIS) environment and complemented with physio-chemical and micromorphological sediment analyses.



Here, we present the results of such an analytical approach applied to the floor at the Late Hallstatt (6th–4th century BC) multi-room Building 24, including insights into the locations of the entrance into the building and various items of furniture, as well as a reconstruction of different activities related to distinct indoor areas. Most notably, the seemingly inconspicuous southern room that provided no hints of its use during the excavation was identified as a smithy.

Blacksmithing activities are evidenced by tiny metallurgical waste debris, namely slag and hammerscale. We have identified several types of hammerscale, mainly related to iron welding and, to a lesser extent, to copper metallurgy. Furthermore, they provide the first concrete evidence for using flux and the type of flux used in the iron welding process during this period. Based on their distribution, we can reconstruct exactly where the anvil would have stood in the room. Similarly, the distributions of slag produced at the bottom of the blacksmith's hearth and of carbonised palaeobotanical remains, both related to day-to-day hearth cleaning activities, allowed us to pinpoint the location of the blacksmith's hearth.

Micromorphological analysis of the floor next to the hearth and anvil revealed the practice of maintaining this intensively used floor section by repeated application of thin clay and lime plasters. In addition, micro-refuse analysis points to two different lime plaster types used within the building, one exclusively around the blacksmith's hearth area and the other across the whole building. Furthermore, they are the first evidence for using calcitic lime technology during the Hallstatt period in Slovenia.

Another fascinating insight was provided by the tiny bone fragments embedded in the floor. Their high degree of fragmentation, relatively abundant pieces of cancellous bone and evidence of boiling point to bone grease processing within the building. Furthermore, by comparing the distributions of cancellous bone and several groups of sandstone, we were able to locate where in the building bone crushing prior to boiling to extract the grease was performed. Interestingly, bone grease processing could directly relate to blacksmithing, as grease may be used as a quenching liquid.

The results demonstrate the remarkable but usually untapped potential of detailed investigations of occupation surfaces and embedded micro-debris for reconstructing past activities and lifeways far beyond what usual archaeological excavation datasets allow.

A Short Overview of the Interdisciplinary Research on Late Prehistoric Pottery

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Although archaeological pottery is considered the most common find at most archaeological sites and has been studied extensively since the earliest archaeological studies, ceramic studies in archaeology have experienced a renaissance in the last twenty years. The reason for »new wave« lies in a clear methodology, the emergence of ceramic experimental archaeology and integration of scientific analyses in most studies concerning ceramics.

The "life cycle" of a vessel or its fragment is a long process, from the collection of the raw material to the moment it ends up in the archaeological record. Although burial gives it a certain stability, it can still be affected by a number of depositional processes. The archaeologist's task is therefore first and foremost to investigate the context of the archaeological find and then to determine the potential and method of investigation. In this paper, we present some case studies of the different steps of pottery production. By focusing on a single step of the so-called ceramic operational sequence, we can go much deeper and focus on questions related to individual processes such as modelling, firing, cooking, etc.

It is precisely in ceramic studies that scientific analyses can make an enormous contribution and help us to interpret remains, which are not visible to the naked eye. With the integration of results from various scientific analyses, ceramic studies have moved into new level. In our paper, we focus on different methods, which help us to better understand mineralogical and geochemical structure, such as ceramic thin section petrography, X-Ray diffraction analysis (XRD), X-ray Fluorescence (XRF) analyses and Scanning Electron Microscopy - EDS analyses, structure of the archaeological find (micro computed tomography), and organic residues (gas chromatography mass spectrometry and isotope analysis).

The analysed pottery dates from Late Bronze to the Early Iron Age. The examined cases came from various archaeological sites in western and central Slovenia. We

established a firm research background by sampling for the different analysis both local materials and samples gathered from different archaeological experiments, which we conducted at the Department of Archaeology Faculty of Arts. The need for archaeological experiments carried out in parallel with archaeological research is no longer in question. In recent years, experimental archaeology has also found its way into Slovenia.

The study focusses on the raw material (clay), the firing structures, the firing techniques, the decoration techniques and the function of the pottery. By integrating different approaches, we can go much deeper in the interpretation of archaeological finds and ask questions about past technological pottery techniques and skills hidden in the mostly man-made final products. We can also look at issues relating to diet and food preparation. Of course, all of this requires a good archaeological background and the quality of the data obtained from the archaeological excavations themselves. A variety of analyses was carried out by a team of experts from the fields of archaeology, geology, chemistry, sculpture, and civil engineering.

Aptamers for the Analysis of Proteinous Organic Residuals Found Within Ceramic Vessels

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Archaeological pottery are the most numerous objects found during excavations and reflect the culinary practices in the last 10.000 years. They reveal cultural associations of meals that were cooked in them and provide data on human diet in specific socioeconomic contexts. However, comparing the shape of pods does not lead to identification of specific food types and commonly results in wrong designations. Because these items are so prolific and because their ceramic structure is very durable, most of them are stored improperly which results in microbial degradation of organic residuals within their porous structure. Therefore, if in the near future research methodologies will not become more accessible and effective in the analysis of ancient organic residuals, the options to reveal the culinary history of Europe will become ever more limited. In contrast to lipids, protein analysis within ancient pottery provides the opportunity for improved tissue and taxonomic resolution of foodstuffs prepared in ceramics, mainly because they hold rich molecular information encoded within the amino acids describing not only the protein type but also its animal origin, directly leading to food type identification. Moreover, the abundance and composition of proteins also influences preservation, with hydrophobic proteins surviving more readily than other proteins or nucleic acid molecules (DNA). ELISA (Enzyme-Linked Immunosorbent Assay) is currently the most accessible (independent of expensive measuring equipment) methodology for the characterization and identification of ancient proteins found adhered to ancient ceramics. It relies on target specific antibodies, which bind to individual protein targets. However, antibodies possess numerous disadvantages such as a complicated and up to a yearlong biological production with high batch-to-batch variability, highly insatiable protein structure which is easily denatured and commonly suffers from cross-reactivity problems due to nonspecific binding or loss of epitopes, a short life span regardless of freezing and irreversible loss of function after repeated thawing. Therefore, there is a need to search for alternative molecular recognition elements to antibodies and one promising option are aptamers. These are single-stranded

oligonucleotides generated via chemical synthesis, which includes reiterative selection cycles, that bind their selected targets with high affinities and specificities, via folding into specific secondary ligand binding structures. Aptamers are high stable at room temperature, have a long shelf-life, no batch-to-batch variability, and a reversible denaturation without loss of function. Strict selection with the tailored isolation process ensures their very high affinity and specificity for target proteins. Therefore, several aptamers were tested for their potential application in immunofluorescence microscopy (IFM; a technique similar to ELISA). In this way, we aimed to prove the feasibility of aptamers for the analysis of proteinous organic residuals found within the ceramic samples in future IFM and ELISA applications.



The Fast and the Furious, The Use of XRF in Archaeology

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With the advent of “new” archaeology and its ontological turn at the end of the sixties, archaeology tried to become more and more scientific. To produce statements based on measurable and verifiable analyses of material remains. This became plausible largely with the use and usefulness of computers in archaeology at the end of the millennium, and the use of chemical analyses of materials. Moreover, if everything seemed easy, decades later we became aware of the major problems created – the samples analysed. It was the biased selection of items that were not statistically significant or representative of the whole assemblage. The solution was provided by the development of devices using nuclear beams and lasers – becoming increasingly important as analytical tools in art and archaeology for dating and characterization studies.

Based on the new advancements in both nuclear technology and commercially available portable systems, the collection and analysis of quantitative data from archaeological samples is becoming one of the most trusted and widespread methods in archaeology. Today are available for rapid, large-scale scale non-destructive detection of chemical elements, portable or desktop XRF devices. Such system designs are compact, low weight, consume less power, and can operate at varying voltages of 40 to 60 kV and variable currents in the range of microamps, obtaining accurate results quickly. Reducing the time of analysis (and costs) enables repetitive measurements correcting the results and gaining insight into the variability of the sample itself. Most important XRF technology can generally detect amounts of major, minor, and trace chemical elements. In particular, it is uniquely capable of detecting trace amounts of heavy elements, such as barium (Ba), antimony (Sb), lead (Pb), and strontium (Sr) that are of major importance in archaeological provenience studies.

Today the main problems of the use of XRF in archaeology is the overestimation of the analyses it can provide and the overinterpretation of the gathered data, as well as the rigid criticism of its use. For example, if one assesses that the surface of archaeological and historical materials has deteriorated and differs in composition from the bulk (the core), the quantitative measurements may require surface abrasion or even sampling, depending on the material. When a measurement has to be strictly non-invasive, one cannot expect reliable quantitative data, but it

enables the recognition of general properties enabling the creation of groups that can enable the relevant and statistically representative selection of samples for more detailed analyses.

The paper will present several ongoing and future archaeological projects where the use of portable XRF will enable the evaluation of the coherence of the assemblages, selection of representative samples out of assemblages, preliminary analysis of the samples as well as the identification of processes influencing the chemical compositions of the samples.



Session 3: Chaired by Boštjan Lesar

Life Cycle Assessment as a Green Heritage Science Tool

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This contribution will focus on the application of Life Cycle Assessment (LCA) in heritage science in order to put forward a set of recommendations to guide the domain of heritage science towards greener and more sustainable practices and impacts. The rapid development of green principles in diverse fields, e.g. chemistry or engineering, could provide a framework for heritage science based on greener, more sustainable practices.

LCA is a standardised, structured, comprehensive, international environmental assessment and sustainability analysis tool and a rapidly evolving field of research. It is a multi-criteria environmental modelling tool for the simultaneous quantification of environmental and human impacts based on prioritised comparable variables such as pollutant emissions, carbon footprint, energy consumption, toxicity, etc. Despite current limitations and the need to improve the accuracy and representativeness of heritage science data in LCA, greener solutions could be developed and a unique quantified approach to sustainability analysis could be provided by quantifying the environmental impacts of the entire heritage supply chain, including conservation products/materials and processes, their use and end of life. New solutions based on environmentally friendly and sustainable materials, methods, procedures and processes (including all aspects of production, use and disposal) using advanced environmental assessment tools such as LCA are needed to promote the sustainable management and use of cultural heritage.

Incorporating LCA into the practise of heritage science, considering the three pillars of sustainability, would create a new paradigm of green heritage science (gHS) that promotes, for example, the use of renewable or recycled natural sources, minimal interventions, minimal use of toxic chemicals, energy-efficient solutions, minimal waste generation and similar, and principles of green heritage science could be put forward. Building on the experience of both scientific (green chemistry, green engineering) and nature conservation sectors, it is proposed that

heritage science should enshrine environmental, economic, and socio-cultural sustainability aspects in its principles. Therefore, the following nine principles of green heritage science are proposed (see Figure 1).

- 1) Minimal intervention, maximum prevention.
- 2) Inherently non-harmful materials and processes.
- 3) Maximise mass, energy, space, and time efficiency.
- 4) Modelling and simulation for improved management.
- 5) Value-led science.
- 6) As simple as possible, as complex as needed.
- 7) Striving towards future-proof heritage.
- 8) Democratisation of heritage science.
- 9) Engaging diverse stakeholders.

However, the proposed principles require a wider debate among heritage scientists and other stakeholders. These principles are intended to provide the basis for a practical and adaptable tool for scientists and stakeholders to engage in a meaningful and informed dialogue about green and sustainable heritage science, and in the fullness of time, develop indicators and quantitative models to assess the green credentials of scientific approaches and of the developed methods and processes.



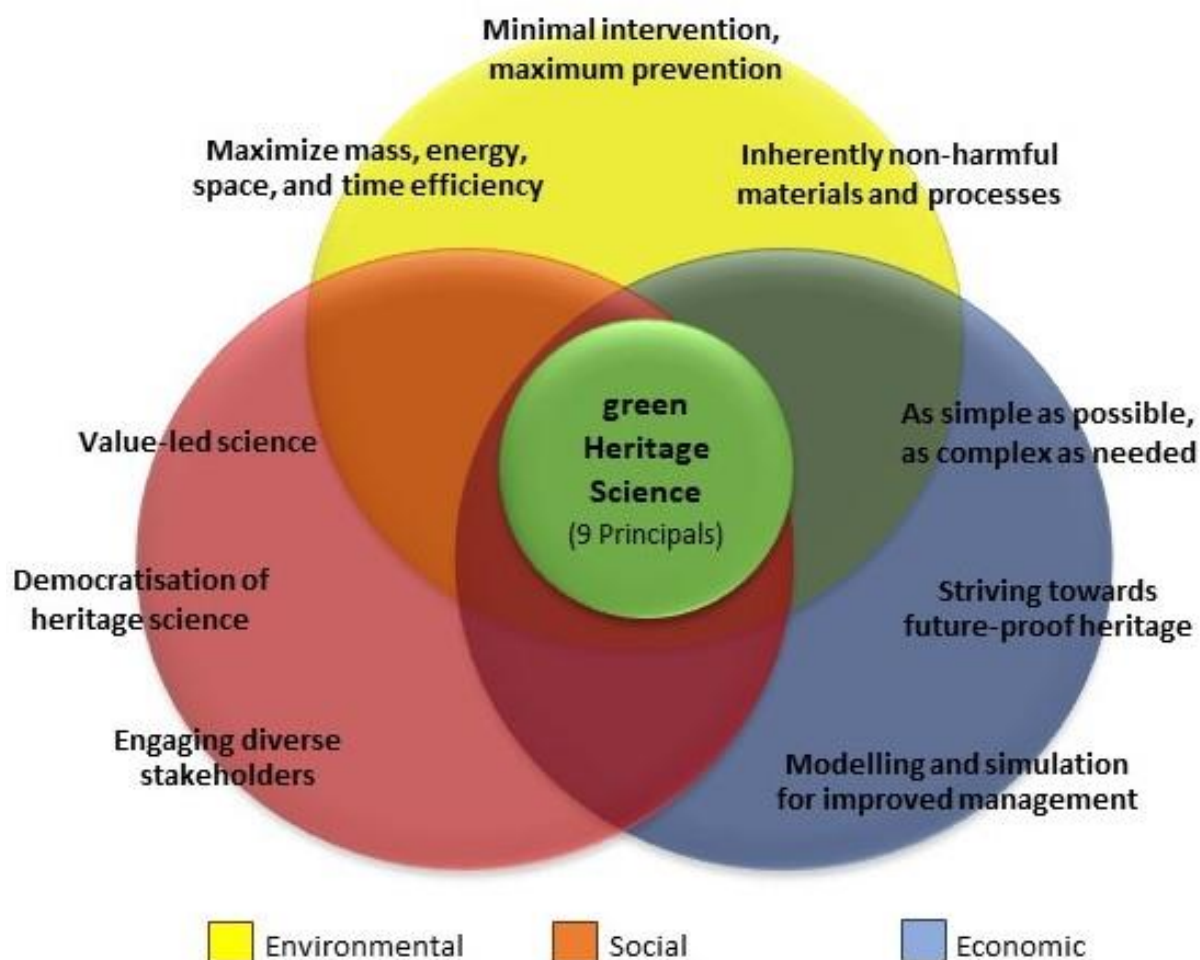


Figure 1. The proposed nine principles of green Heritage Science (gHS) in terms of the three pillars of sustainability (environmental, social, and economic).

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Treatments Preventing Acidic Degradation of Cellulose-Based Paper Artefacts

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Degradation of paper artifacts is a cause for great concern as the information about our cultural heritage needs to be preserved in its original form for a core of valid reasons like national, political, legal, historical, economic, scientific, and emotional [1]. Degradation of paper is caused by physical, chemical and biological factors. Endogenous factors, e.g., pH value of the paper, are crucial determinants for paper degradation and its longevity [1]. Paper acidity arising from the addition of aluminum sulphate $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ (alum), as a sizing agent in the final stages of papermaking from the mid-19th century until the final decades of the 20th century, is generally accepted as a main cause of paper degradation. Consequentially, enormous effort and financial resources are put into development of special deacidification treatments to preserve paper artifacts. The potential for such treatments is huge in Slovenia alone, as 230 km of bookshelves full of archival material exist and $\approx 80\%$ of it was produced after 1830. In this work, the role of cellulose in preparation of non-aqueous colloidal dispersions of alkaline particles and their role in preserving the mechanical integrity of compromised paper artefacts is presented. The stability and particle size in the colloidal dispersions of alkaline particles are evaluated by DLS and turbidimetry. Successful application of the dispersions on model paper artefact is evaluated by chemical analysis (FTIR) and penetration depth using SEM/EDX of paper cross-sections. Neutralisation of the paper's acidity and the added alkaline reserve are determined by standard methods and new protocols for pH measurement and alkaline reserve determination. Finally, the visual appearance of the paper artefacts is evaluated by UV-VIS spectroscopy.

New perspectives of using functional polysaccharides to achieve multifunctionality of speciality treatments for acidic paper artefacts will briefly be presented as well.

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Combining Different Spectroscopic Techniques for the Investigation of Inks: From Mock-Ups to Historical Samples

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Ink has been used for centuries not only for writing and documenting but also for drawing. Many different inks have been used over the centuries, from carbon-based inks to iron gall inks, logwood inks and, more recently, many synthetic inks. Some of the inks were also used in combinations, such as logwood-based ink, which could also be mixed with iron gall ink. Characterising the ink can help to contextualise the works on paper or other supports. It can also help to understand the origin of the ink and ensure better preservation/conservation strategies for historical manuscripts and artworks.

This study focuses on optimising the analytical process to characterise and classify inks using Raman, surface-enhanced Raman spectroscopy, FTIR and XRF spectroscopy, focusing on tannic acid-based inks (iron gall inks), haematein-based inks (logwood inks) and in some cases their mixtures. Iron gall inks are usually deep brown or bluish-black, but it can take several hours or even days for the colour/hue to fully develop after fresh application. This also depends on the relative concentration of ingredients (e.g. tannic acid/gallic acid (from plant sources such as oak galls), iron/copper salt (vitriol)). Logwood inks are derived from the heartwood chips or extract of logwood tree (*Haematoxylon campechianum* – a tree, indigenous to West Indies and tropical America). The main colourant is haematein, which is formed when the haematoxylin present in the heartwood of the tree is exposed to oxygen. Ink is usually prepared from the logwood (extract) mixed with various inorganic salts (e.g. iron (Fe-), aluminium (Al-), chromium (Cr-)) and the colour/hue depends on the metal used for the preparation. In the mid-19th Century, for example, the recipe for Cr-logwood was introduced as an alternative for iron gall ink, as it was less aggressive towards steel writing nibs [1]. On the other hand, even though a decoction or extract solution of logwood can be used to make ink with iron salt, it was preferably used as an additive to tannin inks that were not black enough [2].

The model inks (mock-ups) used in this study to create the spectral database were made according to historical recipes [2,3]. The inks were studied in liquid form, in dried form and as applications on paper. In some cases, selected inks on paper were also artificially aged and their properties evaluated. Artificial ageing (exposure to light or increased temperature and relative humidity) was carried out in climate chambers at the National and University Library of Slovenia, which was made possible through access via the Slovenian E-RIHS node (E-RIHS.si). XRF spectroscopy was used to determine elemental composition, while Raman and FTIR spectroscopy provided information on molecular structure.

In addition, several real historical samples were investigated. In this study, historical samples were selected to gain a better understanding of the materials and techniques used in the 19th Century Norwegian bookkeeping practise. The analysis of these samples was made possible through the E-RIHS.si access. The project was submitted by Ekaterina Pasnak (Department of Conservation and Restoration, NOVA School of Sciences and Technology of NOVA University Lisbon). Iron gall ink was found to be the most commonly used ink in most of the selected real samples, but the presence of logwood ink was found as well.

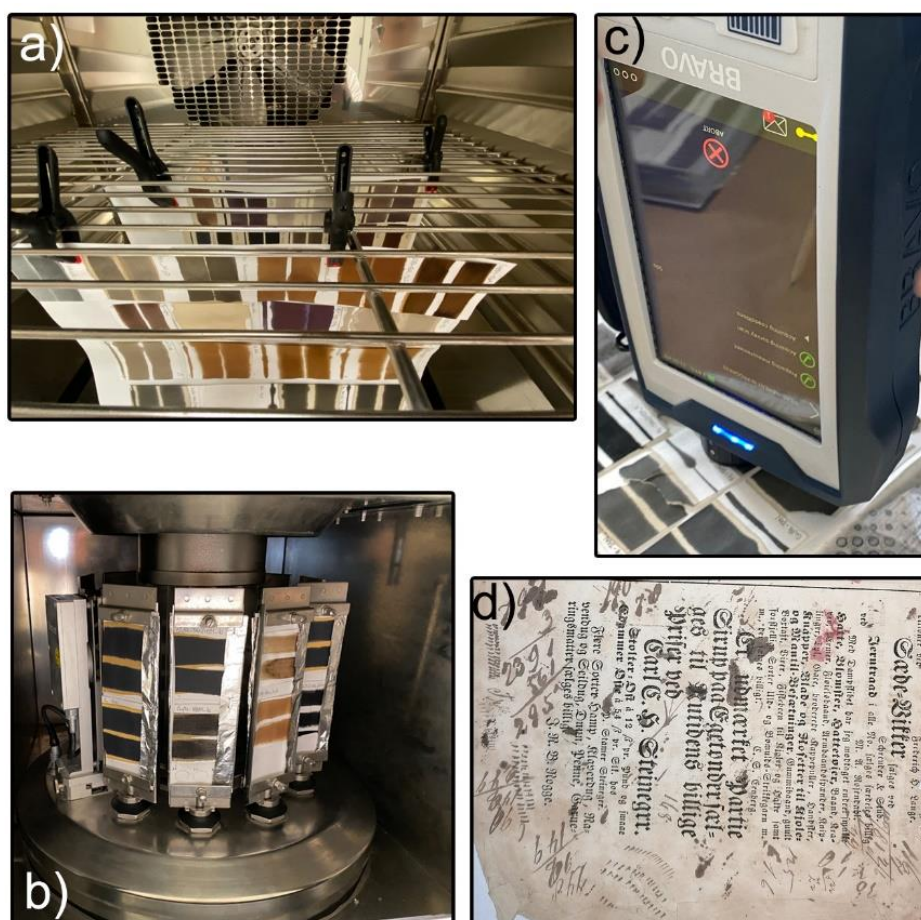


Figure 2. Samples in a,b) climate chambers. c) Non-invasive examination of samples with portable Raman spectrometer. d) Historical sample included in this study.

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Evaluation of Ageing Behaviour of Some Historical Maps Containing Green and Blue Pigments: An Example of E-RIHS Access

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Prof. dr. Andrea Pataki-Hundt from the Department of conservation and restoration, Faculty of cultural sciences, University of Applied Sciences Cologne, Germany applied for E-RIHS.si project. This project was primarily conducted at the National and University library in cooperation with the Faculty of chemistry and chemical technology, where ageing experiments and the analysis of the ageing behaviour of the paper support were performed. The project continued with the analysis of the pigments and the content of transition metals applied to the paper carriers at the National institute of Chemistry and the Institute for the Protection of Cultural Heritage of Slovenia.

The aim of the project was to better understand the of ageing behaviour of some green and blue pigments and their effect on paper degradation. Those pigments were historically used to colour various documents on paper, such as maps and works of art on paper.

To conduct the project, three original historical documents containing green or blue-green pigments on paper supports from the 18th to 19th century were sent to the National and University Library and studied.

Based on visual assessment by the paper conservator from Cologne, it was suspected that the pigments applied could be copper-based green pigments, such as Verdigris. The latter pigment was widely used from antiquity until the 19th century and can be found in illuminations, book illustrations and maps [1]. Green copper-based pigments, such as Verdigris, are known to cause severe damage to many important historical documents. The degree of damage due to green copper-based pigments ranges from the colour change in the painted areas to the total degradation of the pigment and the carrier material, be it papyrus, parchment, or paper [2]. This phenomenon, referred to as “copper corrosion”, is induced by the presence of soluble copper ions [3], which are known to catalyse oxidative degradation of cellulose in an alkaline environment.



In addition to mock-up paper samples, which are usually used to study degradation mechanisms, invaluable disposable historic original paper documents, from which samples can be taken for the studies, are of immense importance to heritage scientists, as they can provide even more information. These documents aged naturally and contain materials specific to the time and place of production.

However, during evaluation of SEC (size-exclusion chromatography) results on changes of the Mw of cellulose on original paper samples, it became obvious that additional analysis of pigment composition had to be performed. Therefore, the analysis was complemented by Raman spectroscopy and Laser Ablation-Inductively Coupled Plasma-Mass Spectroscopy (LA-ICP-MS). The presence of various pigments such as Prussian blue, Paris green (Schweinfurt green, emerald green), and ultramarine, was determined.

To interpret the results meaningfully, many parameters and aspects must be taken into account, from visual assessment of the documents and degradation caused by the pigments to very thin, transparent, or glazing application of the pigment layers. Additionally, the limitations of the instrumental (analytical) techniques in terms of sensitivity must be considered. Even analysis with the most powerful and sensitive techniques can sometimes lead us to even more inconclusive and misleading results.

Based on thorough evaluation of all the results, including Mw determination with SEC, Raman spectroscopy, LA-ICP-MS, and visual assessment of the originals, the results of ageing behaviour of samples containing three different pigments- Prussian blue (iron(III) hexacyanoferrate(II)), Paris green (copper(II) acetate triarsenite or copper(II) acetoarsenite) and an unidentified corrosive copper-based pigment- will be presented.



Figure 1. Recto and verso of sample 4 after undergoing all the analyses.

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Machine Learning for Dating of Historic Paper

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Curators, librarians, conservators, and historians occasionally confront with paper documents that require to be dated, as tens of thousands of undated manuscripts and printed books are conserved in libraries [1]. If the document has historical value or the dating of the document is disputed, which might include forgeries, determination of its age becomes of significant importance. The style of the document, watermarks, and references to eminent individuals or events may help dating within a range. A recent approach based on the analysis of watermarks reported an exceptionally small margin of error of 1 year [1], although some limitations must be overcome, such as the reconstruction of watermarks, especially challenging for those occurring in the inner margins, the time needed to categorise watermarks by similarity, and of course, the presence of watermarks, mostly recurring on handmade papers. On the other hand, other techniques, which have found application also in forensics, such as radiocarbon dating, show limitations for more recent wood-derived papers [2]. In this context, non-destructive methods based on near infrared spectroscopy (NIR) in combination with machine learning are increasingly used for characterisation of heritage materials of organic origin, including dating of paper [3-5], parchment [6], and photographs [7]. NIR spectra are highly complex due to overtones and combination vibrations, which make their interpretation by band assignment virtually impossible. Thus, statistical tools, such as machine learning methods, are used to extract useful information to make quantitative predictions from NIR spectra, comparing reference data and spectral features [8].

We can assume that dating of paper based on NIR spectroscopic data is enabled due to the accumulation of degradation products as a result of ageing, and frequent and well-known changes in the manufacturing processes. Yet the cause-effect relationship between the property of interest and the spectral features, i.e., the underlying process, remains insufficiently clarified, as well as the uncertainty associated with such methods.

Therefore, we have recently investigated the dating method based on NIR spectroscopy and machine learning (Figure 1) to explore (i) the cause-effect relationship between the publication date and the spectral features, (ii) how

accurate the predicted dates are, and (iii) whether and how paper variability and natural degradation influence the dating models [9].

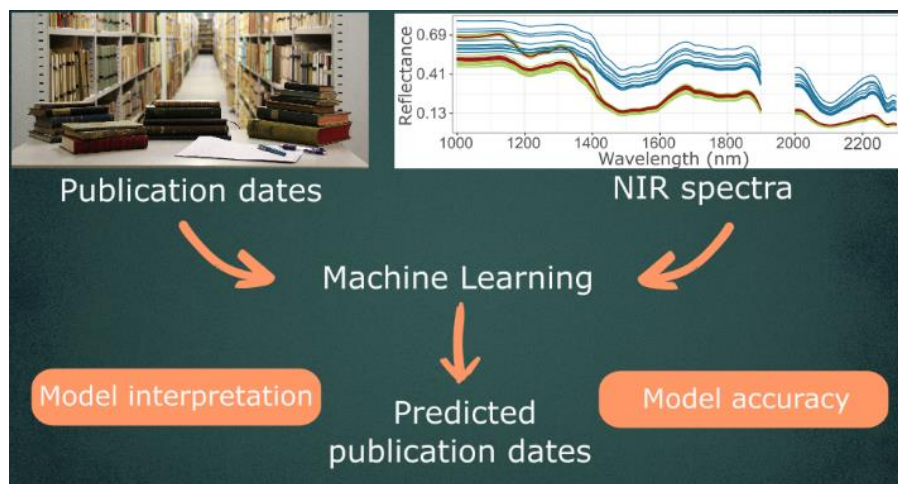


Figure 3. Schematic overview of the study, exploring the interpretative and predictive ability of dating models combining NIR spectroscopic data and machine learning [9].

NIR spectra of 100 books from the collection of the National and University Library of Slovenia were measured. The books published between 1851 and 2000 were of interest to this study. This represents an exceptionally transitional period in papermaking history [10] with the co-presence of rosin-sized paper, bleached paper, and quasi-neutral and alkaline paper with various cationic starching techniques. An age-stratified random sampling with the decade of publication as the criterion for stratification was performed to ensure that the sample books were representative of the entire period. Spectra were acquired on different pages, and at different points in a page to explore the inherent inhomogeneity of real books due to paper variability (pages of the same book block from different batches), and degradation (margins generally more degraded than the centre of a page as exposed to pollutants and light). Three machine learning methods (i.e., partial least squares, random forest and k-nearest neighbours) were compared in terms of model accuracy testing several preprocessing strategies, including spectral preprocessing and variable selection algorithms.

An exceptional accuracy of only 2 years was achieved – better than any other non-destructive method [9]. While we randomly selected the books to have a representative sample set, some types of paper may not have been included in this selection and may need to be in the future, therefore. Moreover, it was shown that spectral features, typical of cellulose and protein structures are of importance for the predictions, rather than degradation, which does not meaningfully influence the prediction accuracy [9]. The results should encourage further studies of IR spectroscopy and machine learning to provide non-destructive crucial data for the characterization of heritage materials of organic origin [9].

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Session 4: Chaired by Jasna Malešič

Heritage Living Labs - Participatory and Inclusive Approaches in HE

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Work in the cultural heritage field of UP FHŠ includes research work and higher education teaching. Intending to transfer current knowledge to students and provide them with a quality foundation for work in the profession, we have developed a series of educational activities that enable an interactive and practical way of learning and teaching, cooperation with society and various stakeholders, and a real study environment as a living laboratory for transfer and verification of theoretical and practical knowledge about heritage. The focus of the work and the critical points of this living lab are the Simon's Bay Archaeological Park and the old town of Koper.

The management of the Simon's Bay Archaeological Park also includes implementing activities, among which student projects enable informal education and creative creation of various contents in a real work environment. The projects creatively intervene in multiple areas, including those that stand out from the classic view and perception of heritage. While working and designing programs for different target groups, students prepare for work in a real environment. A significant achievement is the two-sided learning process, which represents the added value of education. The activities to date have qualitatively linked work with heritage by intertwining various topics and skills, such as conservation, restoration, sports heritage, teaching foreign languages and creative interpretation.

In the urban environment, such work includes active cooperation with local institutions and administration on the promotion of the archaeological heritage of Koper. The target audience and key stakeholders of many activities are city residents, which enables students to learn about participatory approaches to heritage research. Student activities are also intended for temporary residents of the city - students and employees of UP and tourists. As part of project and study activities, students learn about the archaeological heritage of Koper and, in various ways, try to bring it closer to the public with an inclusive approach by following their needs and wishes. The results are manifested on multiple levels in the form of public information through newspapers and social networks, the creation of

promotional materials for various target groups such as picture books for children, exhibitions for the public, the creation of social games on the theme of local heritage and scripts for feature-documentary films.

Using a real environment as a living laboratory for teaching and working with heritage achieved a good response at the level of students and the primary target group - the local community. For students, the success of implementing such a teaching method is the increased volume of independent and creative products in harmony with the local community. The response of key stakeholders reflects in the support and encouragement of student creativity and, finally, in the recognition of UP as an interactive and responsive member of society.

Creating a place or "placemaking" is a concept that encompasses the practices and strategies that the local population (city dwellers, authorities and other actors) invest in places with specific cultural characteristics and co-shape a sense of belonging. Creating vibrant, accessible and inclusive public spaces is critical to creating a sense of community and promoting social cohesion. It helps to create attractive, safe and welcoming spaces where people from different backgrounds can gather, collaborate, build relationships, and shape the physical space. A special role is played by the processes of place creation in historical environments marked by significant socio-political changes.

If properly designed, such places can help address the challenges of modern societies, such as social alienation, mobility issues, climate change impacts, etc. Landscaping can also be an economic driver, attracting new visitors, supporting small businesses and increasing property values.

We used the following methods: sensory analysis of the place, analysis of the soundscape, imagining the development of the city with the help of 4D models, discursive analysis of the naming of streets, analysis of "urban happiness", several methods from tourism management for the needs of the analysis of residents' satisfaction (the KANO method), and informal creation of a place. Some methods were illustrated with the help of Koper organizations and their activities: the participants visited the Koper Regional Museum. They held a round table discussion on the importance of spontaneous cultural practices with representatives of event organizers at the Libertas warehouse - the crossroads of urban culture.

The intensive week of scientific exchanges proved that "place creation", especially with the help of digital tools, is a key element in inclusive urbanism. Koper, with its rich history and many modern creative practices, has proven to be an excellent laboratory and an example of excellent practices.

Revitalizing the Heritage of Underground Architectures and Impact on Society (Sitarjevec Mine, Slovenia)

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Underground architectures, which also include mines, combine the diversity of natural and cultural heritage, which is why interdisciplinary teams of researchers, planners, educators, artists, architects, museologists, designers and workers in tourism are involved in the protection and popularization of their values.

Heritage objects of underground architecture are poorly recognized on the tourist map in Slovenia, except for larger mines such as Idrija, Mežica and Velenje, where the local community has already recognized their heritage and tourist potential as a development opportunity due to their great importance in society. Recently, the local community from Litija has joined these efforts by revitalizing the Sitarjevec polymineral mine which invests considerable resources in the mine and related tourist programs, whereby involving many external professionals in the activities, including the Slovenian National Building and Civil Engineering Institute (ZAG).

In the past, ZAG has therefore participated in, and successfully completed numerous domestic and international projects on the revitalization of the Sitarjevec mine and the recognition of its heritage potential, whereby combining science and art, it contributed to a unique interpretation of the mining heritage, including the use of 3D technologies.

Today, the Sitarjevec mine has been turned into a modern tourist museum, mainly in the light of the discovery of those values of tangible and intangible heritage that we were not aware of until now. The interdisciplinary approach of the completed projects, in which ZAG also participated, is therefore reflected in the enriched interpretation content, which is presented to visitors by a qualified guide when visiting the Sitarjevec mine. ZAG prepared interpretation of heritage, in which external partners from the Museum of Litija, TIC Litija, Odprti krog Architecture Studio, Geological Institute of Slovenia, SIIPS AD d.o.o., Natural History Museum of Slovenia and the University of Ljubljana (NTF Department of Textile and Clothing Design, Faculty of Education, Faculty of Mechanical Engineering). From the intangible heritage, mining stories and cuisine are collected and presented, while the interpretation of the tangible heritage is focused on the material remains of mining and the mineral wealth of the Sitarjevec mine (stalactite, minerals, ore veins, traces of tectonics, pigment...).



That the Sitarjevec mine is alive, that it is a value that has come to life again despite years of abandonment, is a reflection of the strong awareness of the importance of the mining heritage in the local community and represents a solid foundation for new development opportunities in this area in the future as well.

Despite the abandonment of mining in the mid-60s of the 20th century, the strength of the connection of the mining community through the descendants of former miners is still recognizable today, so the local community is intensively involved in new heritage stories, including infrastructure, especially with the desire to make the mine a meeting place of generations that will preserve the memory of mining for years to come.



Assessment of Structural Properties of a Wooden Mosque in Bužim, Bosnia

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Cultural buildings, such as old Bosnian houses, mosques, churches, museums and libraries, are an important part of the history and heritage of Bosnia and Herzegovina. The wood in these buildings is exposed to various biotic and abiotic degradation factors. These buildings are often old and may need repair or strengthening to ensure their safety and stability. In this study, various non-destructive or semi-destructive testing methods, including microscopic analysis, were used to assess the condition of the old wooden mosque in the Bužim municipality. The aim of this study was to assess the condition of these cultural buildings using various non-destructive testing methods and to make recommendations for their maintenance and preservation in the future.

Non-destructive testing methods do not require the destruction of the material to be tested and are, therefore the ideal choice for assessing the condition of historic buildings. The methods used in this study are visual inspection, analysis of the spores, wood moisture content measurement, XRF elemental analysis, non-destructive evaluation of modulus of elasticity, density assessment by screw withdrawal, resistance drilling and microscopic analysis. Visual inspection is a primary method for assessing the potential decay and presence of insects, as well as the potential presence of structural defects. Based on the visual inspection and documentation, a decision is made regarding where the additional measurements should be taken. Time of flight of sound is a non-destructive assessment of the modulus of elasticity that is carried out. Two needles are placed in the wood, and the time it takes for the sound to travel the distance between them is measured. Fakopp Microsecond timber was used for this task. Moisture content was measured using resistance and capacitance measurements. Increased moisture content is usually a sign of increased decay risk. Gann equipment was used. Resistance drilling indicates the structure of the wood across the cross-section of the beams. The method is based on the penetration of the 2 mm thick drill through the cross-section, which allows the detection of potential decay pockets inside the beams. The Resistograph equipment, manufactured by IML, was used. XRF spectroscopy (Olympus Vanta) has been used for non-destructive testing for elemental analysis of wood and provides the information regarding of inorganic elements. This method indicates possible previous treatments of the wood. At

selected sites, density was determined indirectly by the screw withdrawal technique. A screw with a diameter of 3 mm and a depth of 15 mm was screwed into the wood with a screwdriver. The maximum force required to extract the screw was determined using a Screw Withdrawal Resistance Meter (Fakopp Enterprise Bt). In addition, samples were taken from different parts of the building. These samples were examined in detail in the laboratory. Microscopic analysis was done using an Olympus DSX1000 digital microscope (Olympus, Tokyo, Japan).

The wood of the examined mosque is in a pretty good condition, as revealed by the microscopic and mechanical analysis. The decay is limited to some columns of the minaret. The main reason for the good condition of the building in question is the use of durable wood species and sound construction. To protect the respective mosque for future generations, the wooden roof should be maintained regularly to avoid leaks, and the minaret facades should be repaired.



Figure 4. Old wooden mosque in the municipality of Bužim.

Seismic Risk Assessment of Architectural Heritage Building Stock Managed by the Ministry of Justice and Used by the Judicial Authorities

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In areas with high seismic hazard such as Slovenia, earthquakes present the most critical load for immovable heritage built before modern design codes, as buildings were not designed to sustain horizontal loads. Deterioration over time, inadequate maintenance, and renovation, as well as (mis)use, often further reduce their seismic safety.

Being aware of the problematics, the Ministry of Justice has undertaken studies in collaboration with Slovenian National Building and Civil Engineering Institute (ZAG) to develop a professional basis for reducing the seismic vulnerability of the buildings which they own or use, which is also the main objective of the project CPR V2-2257: Strategic Basis for the Reduction of Seismic Risk of Judicial Buildings in Slovenia. Of the 52 judicial buildings considered in the project, 18 have the status of cultural heritage (CH) buildings. In the first phase of the project, the CH buildings under consideration were, based on the available documentation collected and rapid visual inspections conducted, typologically classified according to the period of construction, the number of storeys and the material of the structural elements - features that have a significant influence on the seismic resistance. To assess the seismic risk, the seismic and geological properties of the soil for each building location were determined, as they influence the seismic hazard and define the magnitude of the seismic force that the buildings should withstand. As many as 14 of the 18 buildings are located in an area with an earthquake intensity of VII or VIII, where the buildings are expected to be significantly damaged in case of design earthquake. Furthermore, 4 CH buildings are known to stand in an area with highly unfavourable soils.

Based on the data, a model-based seismic risk assessment of the considered CH buildings was conducted using the POTROG [1] methodology developed at ZAG. Though not the most reliable, such rapid seismic assessment is suitable for an evaluation of a larger number of buildings, given less time (and costs) needed for the assessment. Buildings that do not meet 33% of the seismic resistance requirements according to the current codes (EC8) [2] are considered extremely critical. Their holistic building renovation is prioritised also in the DSEPS [3] strategy. According to the results, 6 of the analysed CH buildings, are such. For a

design earthquake, i.e. a 475-years return period earthquake with a 10% probability of occurrence over the 50-year building lifetime, these buildings would with a probability higher than 25% suffer very severe damage. For another 5 buildings, the probability of such damage is higher than 10%; the model predicts probability of different levels of the building structural damage according to the EMS-98 scale. The results of seismic risk analysis are in terms of damage probability matrix shown for the two most critical buildings of the considered stock in Figure 1 together with their basic characteristics.

Further in the project, detail structural analyses of 8 most critical reference buildings (2 of them CH) will be conducted, including in-depth in-situ structural damage inspections and investigations of the building material and technical characteristics. For these reference buildings analyses of various strengthening measures in terms of their efficiency and costs will also be conducted. The results will serve the Ministry of Justice as a basis for management of the building stock and decision making with clear priorities and known efficiency and costs of possible strengthening measures, enabling more optimal use of the available financial resources for renovations.

Building, Seismic region, Soil type						
LJ1-1, Ljubljana, Seismic zone*: VIII, Soil: C						
			Vertical load-b. structure: Brick masonry Construction year: 1902 No. of floors: B+G+3			
D0	D1	D2	D3	D4	D5	
4%	29%	33%	26%	8%	0%	

Building, Seismic region, Soil type						
VR1, Vrhnika, Seismic zone*: VIII, Soil:						
			Vertical load-b. structure: Stone masonry Construction year: 1554 No. of floors: G+1			
D0	D1	D2	D3	D4	D5	
8%	32%	32%	22%	6%	0%	

D0: No damage	D1: Negligible	D2: Moderate	D3: Substantial to heavy	D4: Very heavy damage	D5: Destruction
	no structural damage, slight non-structural damage	slight structural damage, moderate non-structural damage	moderate structural damage, heavy non-structural damage	heavy structural damage, very heavy non-structural damage	very heavy structural damage
Masonry					
USABLE		TEMPORARILY UNUSABLE		UNUSABLE	

Figure 5. Basic building information and EMS-98 Damage probability matrix results (D0-D5, corresponding damage below) for the most critical brick and stone masonry CH buildings.

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Multianalytical Approach to the Study of the Triptych from the Church of St. Dominic in Izola

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A panel painting by an unknown author from the church of St. Dominic in Izola (EŠD 3714) was the subject of a multi-analytical study. The panel painting is designed in the Gothic style. It has a gilded background and is divided into three sections, thus forming a triptych. The left panel depicts St. Francis, the right panel St. Dominic and the central panel, which is slightly wider than the other two, depicts Mary and the Child (Figure 1a). The triptych is currently dated to the 16th century and has undergone numerous restoration procedures [1].

In order to obtain the most reliable information possible about the material composition as well as the distribution of the materials on the surface of the panel painting and stratigraphically, the triptych was examined by means of hyperspectral imaging (HSI). Four hyperspectral imaging systems operating in different spectral ranges (VNIR, NIR, SWIR and MWIR) were used to investigate their suitability for assessing the condition of the panel painting. The HSI data were pre-processed by principal component analysis. In addition, the HSI results were supplemented and compared with the results of previously performed non-invasive and micro-invasive analytical techniques such as Raman and FTIR spectroscopy in reflection and transfection mode as well as X-ray fluorescence (XRF).

Most of the analysis was performed on the central painting with Mary and the Child (Figure 1_left). The HSI results collected with the VIS-NIR camera in the central field of the triptych showed that the red drapery of Mary and the red cheeks of angels most likely have similar material composition (Figure 1_right). Based on the results of the Raman and XRF spectroscopy and the mapping of the band with the inflexion point at 600 nm [2], it can be concluded that cinnabar is present as a red pigment. The blue areas in the central field of the triptych were painted with paint containing indigo. This was confirmed by mapping the characteristic indigo band in the VIS-NIR spectrum at 660 nm² and by FTIR and Raman spectroscopy. Lipid

components were confirmed on all central figures with the SWIR hyperspectral camera (mapping of CH₂ lipid features at 2348 nm and 2309 nm) [3].

The examination of the triptych did not reveal any trends by which we could determine possible different time phases of individual areas of the painting. In addition, the overall determination of the material composition was complicated by numerous restoration and conservation interventions (e.g. overlapping bands). The study presented here describes the advantages and limitations of various non-invasive and micro-invasive analytical methods for the characterisation of one of the scarcely preserved panel paintings in Slovenia.



Figure 6. Photograph of middle painting “Mary and the Child” during conservation-restoration treatment (left), and a False-colour image VIS-NIR highlighting cinnabar spectral features (right). Lighter colours represent higher reflectance intensity.

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Poster Presentation Abstracts

ARCHE – Alliance for Research on Cultural Heritage in Europe

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“Strong partnerships secure the future of our European heritage”

The field of cultural heritage research and innovation has changed significantly over the last few years. New political, technological, and socio-economic factors underline the need to improve the effectiveness of the protection, conservation, and restoration of Europe's cultural heritage. In this context, it is a priority to introduce new, efficient approaches, combined with the use of green technologies. Moreover, considering the digitizing advances on the global scale, there is an urgent need to develop and exploit high-quality digitalization processes and to enable open access and maintenance of digital cultural heritage assets. There is also a need to increase the innovation potential of the cultural and creative sectors in order to foster sustainable growth and job creation in a context of global competitiveness.

In response to these challenges, the ARCHE project will develop a pan-European framework for a holistic approach to cultural heritage research and development, by creating the Alliance for Research on Cultural Heritage in Europe (ARCHE), a leading coordination network of researchers, innovators, cultural heritage professionals, institutional bodies and citizens. The aim is to involve all cultural heritage stakeholders in the Member States and associated countries in co-designing R&I strategies and roadmaps leading to R&I initiatives that require multidisciplinary approaches and skills.

The ARCHE project consists of work packages and tasks. Since the beginning of 2023, they have been working on establishing ARCHE's vision and mission, which will be presented by the end of April 2024. For this purpose, virtual workshops with representatives of various stakeholder groups participated in the formulation of starting points for the vision and mission. The final document containing the vision and missions will be presented in April 2024.



Looking further into the future, a detailed assessment of R&I gaps and needs for the next decade will be the basis for designing a Strategic Research and Innovation Agenda (SRIA) for joint programming aiming to increase awareness of heritage and European sense of belonging. A new purpose-built governance structure will be proposed that will effectively involve existing networks and new partners from relevant scientific disciplines and industries. It will also promote intensive and wide-ranging collaboration between cultural and creative sector; mainly cultural heritage and the arts. The SRIA and governance structure will be tested in a pilot operation in the third and final year (2025).

Heritage Values and Valuation through the Prism of Sustainability

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There is no disagreement on the fact that cultural heritage embodies and reflects different values. On the other hand, the discourse on the differentiation of individual values, present in heritage, has been a topic of lively scientific, governmental and public debate. In the last decades, political and social factors contributed to institutional and professional understanding of how different types of stakeholders may be gaining benefits produced by different values of heritage. Values and their production of benefits is a dynamic process, which represents the main question in terms of heritage management and conservation, regarding their purpose for society, environment and the economy. The latter are commonly referred to as three pillars of sustainability [3]. To evaluate the benefits that heritage produces for each of the three pillars of sustainability, different approaches are used, depending on the discipline and purpose of the measurement.

Currently, we can pin down two major streams of perspectives on this matter, when speaking about heritage value from the standpoint of conservation. The older view is based on curatorial paradigm that sees the monument as a bearer of heritage values. Smith [9] defined such narrative as authorized heritage discourse. It assumes the intrinsic value of heritage, embodied in the place or object itself, which is set aside from the typical everyday use because of its exceptional cultural value(s). It can be marked by monumentality, authenticity, time depth and aesthetics [10]. Because of that, it requires expert care and interpretation to maintain both its physical state and value for society. The modern, inclusive heritage discourse is related to the perspectives of multiple stakeholder groups and interdisciplinary approaches of valuation [1]. It places a greater emphasis on the uses and functions of historic sites, held by a variety of stakeholders. It emphasises the factors that shape the contexts of heritage places as well as the non-heritage purposes of heritage places, such as economic development, political conflict and resolution, social justice and civil rights issues, or environmental degradation and conservation [1]. In these terms, the social value of heritage represents the meaning that the historic environment holds for modern

community, including the sense of identities, belonging to a place, collective memory, oral history, and spiritual association [6]. This approach focuses on valuation, decision-making, and assessing the social impact of conservation, as opposed to the traditional emphasis on the qualities of materiality and uniqueness of artefacts. International documents have recognised this idea through the designations of Cultural landscapes and intangible heritage [1]. The value of heritage within these terms is usually measured by using social research methods, such as qualitative interviewing, focus groups and ethnographic assessment and is best combined with community participatory practices. The advantage of this approach is that it allows the space for dialogue between communities and heritage professionals, incorporating the values of the first in participatory management and conservation.

Environmental value of heritage is usually seen as the contribution of heritage towards the human-nature relationship [2]. Nature and heritage are linked not only in terms of physical existence. Ecosystems enable specific ways of life, shaping personal, social and group identities, traditions, beliefs and maintenance of historically important places and species. Political perspective on heritage is usually divided between cultural and natural heritage, but this division is increasingly seen as lacking and problematic. UNESCO addressed this formal gap through the introduction of the mixed heritage sites and cultural landscapes [14]. In the environmental science methods, heritage is linked to ecosystem services framework, where it is understood as part of cultural ecosystem services [5;8] It is seen as the non-material benefits, obtained from ecosystems. Another approach is the modified Life framework of values (Kenter, O'Connor 2022), developed to widen the understanding of heritage as source of benefits within the environmental assessment [2]. Contextual and Transcendental values as understood in conservatorship are related to LFV's four components. "Living from" encapsulates the ways in which people are sustained by the environment, such as tradition of fishing or farming; "Living in" represents the environment as the space of our existence, such as ideas of local distinctiveness; "living with" represents the relation to other species, ecosystems and natural processes, e.g. abandoned settlement become a habitat of certain species; "living as" is the experience of being inseparable part of the natural world through heritage experience, e.g. kinship [2].

The economical perspective on heritage is set in the understanding of heritage as cultural capital [13]. An asset contributes to the creation of cultural value and can be understood as a unit of cultural capital [13]. Cultural value is understood as the contribution to existence and development of people's behaviour, as demonstrated in their activities and belief systems. The concept of cultural value is analogical to the concept of heritage value as understood in conservation [12]. It's important to

note the relation between cultural capital in heritage economics and natural capital in the economics of the environment. Natural capital is related to sustainability; its management in terms of ecologically sustainable development involves interpretation of economic, social and environmental values. If we transmit this idea on the concept of cultural heritage capital, it allows us to interpret the heritage through the lens of sustainability [12]. Cultural heritage capital value is two partite, consisting of economic and cultural value. To determine its values, we should use different approaches for each. Economic value is determined in monetary terms, and can be extracted from financial transactions, if we speak about use value. Non-use economic value (passive value) on the other hand is not reflected in financial transactions; such as the utilization of public goods, which we use for free. The non-use value can be divided in three categories: existence, option, bequest value. This concept derives from environmental economics. [12]. The third category, which lies between use and non-use value derives from positive spillovers – externalities. Beneficial externality is a positive effect which an item of cultural heritage imposes on an unrelated third party. For example, inhabitants of the apartments with a view of Ljubljana castle are benefiting from the pleasure of the panorama. Use values are measured through financial transactions. Non-use values are more problematic; common approaches include revealed and stated preference techniques. The latter are commonly used, and they include contingent valuation and discrete choice modelling. Stated preferences stem from the idea of obtaining the willingness to pay or willingness to accept compensation for a loss of a cultural good. Discrete choice modelling is based on evaluation of different attributes of a specific heritage item, such as aesthetic, accessibility... Willingness to pay for specific attributes may be included in the survey as well.

If we now understand the main views on value of cultural heritage and different methods for its valuation, we can conclude, that the common variable in all approaches is the societal perception (belief) about the existence of cultural heritage value. In terms of sustainability, one of the key challenges is how to achieve large scale transformation towards more sustainable behaviour. Heritage has the power to change people's perceptions and beliefs [9]. By holistic evaluation of the benefits that heritage produces for each of the three pillars of sustainability, we can pinpoint the specific values and benefits of heritage that contribute to such change [3]. This will enable us to become more strategic in caring and preserving the values of heritage which might be overseen, despite their potential to foster and contribute to more sustainable future.

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Assessment of Organic and Inorganic Emissions of New Packaging Boxes and Recycled Boxes by Deacidification for Archival Paper Collections Stored in Different Environmental Conditions

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Through the EU GreenArt project (Horizon Europe Framework Programme, grant no. 101060941), new solutions based on green and sustainable materials and methods to preserve cultural heritage will be explored in line with the UN Sustainable Development Goals and the requirements of the European Green Deal.

Proper packaging and storage of objects can contribute significantly to the preservation of cultural objects. It is still unspecified which type of packaging materials (plastic or cardboard, lignin-free/lignin-containing boxes) is more protective for paper collection and which is more environmentally preferable.

This research aims to promote a green approach to preventive conservation by evaluating the environmental performance of packaging boxes used for storing paper-based collection in museums, archives, and libraries. Different types of packaging materials such as cardboard, polypropylene, and natural fibers (lignocellulose and lignin-free fibers), with different configurations and provided by several suppliers (ZFB, Germany; Klug, Germany; JJP, UK), were selected. In addition, new packaging boxes and recycled boxes by deacidification from the national university library (NUK), Slovenia (de-acidified with two aqueous solutions of $\text{Ca}(\text{OH})_2$ and CaCO_3) were tested.

The experimental research will include testing, modelling, and simulations as follow:

Determination of volatile organic compounds (VOC) emissions using sorbent tubes for the collection of emissions prior to gas chromatography–mass spectrometry (GC–MS) and ion chromatography (IC) analysis.

Evaluation of the degradation of stored heritage paper and to assess the long-term storage in the internal environmental factors. Accelerated aging will be carried out for selected archival boxes by subjecting the boxes to temperature cycles while monitoring the VOC emissions. The decrease in the degree of polymerization (DP) of reference paper, caused by interaction with the emissions from the boxes, will also be measured.

The best practice boxes for stored paper collection will be chosen from different suppliers for the assessment from the long-term storage perspectives and compared to the recycled boxes by deacidification from the national university library (NUK).

Life Cycle Assessment (LCA) for packaging boxes and paper collections will be modeled including the following environmental and socio-economic hotspots (raw materials, energy, emissions, waste, stakeholders, and cost).

Preliminary results obtained for the VOC emissions show that the age and type of material used for storage influence what compounds, and how much, are emitted during accelerated ageing. This is reflected also on the impact on the preservation of paper objects stored in proximity with such materials, as shown by the changes in the DP of reference paper exposed to the emissions.

The outcome of this research is to model qualitative and quantitative guidelines for conservation decision-makers, based on the environmental and health impacts of the packaging materials in storage areas of paper collections, using Life Cycle Assessment (LCA) as an internationally standardized (ISO 14040) modelling tool. Greener packaging boxes will be assessed by Life Cycle Assessment (LCA) tool, and the results will be visualized and presented to the stakeholders, decision makers and practitioners regarding the collection demography in libraries and museums.

ACKNOWLEDGEMENTS

The authors acknowledge Ms. Marta Kozole, Faculty of Chemistry and Chemical Technology, University of Ljubljana, for her contribution to the analysis of organic emissions from cardboard boxes.

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The Use of Advanced Digital Approaches for Wall Paintings Assessment

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Wall paintings represent one of the most important types of cultural heritage. As an integral part of architecture their state of preservation usually reflects the history of architecture itself by displaying degradation, damage, numerous historical treatments, and redesigns. Wall paintings, embellishing architectural façades are particularly prone to decay since they suffer direct exposure to environmental conditions. Moreover, digital documentation can significantly improve the understanding of their present state, as well as planning of preservation maintenance, presentation, and promotion. Advanced techniques, such as LIDAR, can be particularly useful in providing an overall assessment of the entire surface investigated, which can be profitably used to identify those specific areas in which further analytical measurements, sampling, laboratory analysis or conservation-restoration treatments are required. Sometimes sites of interest are difficult to access, or the test fields where conservation and restoration interventions have been carried are no longer available after scaffolding has been removed. The use of advanced equipment such as drones is therefore highly desirable, since they offer faster, more advanced (comparison of 3D models taken before and after the procedure), safer and cheaper analysis (no “roadblocks”, scaffolding, permits, or safety requirements e.g. helmets and seat belts) of the object condition. Furthermore, when new materials are developed (such as the new cleaning and consolidation procedures presented in this project), it is very important to monitor the condition of the materials following such interventions, as the long-term effectiveness of such interventions is often still unexplored.

Contribution presents the project “An integrated approach for conservation of cultural heritage wall paintings” (J2-4424). The project is financed by the Slovenian Research and Innovation agency (ARIS) and lasts from October 2022 to September 2025. The project addresses the conservation of wall paintings with advanced methods for estimating the condition of the wall paintings, beyond state of the art conservation-restoration cleaning and consolidation procedures and monitoring the effectiveness of those procedures. By using non-invasive methods (using an unmanned aircraft or so-called drones with various sensors), the condition of

historical materials will be assessed as well as to monitor the effectiveness of conservation-restoration interventions. The solutions developed in the project will be shown as conservation-restoration interventions on a real case study on the wall paintings on the façade of the church of the Annunciation of Mary, Crngrob, Škofja Loka, Slovenia. The church is adorned with 4 outdoor wall paintings: a) Passion cycle from the end of the 14th century on the west façade of the church, b) Holy Sunday from around 1455–1460 on the west façade of the church, c) Saint Christopher from mid-15th century on the south façade of the church, and d) “new” Saint Christopher from 19th century on the west façade of the bell tower. Figure 1 shows the images taken with drones with heat-sensitive sensors on the wall painting.

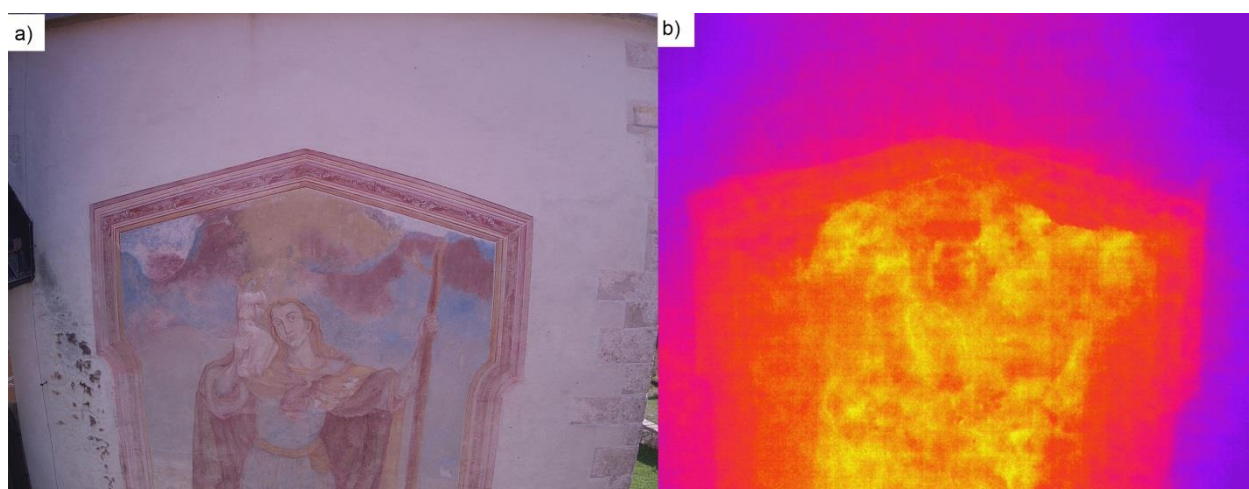


Figure 1. a) Wall painting of Saint Christopher from the 19th century on the west façade of the bell tower of the church, and b) image taken with drones with heat-sensitive sensors (© A. Krivic)

SAFESILK: Metal Salt-Induced Silk Degradation in Heritage Collections

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The SAFESILK research project is devoted to investigating the pressing issue of metal salt-induced silk degradation in heritage collections. It explores the historical significance of textile production and dyeing, spanning from the Middle Ages to the first industrial revolution, while examining a vast array of textile artifacts found in heritage collections. These artifacts range from everyday garments to luxurious tapestries. Despite the exceptional qualities of silk as a textile fiber, it stands out as one of the most vulnerable natural materials to degradation, particularly with weighted silks, which exhibit increased susceptibility.

The 19th century saw the introduction of a dyeing and weight-enhancing process involving metal salts, inadvertently contributing to the accelerated degradation of silk objects. The presence of aggressive metal salts, coupled with a substantial volume of silk artifacts in museum storage, presents a significant threat to the preservation of silk heritage items. Existing conservation treatments have shown limited effectiveness, making metal-induced silk degradation an ongoing concern for museums.

To address this challenging issue, the project is driven by the objectives of comprehending, preventing, and treating metal salt-induced silk degradation. The approach involves studying the complex degradation pathways and evaluating the impact of various internal and external factors. Synthetic materials or mock-ups, made of new silk which will be weighted and artificially aged to mimic historical silk, will be synthesized and subjected to comprehensive chemical analysis to yield valuable insights. These findings will be validated through the analysis of carefully selected historical study objects. This knowledge will guide the development of a practical decision-making tool for managing museum collections, known as a 'damage function.' Furthermore, the project explores the potential of enzymatic treatments for consolidating deteriorating historical silk fabrics. SAFESILK aspires

to secure the rich legacy of silk artifacts by effectively addressing their degradation challenges.

Within the context of the project, preliminary results have emerged through the development of initial mock-up silk samples. These samples underwent a sequential process, including tin-weighting, preparation, and exposure to artificial aging conditions within environmental aging chambers. These chambers were designed to simulate various factors, such as UV-induced photoaging, elevated temperatures, and temperature and humidity variations, with different exposure times and parameters.

Subsequently, these artificially aged silk samples were carefully collected for in-depth investigation. The analysis encompassed a range of microscopic and spectroscopic techniques, including colour analysis, FTIR spectroscopy, optical microscopy, XRF analysis, SEM-EDS (Scanning Electron Microscopy with Energy Dispersive Spectroscopy), XRD (X-ray Diffraction), and SAXS (Small-Angle X-ray Scattering).

In addition, a museum survey was conducted on selected objects to identify silk-made artifacts, assess observable damage, determine their weighting status, and establish their predominant elemental composition. These investigations aimed to comprehend the degradation process and establish connections with observable degradation phenomena in naturally aged silk or real silk artifacts.

The SAFESILK project (N1-250) is funded through the WEAVE program in collaboration between FWO (The Research Foundation – Flanders) and ARRS (Slovenian Research Agency). It involves ARCHES (Antwerp Cultural Heritage Sciences) at the University of Antwerp, Belgium, and HSLL (Heritage Science Laboratory) at the Faculty of Chemistry and Chemical Technology, University of Ljubljana, Slovenia. The project is also conducted in collaboration with MoMu – Fashion Museum Antwerp and Narodni muzej Slovenije – National Museum of Slovenia, Ljubljana.

Stucco Marble Altars in Slovenia: Materials, Conservation, and Meaning

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A new project has been granted by Slovenian Research and Innovation Agency (ARIS), focussing on stucco marble altars in Slovenia from different perspectives: art historian, material and conservation-restoration.

Stucco marble is a unique, relatively seldom used technique, used for decoration of walls and altar constructions. It was used as a cheaper technique to imitate stone. The general composition is known from the literature, however territorially and workshop conditioned differences can be observed. On one hand, these differences can give information, which can support art historical research, and on the other hand, differences in composition can influence conservation-restoration processes. Art historical data are scarce, since in some regions the passing of the knowledge was forbidden by law. The interdisciplinary project aims therefore to carry out material analyses, supported by art historical and conservation-restoration research in order to gather information about composition, technique, state of preservation and appropriate treatments of baroque stucco marble on Slovene territory. The results will help preserve a unique technique and are valuable not only for Slovene territory, but for all regions (mainly Central and Eastern European) where this technique was used.

The altarpieces are mentioned in some surveys of the baroque sculpture and only a few of them were studied more in detail in recent years. Still, there seems to be no study that would present and analyse the stucco marble altarpieces related to their material specifics, artists involved in their production, as well as patrons and their role in choosing this rather expensive material rather than polychrome wood. On the other hand, there is not any in depth comparative study that would analyse the position of this type of altarpieces within the general production of altarpieces in the same period.

Stucco marble can vary in composition. The fresh stucco marble paste has a composition, which allows kneading, and when set it allows smoothing and polishing. The goal was to use different additives to provide the highest degree of



hardness and retard the setting of the mass. Stucco marble is made of gypsum (often with addition of lime) mixed with pigments, water and animal glue. Different organic and inorganic additives were used in different workshops to obtain a variety of properties and colours. Different additives were added at different stages of the working process to increase hardness, resistance, durability and to retard the setting. With addition of surface treatment (grinding and polishing with mixture of glue and gypsum and finishing with wax or oils), a marble-like appearance can be obtained.

To obtain information about historic techniques of its production and their current state of preservation, a variety of analyses will be applied on stucco marble during the project. The material analyses will be carried out non-invasively on materials' surfaces with portable equipment (FTIR, Raman, XRF, stereomicroscope, UV camera) as well as in laboratories on extracted microsamples.

It is well known that material porosity and stucco marble water transmission rate affect the penetration of capillary water or air humidity and potential dissolution of the stucco marble, as well as the rate of salt crystallization at or beneath the surface.

High glue content stucco marbles are known to have a distinctly layered structure, consisting of a porous bulk and a compact, glue-rich surface. Since glue swells easily, such stucco marbles usually have a higher water uptake and could respond unfavourably to cyclic humidity typically observed in churches. Proteins in glue degrade through time, accompanied by changes in amino acid composition – the mechanism depending on the presence of alum and copper ions.

The inhomogeneous, layered structure of stucco marble often represents a conservation problem, as the surface is generally less porous than the bulk of the material, which is itself susceptible to moisture and water penetrating through the building envelope. The surface layer loses its shine due to chemical corrosion or mechanical erosion.

Traditionally, stucco marble surfaces were cleaned with water, which could on long-term lead to loss of gloss, cracks formation and damages. Loss of gloss often resulted in the subsequent application of various surface coatings: natural wax, shellac and other natural or synthetic resin varnishes. These materials can yellow, darken or degrade and change the original surface's colour and lustre.

The project aims to address the above-mentioned issues with an interdisciplinary approach. The goal is to understand the technique, influence of patrons and trading routes as well as material properties and possibilities of their preservation.



Ljubljana, St. Florijan Church, around 1738,
(© Matej Klemenčič)



Golo above Ig, (from monastery in Kostanjevica na Krki), Stuccateur Joseph Gebhardt and others, 1740-ies,
(© Matej Klemenčič)

Paint Binder Analysis of Croatian Wall Paintings: Immunofluorescence Microscopy with Anti-Ovalbumin and Anti-Casein Antibodies

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We aimed to use immunofluorescence microscopy to identify two types of protein binders in 10 polished cross sections of micro samples, which were obtained from real (originating from Croatia) and mock-up wall paintings. We employed a two-step antibody hybridisation procedure, in which the same micro samples were hybridised with anti-ovalbumin and subsequently with anti-casein antibodies and between the hybridisation steps, the sample's cross section was slightly re-polished and cleaned in order to remove all primary and secondary antibody remnants, which remained attached from the first hybridisation step (anti-ovalbumin). This allowed us to reduce the costs and operational difficulties, which are normally encountered, when antibodies, targeting two different proteins, are simultaneously mixed together. To reduce unspecific fluorescence, to amplify the fluorescence of the proteinaceous binders and to construct 3D surface topography models, apart from widefield fluorescence, laser-scanning confocal microscopy was performed. In parallel, FTIR spectroscopy analysis, of finding proteinaceous materials in micro sample cross sections, was also conducted. Results show that our two-step hybridisation procedure was successful in the accurate localisation of both types of proteinaceous binders without any interference from the first hybridisation step. Ovalbumin was found in micro samples MA02 2, MA04 1 and MA04 2 and sample MA02 1 was positive for casein (see Figure 1; sampled from the “Dvorac Livadić” wall painting; museum in Samobor). None of the micro samples proved positive for both proteinaceous binder types. Lastly, for the majority of micro samples, FTIR spectroscopy results completely matched those of immunofluorescence microscopy. Mismatches were found only for micro samples MA02 3 and MA03 3, which proved anti-ovalbumin and anti-casein negative. Until now, this was the first immunofluorescence

microscopy attempt of targeting two different types of proteins on the same cultural heritage micro sample. This research has been developed based on E-RIHS.si access.

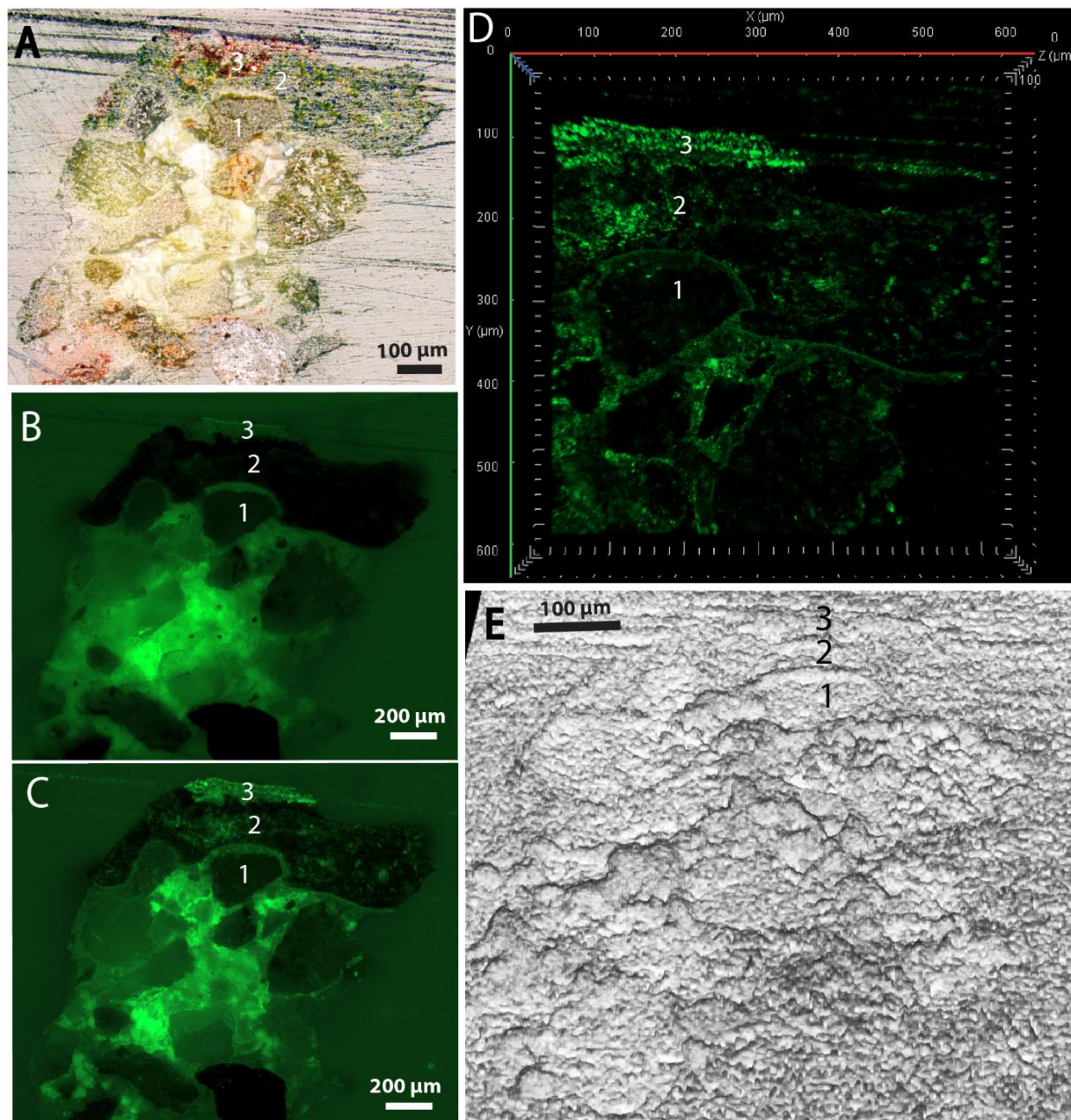


Figure 1. Cross section images of the micro sample MA021, from the “Dvorac Livadić” wall painting (red, south lunette, right side; museum in Samobor), photographed prior to antibody hybridisation using the reflected-light brightfield observation (frame A) and the widefield fluorescence observation (frame B) modes. After anti-casein primary antibody hybridisation and secondary antibody hybridisation, the sample was again captured in the widefield fluorescence observation mode under the same illumination conditions (frame C) and was laser scanned using confocal fluorescence microscopy (frame D) and surface topography scans (frame E).

Effects of Lignin on the Degradation of Historic Paper

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Paper has for centuries been one of the humanity's most important information carriers and is therefore an important part of many heritage collections. The main raw material used in industrial production of paper since mid-19th century is groundwood [1], a mixture of various substances including cellulose, hemicelluloses and lignin. Paper produced from groundwood until late-20th century is usually characterised by acidic pH values and it is among the most fragile types of paper due to loss of mechanical properties caused by the hydrolytic degradation of cellulose chains accelerated by low pH [2]. This is leading to significant problems for the heritage industry, as it has been estimated that up to 80% of library and archival material is prone to rapid embrittlement [3].

This project aims to explore the effect of lignin on the degradation of cellulose-based materials in two “extreme” contexts: during long-term environmental degradation in archives and during composting of waste. The results will enable an understanding of the impact of lignin on long-term degradation of lignin-rich paper in heritage collections and a better design of parameters affecting biodegradability of lignin-rich materials.

Based on numerous model and experimental studies, the rate of degradation of paper as a function of its acidity, as well as of environmental conditions such as temperature and relative humidity, has recently been modelled [4]. Possible sources of acidity in paper include cellulose, lignin, resin acids and alum (in rosin-alum sized paper), and compounds related to air pollution [5]. Organic acids with low molecular weight, such as acetic, formic, and lactic acid are traditionally considered the most likely contributors to the low pH of paper. However, because lignin functions both as a radical scavenger as well as the originator of organic acids [6], the overall effect of lignin content on cellulose degradation remains unclear.

In our research, model samples of paper with lignin or abietic acid (the main resin acid) in concentrations similar to those found in real historical papers were



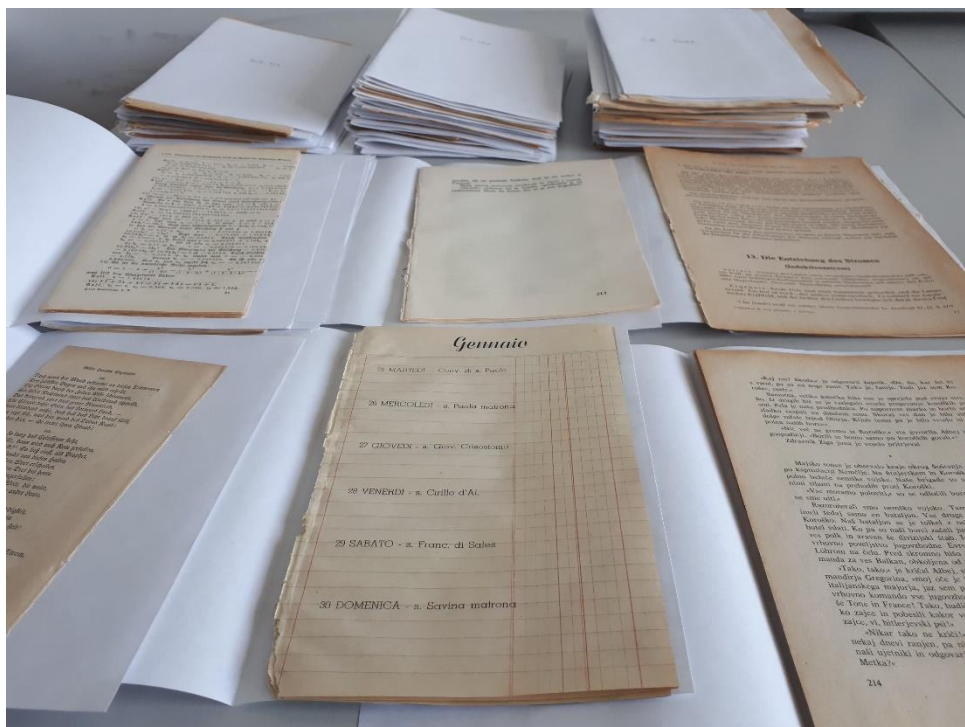
degraded under elevated temperature and humidity. The model samples and a collection of 91 naturally degraded samples of European paper produced between 1844 and 1990 (a part of the SurveNIR reference collection) were analysed for organic acids.

In non-cellulosic model papers, both lignin and abietic acid were proven to be a source of organic acids, with lignin being the larger contributor due to its higher abundance in paper. Acetic, formic, and oxalic acid were produced in larger amounts, while other acids (lactic, succinic, maleic, fumaric) were produced in smaller amounts. In cellulosic model papers, the total production of acids was three times higher in the resin-treated sample than in the pure cellulose sample, while in the resin-alum treated sample, the production was seven times higher. Formic, acetic, succinic, and oxalic acid were determined in larger amounts.

In historical paper, oxalic acid represented almost half of the measured total organic acid content, and its concentration correlated well with paper pH, presumably due to oxalic acid's low volatility compared to the rest of the acids.

These results indicate that oxalic acid is an important contributor to paper acidity, and that even though acetic and formic acid do form in groundwood paper, their relative contributions may be less significant. This hypothesis could re-open the question about the importance of lowering the acetic acid concentration in archival air for longer paper durability.





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ABC – Ancient Book Crafts

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The understanding and interpretation of archival heritage, such as manuscripts, books, and incunabula, heavily hinge on their material history, with significant interest in the production date. A known date allows researchers and scholars to build evidence-based narratives about the development of the crafts, literature, and history, helping bridge the gap between the past and present while enhancing the preservation of these artifacts for future generations.

Many dating methods based on contextual cues have been adopted in libraries and archives, such as palaeography, dendrochronology, watermarks, and leather motif analysis, in addition to historical evidence. However, all these methods face challenges and limitations, where scientific evidence from scientific dating tools is a good complementary. One such method is radiocarbon dating (C14), which requires sampling.

IR Spectroscopy, as a non-destructive technique, has proved its potential for analysing and dating artifacts, especially those made of cellulosic materials like paper, and parchment. The IR spectrum holds the complex and interrelated changes that reflect the complexity of historic archival artifacts due to various production techniques and materials, heterogeneous nature and various degradation processes in unknown storage conditions over time.

The interdisciplinary integration of IR spectroscopy, multivariate data analysis and palaeographic/historical analysis will lead to a novel and robust method of dating of archival and library objects.

In line with this, the ABC project aims to systematically explore the potential of non-destructive IR spectroscopic methods to date library materials using Near Infrared (NIR) or Fourier Transform mid Infrared (FTIR) (Figure 1). This will be followed by multivariate calibration conducted on a set of well-dated objects covering the

Mediaeval era, from collections at KN-Klosterneuburg (Austria), NUL - the National and University Library (Slovenia), and in collaboration with further collections at NLCR – Czech National Library in Prague for validation purposes. This will enable comparative studies of methods and calibrations leading to an evaluation of the analytical robustness of the developed dating methods. It will also involve an exploration of the influence of the storage environments, material types and properties, spectroscopic approaches, as well the transferability of the methods.

Currently, the ABC project (Figure 2) is in its first stage (Data Gathering), where archival collections at NUL and KN are selected and scanned using IR Spectroscopic methods. In parallel, historical and codicological information is being gathered for the selected objects. The different setups and parameters that affect the quality of the gathered spectral data from each IR method are examined as well. The next stage will focus on building the dating models and conducting data analysis. Subsequently, models validation and the evaluation of method transferability will be undertaken.

The ABC project (N1-0271) is funded through the WEAVE program in collaboration between FWF (The Science Fund – Austria) and ARRS (Slovenian Research Agency). It involves BOKU (University of Natural Resources and Life Sciences, Austria), ÖAW (Institute of Medieval Research, Austria), NUL (National and University Library, Slovenia) and UL (Heritage Science Laboratory at the Faculty of Chemistry and Chemical Technology, University of Ljubljana, Slovenia). The project also collaborates with NLCR (National Library of the Czech Republic) and KN (Abbey Library and Archives of Klosterneuburg).

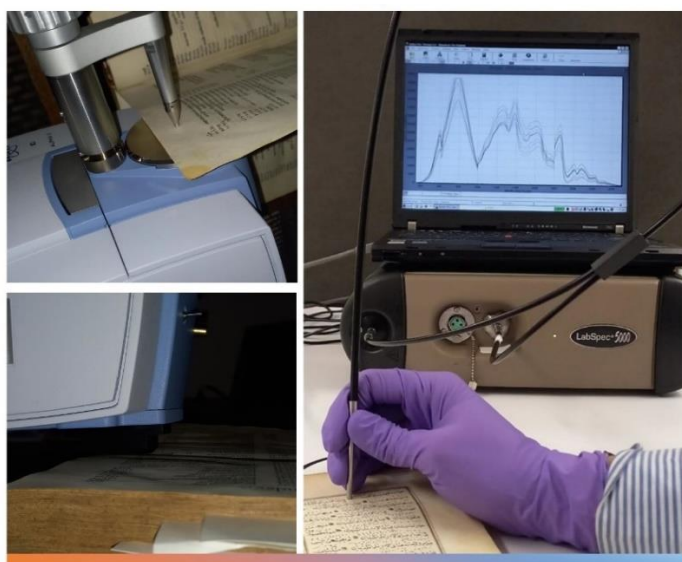


Figure 1. (Left) Bruker Alpha II FTIR spectrometer using external PC with OPUS software; two sampling modules, 1) ATR and 2) reflectance (contactless, video assisted), (Right) Portable UV-VIS-NIR ASD LabSpec® 5000 Spectrometer, equipped with a built-in light source, works with a fiber-optic probe has a diameter approx. 3 mm with Indico™ Pro software (version 6.0.3).

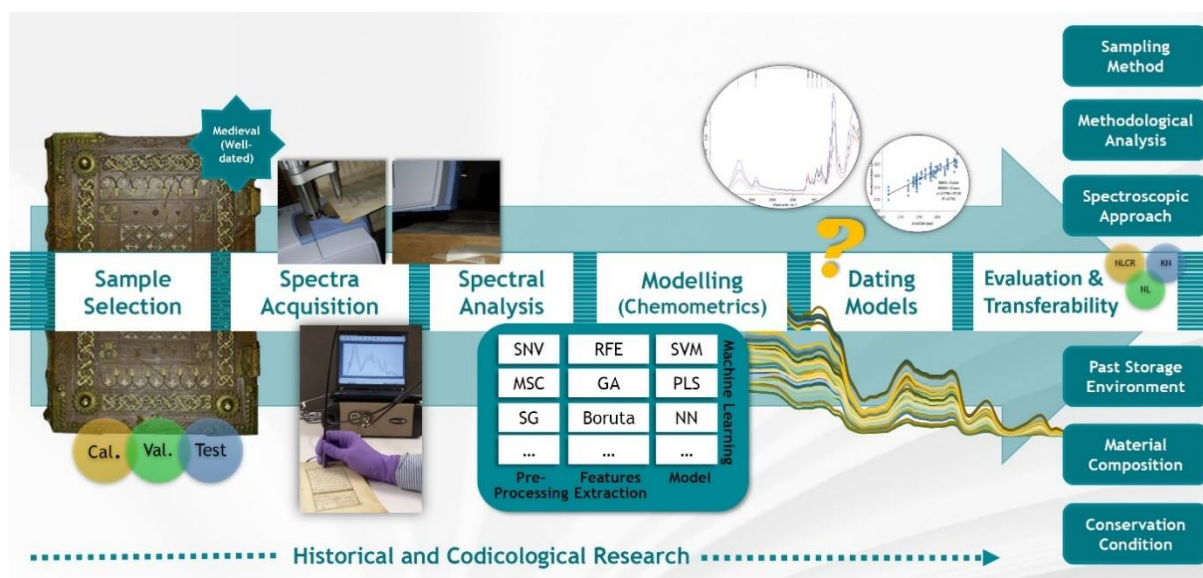


Figure 2. Scheme of ABC project.

Recent Activities at the In-Air Beamline of the Tandetron Accelerator at JSI

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In-air beamline of the Tandetron accelerator of the Jožef Stefan Institute in Ljubljana is intensively used for the analyses in archaeometry and specific issues in cultural heritage. Recent applications based on the analytical methods PIXE and PIGE include studies of historic metals and glasses. Below are current examples:

1. Research of silver knitwear from a medieval grave in Gutenwerd

We found out that the object is made of high-quality silver alloy with Ag>90%. As the object is very delicate – it is composed of a thin silver ribbon wrapped around a thread, a non-invasive approach of PIXE is necessary for the compositional analysis.

2. Research of a potential mold from Gutenwerd [1]

A stone object was supposed by archaeologists to be a mold for casting metal. The supposition was confirmed by PIXE analysis, as we confirmed the presence of tin and lead in small holes and grooves. In this case, the advantage of PIXE – besides its non-invasiveness – was its geometrical precision, as we could easily separately analyse the grooves and the nearby surface.

3. Metals studies of coinage from Asia Minor around 100 BC [2]

A long-range informal project aims to determine compositional groups among the 1st c. BC coins of Asia Minor, minted in Pontic kingdom during the reign of Mithridates VI. It is specific that during this period the first brass coins were issued, which enabled Mithridates to finance his growing war expenses.

4. Bronze Age glass beads from Slovenia [3]

Three beads discovered during the recent excavations were analysed by simultaneous PIXE-PIGE method. All three beads differ according to the flux used: one was made of mixed alkalis and closely resembles the beads produced at Frattesina in Northern Italy. The second bead is made of alkalis obtained from the ash of halophytic plants, characteristic of the Bronze Age. The third bead is made



of natron, which excludes its Bronze Age dating; it is rather an Iron Age infiltrate among the Bronze Age layers.

5. Analysis of glass objects from the Cathedral of the Assumption of the Blessed Virgin Mary in Dubrovnik [4]

Glass fragments discovered during the 1987 excavations were analysed by the simultaneous PIXE-PIGE methods. The largest fraction of glass was made from the ash of halophytic plants, with recognizable groups of common glass (*vetro commune*) and white glass (*vitrum blanchum*). One glass bead was made of refined alkalis, characteristic for the 17th century and some examples were made of natron glass as well as industrial soda. The measurements showed a rather diverse origin of siliceous materials, which confirms the wide-spread commercial relations of the Dubrovnik republic.

6. Composition of the 6th C. AD glass around the Danube limes [5]

The composition of the glass from four Byzantine fortifications on the Danube limes (Svetinja, Diana, Pontes and Hajdučka vodenica in Serbia) were analysed. The results show predominance of only one type of glass, Foy 2.1 with its origin in Egypt, over the various glass types present earlier in the 4th c. AD. This signifies centralized glass supply during the Justinian period.

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ODOTHEKA: Exploring and Archiving Heritage Smells

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In an opinion survey conducted with more than 540 library and archive users in 2014, the smell of books and paper was highlighted as an important reason to visit such institutions, and as part of the material values of the material. Several examples of well-established museums such as Jorvik Viking Centre (United Kingdom) and temporary exhibitions such as *Follow Your Nose* in Ulm Museum (Germany) show the importance of a multi-sensory, holistic presentation of heritage to involve and attract the audience, by offering an experience that is not limited to visual communication. Olfactory exhibitions also lead to a re-evaluation of the smell of objects as a quality worth preserving, in turn revealing an interesting restoration-conservation conflict, as smell is sometimes regarded as evidence that an object needs to be cleaned. There are increasingly compelling examples of the value of olfactory heritage evidence. Despite this, why is the smell of objects an “impurity” to be cleaned? Why are odours, often carried by molecules in concentrations that may be insignificant in the sense of preventive conservation, undesirable for cultural heritage objects?

The ODOTHEKA project [1] aims at exploring the smell of museum objects from the chemical, sensorial, and historical point of view, both to promote the preservation of this intangible aspect of cultural heritage, and to investigate whether this should be considered as a risk towards the object, and more in general in museum display and storage areas. By studying ten historical objects, selected from the collections of the National Museum of Krakow and the National Museum of Slovenia, the ODOTHEKA project aims at developing an international archive of heritage smells. A full protocol for the chemical and sensorial characterization of the smell of each object has been developed in the first phases of the project. This protocol is now being applied to real museum objects, with the final goal to reproduce their smell and use it for olfactory exhibitions in the future.



ODOTHEKA achieves a perfect combination between the sensorial and chemical analysis of the objects with the use of gas chromatography coupled to mass spectrometry and olfactometry detection (GC-MS-O – see Figure). After the smell of the object is assessed and characterised by a panel of trained experts, samples of the air around the object (or headspace) are collected using Tenax® TA sorbent tubes, which collect the volatile organic compounds and allow for their injection into the instrument. The gas chromatography provides separation of the single compounds making up the smell of each object. These compounds can thus be individually characterised via mass spectrometry, a powerful detector which accurately identifies each of the components. At the same time, each compound is transported to the olfactory port, where trained researchers can smell and describe each component separately. The olfactory characterisation not only enriches the identification by providing information such as the intensity of the smell, but it can also help in detecting compounds with a very low smell threshold, which might be smelled at such low concentrations as to still be invisible to the mass spectrometry detector.

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Figure 1. Left: Sampling of one of the ODOTHEKA case studies, a 20th century perfume flask. Right: Emma Paolin, one of the ODOTHEKA researchers at the University of Ljubljana, during the GC-MS-O analysis.

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PVCare: Preventive Conservation Strategies for Poly(vinyl chloride) Objects

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Research has shown that poly(vinyl chloride) (PVC) accounts for 13% of all plastic objects in contemporary art and design collections and has been identified as one of the polymers most prone to degradation. PVC objects pose a challenge to conservators and curators with showing signs of degradation, such as yellowing, sweating and cracking. The threat of irreversible loss of tangible cultural heritage of the 20th and 21st centuries is a result of the fact that industrially manufactured plastics were meant for short-term use. They have in-built lifetimes ranging from 1 (supermarket carrier bag) to 50 years (u-PVC window frames) and when exposed to unsuitable environments they may exhibit rapid ageing, leading to the loss of their original properties. The need to understand these objects and form evidence-based guidelines are therefore essential for appropriate preservation and conservation.

To fill this gap in knowledge, researchers from the Laboratory for Heritage Science (Faculty of Chemistry and Chemical Technology of the University of Ljubljana), the Faculty of Chemistry of the Jagiellonian University and the Jerzy Haber Institute of Catalysis and Surface Chemistry of the Polish Academy of Sciences have combined their expertise to study the condition and behaviour of PVC objects in heritage collections. Conservators and curators from the Centre for the Documentation of Art of Tadeusz Kantor Cricoteka in Krakow, the Museum of Contemporary Art Metelkova in Ljubljana, the Museum of Architecture and Design in Ljubljana, and the Centre Pompidou in Paris are some of the partners participating in the project.

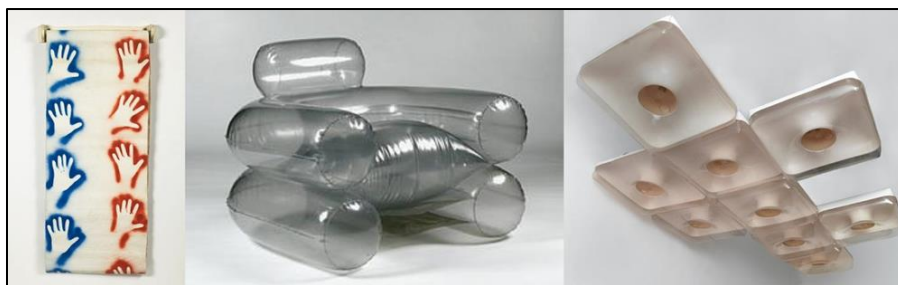


Figure 1. Examples of iconic PVC art and design objects. Left: Essuie-mains / Hygiène de l'art, 1971 (inv. no. AM 2006-114), middle: Fauteuil Blow, 1967 (inv. no. AM 2007-1-38), right: Plafonnier, 1968 (inv. no. AM 2007-1-5) from MNAM, Centre Pompidou, Paris, France.

So far, PVC as a material has been extensively studied by scientists and engineers, but mainly at elevated temperatures or under UV irradiation, with degradation of PVC as subject of research. Such studies are of limited use for the conservation protection of works of art. The importance of PVCare lies in its focus – it concentrates on models that describe the degradation processes of interest to conservators, at conditions of storage, modelling the accumulation of damage over periods of time that are not of interest to industrial polymer chemists and engineers, i.e. a few decades and centuries.

The main objective of the research is to determine the relationship between chemical degradation and mechanical damage and to use this information to develop guidelines for the preventive conservation of modern cultural heritage and art collections made of PVC.

PVCare will focus on the following research questions:

What is the frequency of the most prevalent damage processes observed in PVC collections?

Can we computationally model PVC yellowing, plasticizer surface accumulation, and cracking?

Can preventive conservation guidelines be developed based on computational models?

This will be achieved through an in-depth analysis of the degradation processes of PVC using various techniques. Data on the composition of PVC has been obtained through the scientific study of more than 70 historical PVC sacrificial samples. Accelerated degradation experiments are conducted on these well-defined samples under different conditions to evaluate the rate of degradation. The damage that occurs is quantified in order to develop models, i.e. damage functions, that quantitatively describe the relationship between degradation rate, environmental conditions and sample composition. An important aspect of the project is the analysis of real heritage collections using non-destructive techniques

to determine material composition and quantify the extent of damage. The PVCare project plans to develop scenarios for preventive conservation.

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Microstructural Insight into Plečnik's Terrazzo: Components, Properties, and Originality

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Slovenian architect Jože Plečnik (1872-1957) made an indelible mark on Slovenian landscape architecture, some of his works are included in the UNESCO World Heritage list. One of Plečnik's predominant architectural feature is also cementitious terrazzo, celebrated for its durability, cost-effectiveness, and aesthetic charm, adorning numerous landmarks in Ljubljana, including The Triple Bridge, The Križanke outdoor theatre, and The Cobblers' Bridge. He often blended terrazzo with other materials, such as wood, metal, ceramic and brick, to create contrast and harmony in his designs. This not only made his buildings durable, but also shaped the modern architectural style of Ljubljana. Plečnik's innovative use of terrazzo in these historic monuments is a testament to his enduring impact on the city's architectural heritage. Study presented here studying concrete microstructure of various structural and non-structural elements such as columns, pillars, roof tiles, and other pieces of urban equipment deepens and broadens our understanding of terrazzo composition and, by extension, the terrazzo manufacturing techniques employed by architect Jože Plečnik. Additionally, it provides insights into the provenience of raw materials, which will be invaluable in guiding appropriate conservation- restoration interventions. The objective of our study was to characterize the materials used in the construction of precast terrazzo elements. A variety of analytical techniques, including optical microscopy, scanning electron microscopy, X-ray powder diffraction and thermogravimetry differential thermal analysis was employed. Fundamental characterisation was extended with identification of the type and the provenance of used aggregate, the nature of cement used, and the presence of mineral additives. Two distinct types of terrazzo were identified based on the colour of the aggregate grains: 1) white-grey terrazzo with white and light grey grains, and 2) black-white terrazzo with black, dark grey, light grey, and white grains. Coarse aggregate used was mainly

dolomite, limestone and mixture or both. Additionally, numerous unhydrated remnants of Portland cement clinker were noticed that differed in their size as well as their amount among the samples. Most samples also contained ground granulated blast furnace slag as a mineral additive. These findings confirm the use of locally sourced raw materials, such as crushed limestone and dolomite from quarries near Ljubljana, in crafting terrazzo elements. However, results also revealed that not all samples are built as original construction, as the increased porosity in some samples indicates the use of air-entrained concrete in performed restoration and conservation interventions.





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