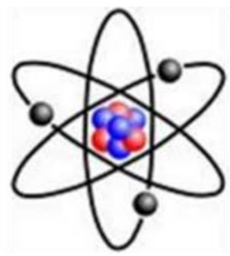
ISSN: 2167-9851

RATS

RESEARCH AND TECHNICAL STUDIES



Research and Technical Studies
Speciality Group Postprints

From the 52nd Annual Meeting of the
American Institute for Conservation

Salt Lake City, Utah

May 20-24, 2024

Volume 12
2025

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Volume 12
2025

American Institute for Conservation

ISSN: 2167-9851

American Institute for Conservation

757 15th Street, NW, Suite 500, Washington, DC 20005-1714

www.culturalheritage.org

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"There is no such thing as a green solvent" - updates from Sustainability in Conservation's Greener Solvents Project

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Extended Abstract

The aim of the Greener Solvents Project, conceived by Sustainability in Conservation (SiC), is to create accessible resources for promoting and disseminating greener solvent research, and support conservators in their safe and appropriate implementation of greener solvent approaches. Whilst 'green' is a widely popular and often arbitrarily-used term, in accurate accordance with its origins in Green Chemistry[1], there is no such thing as a green solvent. Recognising the need for a clearer definition, our research and resources have aimed to highlight the comparative nature of solvent 'greenness', and the requirement to incorporate human health, environmental and professional considerations for solvent selections in conservation practice. Thus rooted in sustainability, with approaches based on hazard and life cycle assessment methods, we have worked to develop and disseminate a clearer definition and perspective of greener solvents in conservation, with a focus on application specificity, and correct, yet simplified, procedures for solvent selection by conservators.

Since the project was launched in 2020 we have been actively creating such open access resources for the conservation field. Our handbook, titled "Greener Solvents in Conservation: An Introductory Guide," edited by G. R. Fife, reviewed by an expert scientific committee and published by Archetype Publications in 2021, is freely accessible on SiC's website. This provides valuable information on identifying the most harmful solvents, practical methods for identifying alternative solutions readily available in studios, and a step-by-step guide to implementing greener solvent practices immediately.

Acknowledging that solvent use in conservation must be changed to benefit the health and safety of the conservator and environment, a key further action point identified has been the need to survey the field to understand the current practices and solvent use within conservation. The dual aims were to inform areas of greatest research need and to use ethical data collection practices. With partners at the University of Delaware a survey was accordingly developed with advice from experts within conservation and public health. In addition to an English version, the survey was made available in eight languages prior to wide

"There is No Such Thing as a Green Solvent" - Updates from Sustainability in Conservation's Greener Solvents Project

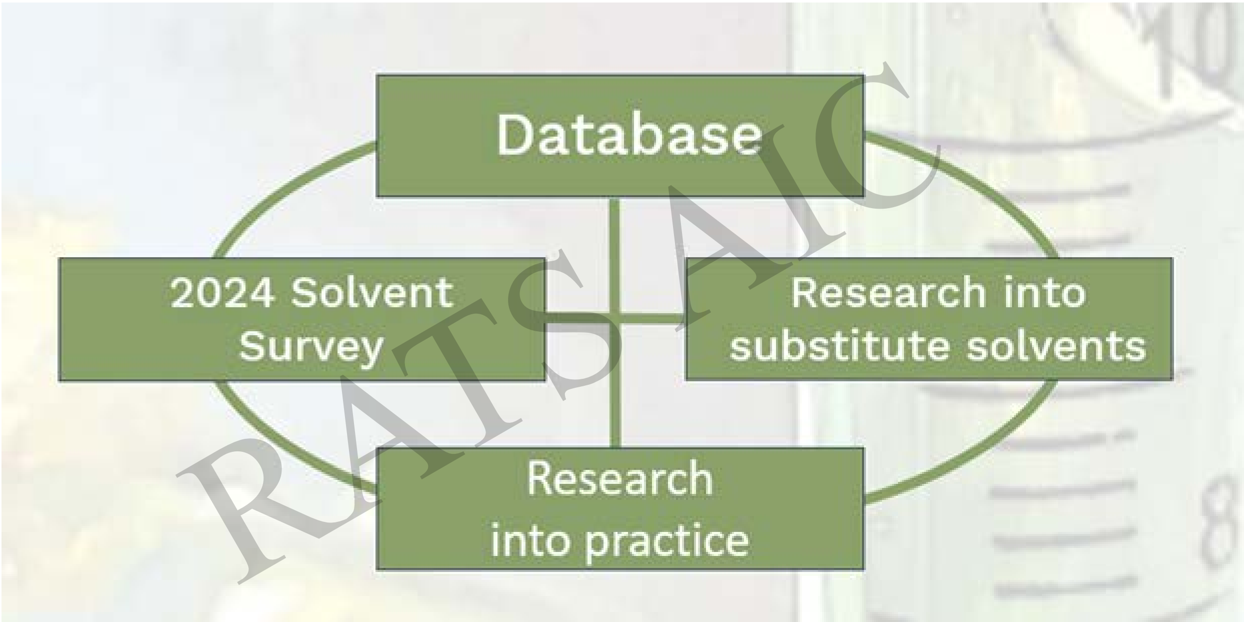

Figure 1. Linking research with practice: the solvent survey, development of the database, solvent modeling and assessing in practice.

dissemination between March and May 2024. Thanks to funding from the Royal Society of Chemistry, the results were analyzed with two graduate interns during summer 2024. The results will be launched at the ICON Sustainability Group 2024 Conference and will be published in Fall 2024 on the project website.

We have also developed a solvent database in collaboration with the University of Delaware. This database offers conservators a comprehensive view of potential greener solvent alternatives based on the specific substrate and their environmental impact. The database includes twenty-four data inputs, categorized into four main sections: identification, solvent properties, health and safety information, and details on the solvent's application in conservation. Our strategy in developing this database consists of a linked approach to actively research greener solvent alternatives, which we are continuing in partnership with industrial and academic research partners in the US and EU.

Consistent with an aim from the beginning of the project - to enable conservators to stop using their most harmful solvents - our current research focuses on substitute solvents for replacing toluene/xylene in varnish applications on paintings and coatings on metal using a variety of modeling tools.

Endnotes

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Safer Solvent Selection for the Removal and Application of Synthetic Resins

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Original Abstract

Cultural heritage conservation commonly uses solvents for the application and removal of polymeric resins in object disciplines from wall paintings and stone to easel paintings, ceramics and glass, ethnographic objects, and others. Polymeric resins carried in solvent are applied in a variety of object treatment schema. The most common of which are: 1) consolidants, fixatives; 2) coatings, lacquers or varnishes; 3) adhesives; 4) binding media of paints and fillers used for restoration, and 5) barrier layers on porous surfaces.

Conservators prefer solvents that minimally impact health and the environment, typically those with low/no odor. Thus, identification and selection of safer solvents with the required solvation and final film properties for resins of interest are of great importance to the field. This work is developing a repository of solvents that both meet specific GHS-defined safety criteria and readily solvate the specific resins of interest. Two bespoke computer assisted systems from Dow were used in the solvent identification and selection process: CHEMCOMP™ Service and a custom CAS Sci-FinderN portal. (CHEMCOMP Service is a series of computerized solvent modeling programs: Evaporation Rate Program, Solvent Blend Program, VOC Program, Flash Point Estimator, and Hansen Solubility Parameter Sphere Estimator.) This CHEMCOMP™ Service is built upon an internally developed database of solvents and polymeric resins supplemented with a few additional materials commonly used in cultural heritage conservation.

The CHEMCOMP™ solvent database was analyzed using the CAS Sci-FinderN tool that identified those solvents that met physical, health and environmental GHS Hazard Phrase requirements outlined by the team. The Hansen Solubility Parameter Sphere Estimator functionality within CHEMCOMP Service then provided computational predictions for which safer solvents solvate the resins included in this pilot study. The solubility predictions of interest have and continue to be validated at the bench and in silico. Physical and mechanical properties of the resulting polymeric resin films cast from a sub-set of the safer solvents and solvent blends will be reviewed to provide an initial assessment of the functional performance of the polymers in use. The full solubility data will be disseminated once thoroughly developed and vetted by those appropriately skilled and qualified in art conservation practices.

Barriers to Embedding Sustainability in Conservation Education and Practice

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Extended Abstract

The UCLA/Getty Interdepartmental Program in the Conservation of Cultural Heritage is engaged in multi-phased research to develop methods for embedding sustainability in conservation education, supported by a generous grant from the National Endowment for the Humanities. Our first phase focused on building a strategic plan to integrate sustainability theory and practice into course offerings. Our second phase activities included research, analysis, and dissemination of data on barriers against integrating sustainability in conservation and its educational institutions. Our overarching goal is to develop methods for mitigating sustainability barriers that will have an impact across the humanities.

In our first phase preliminary research we analyzed and compared the following concepts for embedding sustainability: standalone sustainability classes aimed toward cultural heritage, single modules or activities designed for each course, and engaging sustainability topics throughout everything we teach. We learned that sustainability is not only environmental, but also social and cultural, and that in order to broadly influence conservation decision making, we need to build components into both theoretical and hands-on courses. We examined methods for building sustainability education into fields outside of conservation to find frameworks and case studies, and we made prototype exercises for faculty to test in their courses.

As a preliminary measure, we explored the state of the field of conservation education through a survey to better understand the extent to which sustainability is embedded throughout a curriculum versus as a standalone course, which kinds of sustainability are addressed, and what types of assignments and activities are being utilized. The survey was anonymous, unless contact info was volunteered, and many but not all respondents worked for universities. We were pleased to hear that more than half of respondents included sustainability topics in their course curriculum, with 68% integrating sustainability into more general courses. Many ways of teaching were used to convey these topics, and many different forms of sustainability were considered for holistic outcomes. We also included questions about lab greening initiatives to gauge time and resources dedicated to having a sustainable lab as a teaching space for graduate students. More details about this survey can be found in the preliminary research published in Studies in Conservation (Wuebold, et al, 2022).

Through this survey, we learned that barriers exist to integrating sustainability, not only in teaching curricula, but in all forms of conservation practice. We decided to embark on a second phase of this research to more clearly understand the barriers that conservators face in practice and in educational settings. We reviewed the literature in conservation and adjacent disciplines and interviewed key educators and practitioners on the barriers they encounter in their work. We brought on co-author and graduate research fellow, Chedeya Brown, doctoral student in UCLA's Institute for the Environment and Sustainability, to assist us with searching journal articles focused on barriers and successes to embedding sustainability. The articles that have informed our research discuss techniques for engaging students using modular and adaptable exercises, address barriers to prioritization in decision making (for example, strategies pertaining to coastal site management), and provide conceptual frameworks for forward-thinking and transformative cultural heritage preservation practices in the face of climate change. Many discuss a paradigm shift that requires training and practices to anticipate these real-world changes and prepare students for the increasingly complex problems they will be facing in a changing world. As a research project with many collaborators, we recognized the need to unify our interpretive framework for the evaluation of readings, interviews and focus groups. Independent tagging revealed our tendency to find different associations for the same article, so co-author Ellen Pearlstein developed a set of guidelines and definitions for our keywords, and we worked together to use these keyword definitions, so that any one of us would be able to call out the major themes in an article or interview on behalf of the team.

We elected to interview a geographically dispersed group of professionals at different stages of their careers and working in different types and sizes of institutions, including private practice. We also worked with a sustainability coach, educational evaluators, peer reviewers, and other advisors who assisted with our research to better understand these barriers and how to mitigate them. During this research we identified and formulated responses to root causes, including resistance, time constraints, and financial barriers to sustainable practices. We aim to formulate strategies for breaking down these barriers in both practice and teaching that prevent our sector from fully embracing a more thoughtful, balanced, safe, and ultimately carbon-neutral approach to conserving cultural heritage collections. After collecting so much qualitative data, we realized the challenge of keeping all of our interviewees' insights at the forefront of our minds for later interpretation. This style of data coding suggested by our co-author, Glenn Wharton, has been an important way to track where exactly ideas occurred and how often. While this is not a new style of data tracking, we intend for this template to be most helpful for writing for publications.

Through our work completed thus far, we have identified at least nine barriers that are often inter-connected and include multiple nuances (See **Table 1**). Our goal in this phase is to find examples of replicable successes, or ways around barriers. Here are some steps being taken that have led to remarkable success (See **Table 2**).

Drawing from all of our conversations, survey results, and literature review, we continue to develop an interpretive framework to apply successes and case studies to embedding sustainability principles in our graduate education. We are moving forward in our timeline toward focus groups, and regular meetings of educators who have volunteered to share their conservation syllabi and discuss sustainability. We will also plan on sharing outcomes from this research with the broader community. In the next phase of our research, we will build on this understanding of barriers to integrating sustainable strategies in practice and education. Our ultimate aim is to develop and disseminate pedagogical models representing activities that embed environmental, social, cultural, and economic sustainability in all its forms. These pedagogical models will be presented at a later date.

Table 1. Nine barriers identified

Social	Difficulty building enthusiasm among leadership and colleagues
	Heavy workloads for faculty and students
	Urgency of climate change isn't apparent in day-to-day
Process	Working within university/institution protocols and infrastructure
	Proceeding with incomplete knowledge and accepting mistakes
	Achieving a shared definition of "Sustainability"
	Investment in traditional practices
Resource	Lack of information: consumption audits and greener materials research
	Broad, time-intensive communication required to include all stakeholders

Table 2. Steps to success

Social	Sharing materials through community resource distribution
	Assuring mental wellness in conjunction with action
	Learning how colleagues with few resources do more with less
Model	Demonstrating local procurement as being sustainable
	Contracting with sustainable businesses
	Motivating with Carbon Literacy Training pledges
Activity	Developing Sustainable Action Plans
	Developing student-led research
	Exploring sustainability through cross-disciplinary field trips or gardens

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A Hairy Situation: Revisiting the Species Attributions of Méret Oppenheim's Fur-lined Teacup at The Museum of Modern Art

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Keywords: Méret Oppenheim, animal hair, microscopy, DNA analysis, Peptide Mass Fingerprinting (PMF), species identification

Extended Abstract

Created in 1936, Méret Oppenheim's *Object* is perhaps the best-known artwork from the artist's oeuvre. The spectacle and absurdity of the fur-lined porcelain teacup, saucer, and metal spoon provoked immediate fascination and derision. Almost instantly, *Object* became synonymous with the Surrealist movement and part of the art historical canon, entering the collection of The Museum of Modern Art (MoMA) shortly after its creation. Despite its notoriety, the exact nature of the materials used to create *Object* have not been fully understood for almost a century. Originally described by the artist as being made with the "pelt of a Chinese gazelle", conflicting historical records, purposeful obfuscation by the artist, and a lack of concrete analysis have put this attribution into question, with other attributions such as white-tailed deer (*Odocoileus virginianus*), Sitka deer (*Odocoileus hemionus sitkensis*), and domestic cat (*Felis catus*) joining the fray.

Accurate species identification is important for a few reasons, but one of the most significant would be legal due diligence. Ratified in 1973, CITES established regulations to "ensure that international trade in wildlife is legal, sustainable, and traceable". For museums, this means that when an artwork travels the museum must apply for a permit which attests, to the best of their ability, the accurate identification of the plant or animal species present in the artwork. Beyond this, species attribution can help conservators understand current and future degradation which can be inherent to certain species.

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The critically endangered Przewalski's gazelle is the only species that could be called a true "Chinese gazelle". However, a number of related species could also be interpreted as a Chinese gazelle, including the Mongolian gazelle (*Procapra gutturosa*), goitered gazelle (*Procapra subgutturosa*), and Saiga (*Saiga tararica*). Each of these species inhabited adjacent areas in northwestern China and Inner Mongolia, and would have had healthy populations at the time. One of the largest fur companies during the late 19th and early 20th century, Revillon Frères, had outposts within the habitat range of these species and supplied French department stores with furs imported from Asia, as well as North America. During the late 1920s, gazelle skin coats reached the peak of popularity in Paris and the US, leading to an increase of imports of gazelle pelts during this time. Other attributions to the teacup (i.e., white-tailed deer, Sitka deer, and domestic cat) were also well-represented in the fur trade at this time.

Polarized light microscopy (PLM) analysis – MoMA

Hairs obtained from *Object*, along with hairs from the above mentioned historically attributed species were analyzed with polarized light microscopy (PLM) (**Fig. 1**). Comparisons of the morphological characteristics are outlined in **Table 1**. PLM results indicated that *Object* was not made from the pelt of a white-tailed deer, Sitka deer, or domestic cat. Results also indicated that the hair belonged to an animal within the Artiodactlya taxonomic order, based on the presence of a honeycomb-like medulla and a mosaic scale pattern. However, due to a lack of hair morphology data of gazelle and antelope species available at the time of this presentation, species identification could not be taken further with this technique.

DNA analysis – John Jay College of Criminal Justice

DNA was extracted from hide and hair samples obtained from *Object* and was sequenced. The majority of the DNA yield was attributed to contaminations, which included bacterial, human, insect species, fungi associated with food rot, domestic livestock, and banana. DNA from a nematode species that specifically parasitizes Spanish red deer (*Cervus elaphus hispanicus*) was also found; however, the high potential of cross-contamination from other pelts while part of the fur trade put this attribution into question. Only a small DNA yield was associated with the fur, but the sequences were highly fragmented and very short (~50-100 base pairs), making accurate library matching challenging. The fragmented and poor yield was likely due to the natural degradation of the DNA, as the fur is over 100 years old, and being subjected to fluctuations in temperature and relative humidity early-on, which contribute to DNA degradation.

Peptide Mass Fingerprinting (PMF) – Dr. Daniel Kirby

Hide samples from *Object* were analyzed by PMF (Kirby, 2013), and results indicated relatively uncommon A ions (PMF markers) at 1166 and 1182 Da. These ions, along with other markers in the spectra, clearly indicated that the *Object* sample was Bovid not Cervid in origin, and based on markers in Janzen *et al*., 2021 was likely from the Antilopinae subfamily and specifically the genus *Madoqua* (dik-diks). PMF spectra from three of four extant members of Madoqua: Günther's dik-dik (*Madoqua guentheri*), Kirk's dik-dik (*Madoqua kirkii*), and Salt's dik-dik (*Madoqua saltiana*) were compared with that from *Object*. Based on the high similarity of the spectra along with the unique A ions, the hide from *Object* could confidently be identified as being from the genus *Madoqua* (**Fig. 2**), although the specific species could not be determined.

A Hairy Situation: Revisiting the Species Attributions of Méret Oppenheim's Fur-lined Teacup at The Museum of Modern Art

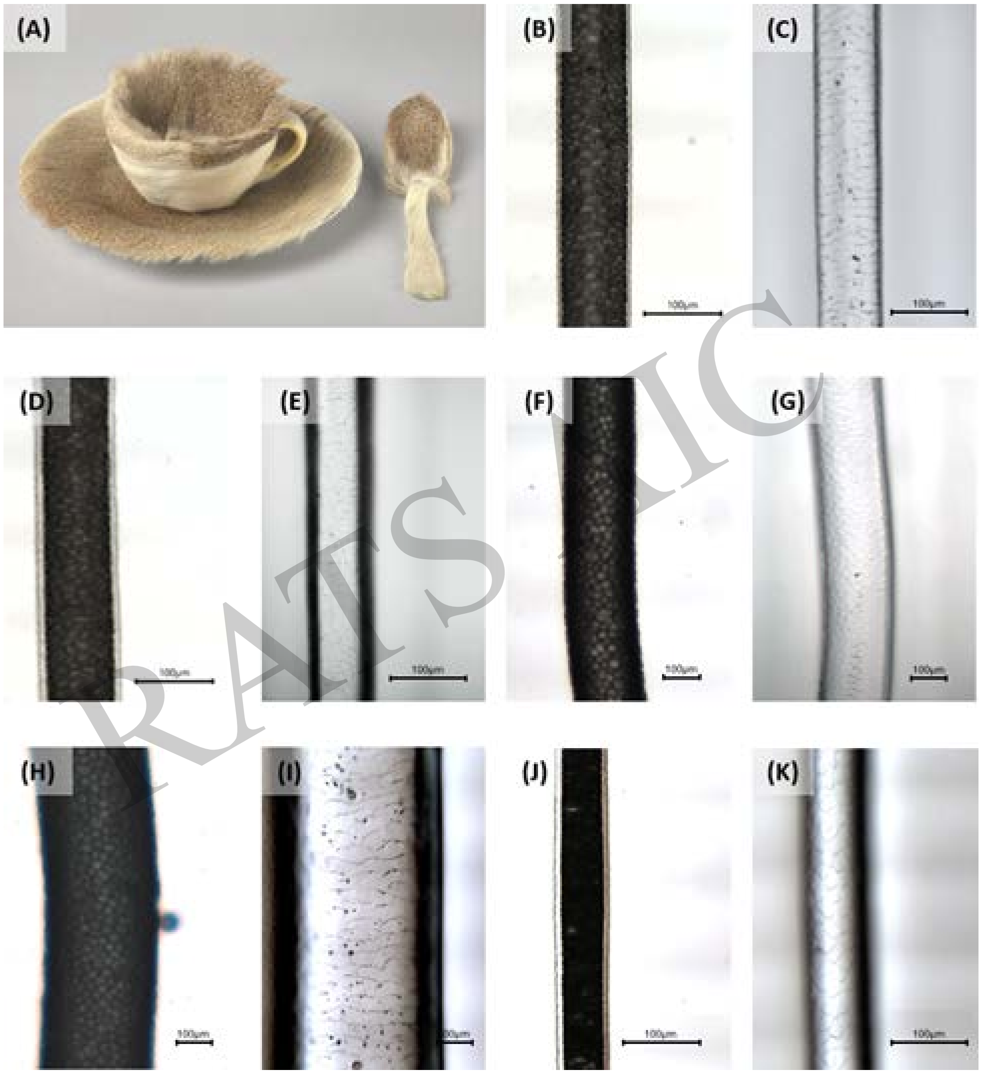

Figure 1. Micrograph images of hairs obtained from *Object* and animals it has historically been attributed to. All fibers were mounted in Cargille MeltMount (n=1.66). **(A)** Méret Oppenheim, *Object*, 1936. Fur-covered cup, saucer, and spoon. © 2024 Artists Rights Society (ARS), New York / Pro Litteris, Zurich. Department of Painting and Sculpture, The Museum of Modern Art (MoMA). **(B)** Medulla of hair obtained from *Object*, 16x. **(C)** Scale cast of hair obtained from *Object*, 16x. **(D)** Medulla of hair from a Mongolian gazelle (*P. gutturosa*), 16x. **(E)** Scale cast of hair from a Mongolian gazelle (*P. gutturosa*), 16x. **(F)** Medulla of hair from a white-tailed deer (*O. virginianus*), 10x. **(G)** Scale cast of hair from a white-tailed deer (*O. virginianus*), 10x. **(H)** Medulla of hair from a Sitka deer (*O. hemionus sitkensis*), 10x. **(I)** Scale cast of hair from a Sitka deer (*O. hemionus sitkensis*), 10x. **(J)** Medulla of hair from a domestic cat (*F. catus*), 16x. **(K)** Scale cast of hair from a domestic cat (*F. catus*), 16x.

Table 1. Morphological characteristics of hairs obtained from Méret Oppenheim's *Object* (1936), Mongolian gazelle (*P. gutturosa*), white-tailed deer (*O. virginianus*), Sitka deer (*O. hemionus sitkensis*), and domestic cat (*F. catus*) observed with polarized light microscopy.

Sample	Hair Diameter (µm)	Medulla Pattern	Medullary Index	Scale Pattern	Scale Width (µm)	Scale Frequency (scales/100µm)
Object	83-88	Flattened, fine lattice-like pattern	9/10	Flattened, imbricate scales; appear similar to torn paper	11-15	9-11 scales
Mongolian gazelle (*P. gutturosa*)	85-130	Flattened, fine lattice-like pattern	9/10	Flattened, imbricate scales; appear similar to torn paper	12-20	7-9 scales
White-tailed deer (*O. virginianus*)	180-280	Large, rounded, honeycomb-like pattern	N/A (medulla occupies majority of hair shaft)	Narrow, fish scale-like pattern; densely packed	20-30	5-7 scales
Sitka deer (*O. hemionus sitkensis*)	270-320	Large, rounded, honeycomb-like pattern	N/A (medulla occupies majority of hair shaft)	Narrow, fish scale-like pattern; densely packed	20-30	4-5 scales
Domestic cat (*F. catus*)	50-80	Fine lattice-like pattern to amorphous pattern	3/4	Elongated, petal-like scales; very evident at proximal end of hair shaft	20-28	5-6 scales

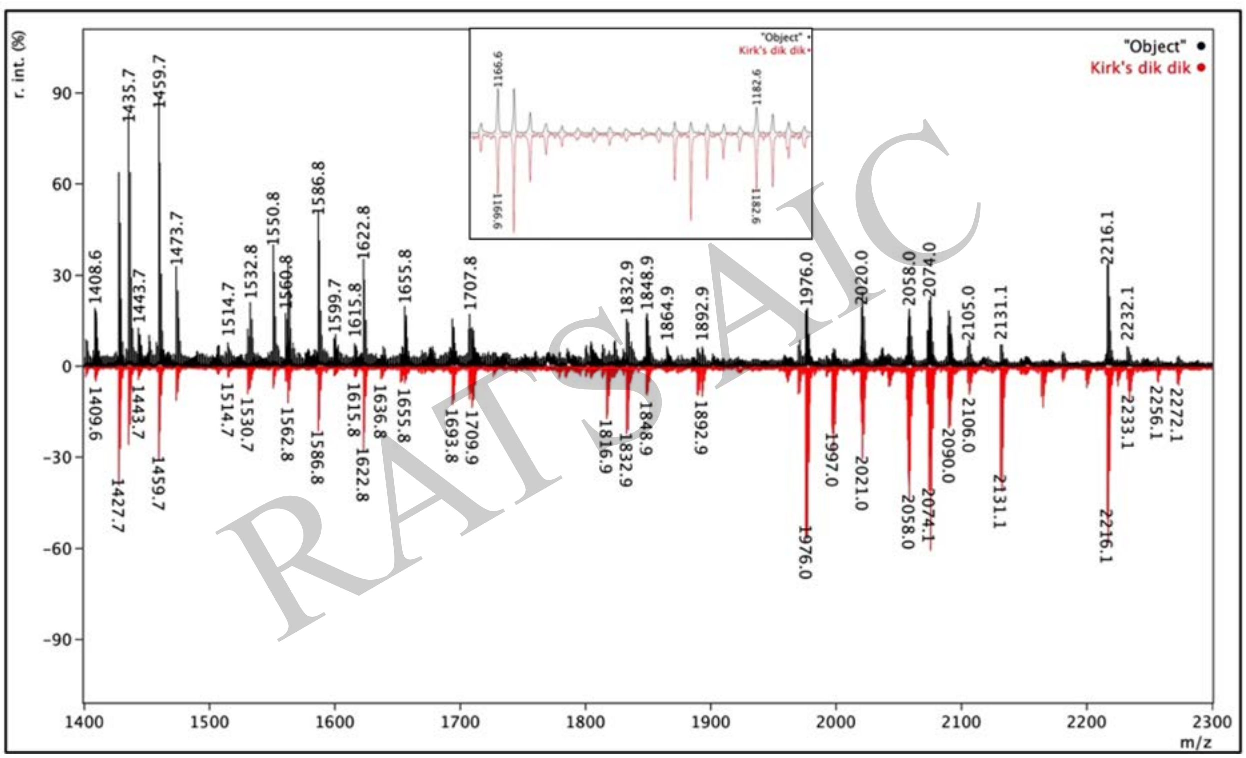

Figure 2. Partial PMF spectrum from hide obtained from Méret Oppenheim's *Object* (1936) (top, black) compared with that of the Kirk's dik-dik (*M. kirkii*) (bottom, red). The inset shows the A ions at 1166 and 1182 Da.

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Overall, the three techniques were able to eliminate possible groups of animals that the pelt could be and worked toward a specific identification. In this phase of research, PLM could confidently give the taxonomic order rank, DNA gave a potential family rank to consider but was hindered due to degradation, and PMF provided a confident identification of the genus. Furthermore, this study illustrated the advantages and disadvantages of each analytical technique. Apart from accessibility and cost, level of identification specificity, and impact of material degradation and contamination, the main disadvantage among all techniques was that their efficacy was severely hindered by the limited reference libraries that lacked accessible information from many non-North American species.

The simple goal of identifying the species of fur used on Méret Oppenheim's Object underscored the importance of a multidisciplinary approach to analytical research. Combining historic research with analytical techniques provided more clarity on the potential fur used, added further credence to the artist's attribution, and narrowed down the possibilities. Future research into characterizing more Asian and African mammals will likely lead to a positive species identification, as well as have implications beyond art history and cultural heritage, namely for ecological conservation.

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Novel Non-invasive Method for Extracting Proteinaceous Binders from Panel Paintings

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Original Abstract

A new method for the non-invasive extraction of protein binders in panel paintings using high-acyl (HA) gellan gum was proposed, which solved the limitations of previous non-invasive extraction methods, which mainly focused on the shallow surface of cultural relics and were susceptible to environmental pollution. The extraction effects of different gums on the protein binders in the simulated panel paintings were compared and characterized in terms of protein concentration, macro and micro appearance, color difference, pH and contact angle. Next, Fourier-transform infrared spectroscopy was carried out to analyze the extraction mechanism. On this basis, the non-invasive extraction of panel paintings containing different types and concentrations of protein binders using HA gellan gum was explored.

The results showed that neither HA nor LA gellan gum significantly affected the surface color, pH, contact angle and visual appearance of the paint layer. The concentration of protein solution extracted from HA gellan gum was 2.4 times higher than that of LA gellan gum, and the possibility of gel residue was small. In addition, HA gellan gum showed good extraction effects on different types and concentrations of protein binders. Therefore, it is expected to be an effective means for non-invasive protein extraction in painted cultural relics.

Developing Genomic Tools to Determine the Maker of a Modern Gofun Paint Preparation

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Original Abstract

Genomics can offer unique perspectives into the creation and history of cultural heritage objects. The possibility of learning more about the makers of objects through genomics is tantalizing: there are examples where an artisan's intimate contact with the manufacturing of art materials suggest that genetic information may survive. Gofun, a calcium carbonate pigment commonly found in traditional Japanese paintings, is one of these examples, and this abstract describes our attempts to isolate the genetic information of the maker from a modern preparation. The paint is prepared from gofun powder, which is made by an intensive pulverization of air-dried oyster shells and kneaded by the artist or their assistant with an animal binding glue. A small amount of water is added before application to a textile or paper support. The paste is kneaded by hand for at least an hour, thus increasing the opportunity for skin cells from the artisan's hands to become incorporated into the paint. Since these skin cells carry the artisan's DNA, this phenomenon sparks intriguing questions about what information genomic tools can provide about the history of a painting such as: Who prepared the paint? Could that correlate to the attribution? Does attribution require a combination of human and microorganism genetic information? What microorganisms and organic material was the painting exposed to, and how might that impact conservation treatment?

This project, representing a novel collaboration between the Metropolitan Museum of Art and the Mason Laboratory of Weill Cornell Medicine, explores the extent to which these questions can be answered using the smallest paint sample possible. As sample size is the limiting factor for most art analysis, especially Asian art, which typically is painted in very thin layers, the following work describes what might be possible on milligram sample sizes with the hope that miniaturization could be achieved. A modern gofun paint mockup, prepared by a Met conservator, served as our paint source. A protocol optimized for highly-fragmented DNA from calcium-based sources (bone) was implemented on four microsamplings, ranging between 1 - 8 mg of paint. We selected a protocol that was sensitive to small fragments of DNA as the paint source was exposed to light, water, and nucleases, all of which drive DNA degradation reactions. Moreover, calcium ions interfere with extraction by tightly binding to DNA, so a protocol that sequesters calcium was important for DNA recovery. As the extraction yield was too low for detection, we amplified the extracted DNA to reach the minimum input required for sequencing. We compared sequencing data from the paint samples to the conservator's genome to determine sequence overlap. Fluorometry and automated electrophoresis following amplification support the presence of DNA in the paint microsamples. Genomic isolation and analysis from microsamples of gofun is possible, however there are remaining challenges in determining the organisms represented in the generated genetic profile due to the presence of additional extraction and amplification inhibitors. Future studies will probe the interference of metal ions in the chemistry of DNA extraction, amplification, and sequencing.

Advancing Conservation Techniques through Deep Learning of Optical Coherence Tomography Images for Classifying Kozo-Fibered Papers

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Original Abstract

In this presentation, we will share a novel method of acquiring the cross-sectional images of 35 sample papers using optical coherence tomography (OCT) and feeding the images through Deep Convolutional Neural Networks (AlexNet) to achieve highly accurate and non-destructive classification. Paper identification and analysis of morphological characteristics related to plant cultivation and craft tradition have long relied on interpretive observation and/or destructive fiber sampling techniques [1-3]. Optical coherence tomography (OCT) is a non-invasive technique used for medical imaging that has been applied to art conservation to capture both the surface and subsurface structure information of cultural heritage objects [4]. Thirty-five paper samples were sourced from a conservation vendor specializing in Japanese handmade papers. These were selected based on their known fiber content and production methods as well as use in book and paper conservation treatments for hinging, tear repairs, and loss compensations. Cross-sectional images of the samples produced by OCT reveal how light scatters in the paper substrate. The patterns of scattering light seem arbitrary to the human eye, however, AlexNet, first introduced in 2012 as a convolution neural network (CNN) for image classifications [5], can be used for deep learning to classify these papers. A total of 35,840 OCT cross-section images were generated, of which 3,500 images (~10% of the dataset) were used for training, 8,960 images (25% of the dataset) were used for validation, and 23,380 images (~65% of the dataset) were used for testing. The AlexNet achieved a test accuracy of 98.99%, with 23 out of 35 paper samples achieving 100% accuracy in the tests. This presentation will share information on this testing methodology and equipment, as well as a summary of the results which demonstrate that combining OCT with AlexNet can provide conservators with a highly accurate tool for classifying papers used in treatment repairs.

Advancing Conservation Techniques through Deep Learning of Optical Coherence Tomography Images for Classifying Kozo-Fibered Papers

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Wood Identification in Historic Furniture: Optimization of Machine Learning Approaches for Processing LIBS and Py-GC/MS Data

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Original Abstract

This study focuses on the challenging task of identifying various species of mahogany, a prized wood sourced from the Caribbean in the 18th and early 19th centuries. Distinguishing between 'true mahogany' species and other tropical hardwoods, as well as North American woods mimicking mahogany, poses a significant challenge. Accurate wood identification is crucial for understanding the origins of raw materials, craftsmanship choices, and for effective conservation. Traditional methods involve microscopic examination by a wood anatomist, but obtaining suitable samples may not always be feasible or desirable. An alternative approach utilizes chemotaxonomy, leveraging variations in organic and inorganic chemical composition for wood differentiation.

In collaboration with Yale University Art Gallery, our ongoing project employs handheld laser-induced breakdown spectroscopy (LIBS) and pyrolysis gas chromatography-mass spectrometry (Py-GC/MS), complemented by machine learning (ML). Our goals are to distinguish mahogany from similar-looking woods and, ultimately, to differentiate between the three Swietenia mahogany species. Promising outcomes have emerged from the analysis of numerous samples, including those extracted from furniture. This presentation will highlight recent efforts to optimize data preprocessing steps, effectively deploy machine learning tools, and develop more robust classifiers. A collection of over 400 wood reference samples were studied with the two techniques, prior to examining approximately 200 areas on historic pieces of furniture employing the same approach.

Py-GC/MS is well-known among conservators for its efficacy in characterizing heritage materials. This method utilizes small samples of wood, either as tiny fragments or powdered material obtained with a hand drill. It takes about one hour to analyze a single sample in the laboratory. The resulting pyrograms show the presence of materials associated with cellulose, hemicellulose, and lignan, which are polymeric components common to all types of wood, as well as extractives, the non-structural, low molecular weight organic molecules that are the principal source of chemotaxonomic discrimination.

Wood Identification in Historic Furniture: Optimization of Machine Learning Approaches for Processing LIBS and Py-GC/MS Data

LIBS is a form of optical emission spectroscopy capable of simultaneously detecting all elements within a single laser pulse. Consequently, a broadband LIBS spectrum can be likened to a diagnostic fingerprint. With a commercially available handheld instrument, it is possible to analyze objects in situ in a matter of seconds. Notably, LIBS enables the detection of light elements, including both organic (e.g., C, H, O) and inorganic components (e.g., Li, Na, Mg, Al, Si, K, Ca, Ti, Fe, Zn, Sr).

Before applying machine learning tools, a preprocessing protocol was developed for the LIBS and Py-GC/MS data. This included baseline correction, alignment to ensure that the wavelength or retention time values were standardized across all data collections and were therefore directly comparable, and, in the case of LIBS, the removal of data with low signal-to-noise ratios (SNR) based on a spectral similarity analysis. Principal Component Analysis (PCA) and Partial Least Squares Discriminant Analysis (PLSDA) was then applied to build classifiers. Iterative refinement of ML algorithms and preprocessing steps resulted in models with a high level of classification success. Software was then developed to allow chemometric processing of LIBS data to be carried out in real-time in a gallery space.

Plastics BINGO!: Identifying Plastics in the Collections of Cooper Hewitt, Smithsonian Design Museum

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Original Abstract

This poster summarizes the results of a short internship in 2023 focused on plastics identification at Cooper Hewitt, Smithsonian Design Museum in New York City. The goal of this research was to more accurately identify a selection of plastics in collections objects and deepen my understanding of the types of polymers typically found in design museum collections.

This project follows up on a year-long survey begun in 2012. In this survey, ca. 1,500 collections objects were assessed for condition, storage recommendations were made and implemented, and a handful of objects were analyzed using portable Raman and Fourier-transfer infrared (FTIR) spectroscopy by conservation scientists. My project focused on a small subset of the objects included in the earlier survey. Over four weeks, 37 collections objects and 58 reference samples were analyzed using Attenuated Total Reflection (ATR)-FTIR spectroscopy.

Cooper Hewitt's remit is to collect and care for important and impactful design. As indelible materials of the 20th century design narrative, its Product Design and Decorative Arts curatorial department is filled with examples of natural (horn, tortoiseshell) and early plastics such as those made of cellulose derivatives and formaldehyde-based resins (i.e., Bakelite). Modern plastics like polyvinyl chloride (PVC) and polyurethane foams have consistently made their way into the collection over time. As today the museum collects a wide variety of objects, from one-of-a-kind works of art to disposable commodity items, an impressive range of plastics in varying conditions are present both on display and in museum storage.

It's no secret that art and design museums face unique challenges when it comes to understanding plastics in their collections. Plastics are made from varying proportions and mixtures of polymers and additives and can be nearly impossible to distinguish from one another, even if their degradation phenomena and aesthetic qualities appear nearly identical. The complex composition of these objects challenges both identification and appropriate treatment and/or storage options. Complicating matters is the fact that many design objects exist as multiples or editions, calling into question long-held conventions in our field regarding authenticity, authorship, and ownership.

Plastics BINGO!: Identifying Plastics in the Collections of Cooper Hewitt, Smithsonian Design Museum

While many objects in our survey were identified with confidence, matches using FTIR were not always straightforward. Plasticizers and other additives can obscure spectra, rendering confident identification nearly impossible. Compounding the complexity of the task is the fact that many objects are made of composite materials. While ATR-FTIR is a very useful technique for bulk polymer identification, not all collections objects are suitable for this technique due to their size, shape, and/or condition, among other factors. It thus became vital to use a three-pronged approach: considering historical context along with sensory information and the use of scientific analysis to accurately determine polymers. The short but ambitious project provided the institution – and me – with a wealth of information about the complex plastics materials increasingly encountered by cultural heritage professionals, especially those working in modern and contemporary design collections.

Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy

Riley Cox[1], Mollie Crossman[2], Garrett Hill[2], Maggie Wang[2*],
Dr. Margaret G. MacDonald[3]

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Original Abstract

Egyptian limestone objects are known to be sensitive to unstable conditions in storage. Exposure to fluctuating humidity can cause the soluble salts inherent in these objects to dissolve, migrate, and recrystallize leading to delamination, flaking, and general loss of structural stability. The Walters Art Museum found three such objects in their collection in need of stabilization through desalination. These Egyptian limestone works were determined to be too fragile to be treated through the traditional desalination approach of submersion in a water bath. The conservators sought an alternative approach to desalination with agarose hydrogel poultice, which desalinates the stone through the formation of a concentration gradient. Prior to treatment, the surface will be secured with B-72 consolidant to preserve its structural integrity.

This research explores the effect of consolidation on the rate of desalination and the efficacy of the treatment using an NMR-MOUSE spectrometer, a non-invasive analytical technique that measures the transverse relaxation time (T2) of the protons in limestone-bound water. As such, T2* rates measured over the course of the treatment allows direct observation of the salt changes in the stone. Preliminary data suggests that the non-consolidated stone reached full desalination after 5 days compared to the consolidated stone which took 11 days. The data suggests that use of an agarose hydrogel treatment is feasible even after the application of the B-72 consolidant.

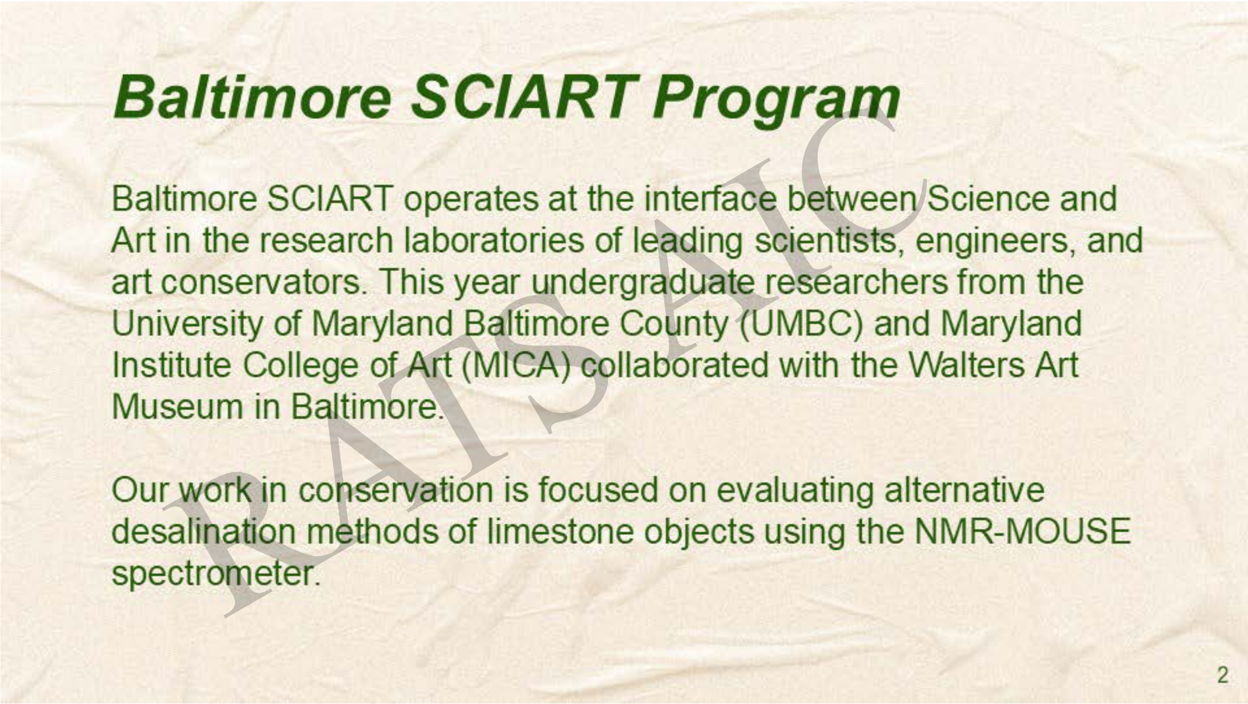
In addition to NMR relaxometry measurements, ICP-MS, SEM-EDX, and a series of microchemical tests were employed to analyze the salt composition of powder which had delaminated from the three Egyptian limestone objects found in the Walters Art Museum's collection. Quantitative evidence of Na^+, K^+, and Mg^{2+} cations were found in each sample in addition to the likely presence of phosphates, sulfates, and chlorides. This project advances the understanding of the use of agarose hydrogel for the desalination efforts of fragile objects. The NMR-MOUSE and other laboratory instruments can be applied to the cultural heritage field to better understand the treatment approaches already in use and to assist the development

of new processes. This collaborative effort between the scientific research and art conservation fields exemplifies the knowledge that can be gained through interdisciplinary work.

This research was performed as part of the Baltimore SCIART Program, which is supported by the Andrew W. Mellon Foundation under Award 41500634.

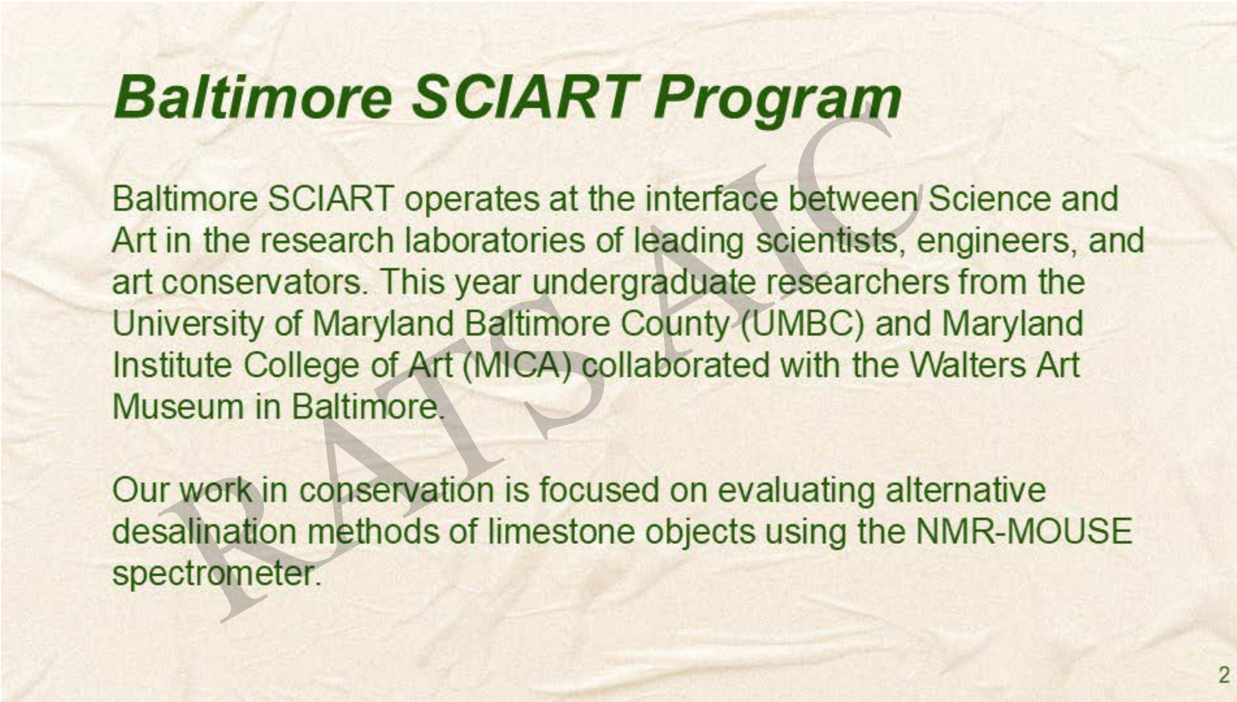
Slide 1. Hello everyone, my name is Maggie Wang and I will be presenting Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy. My co-authors were unable to join me today but I am excited to share our research.

Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy



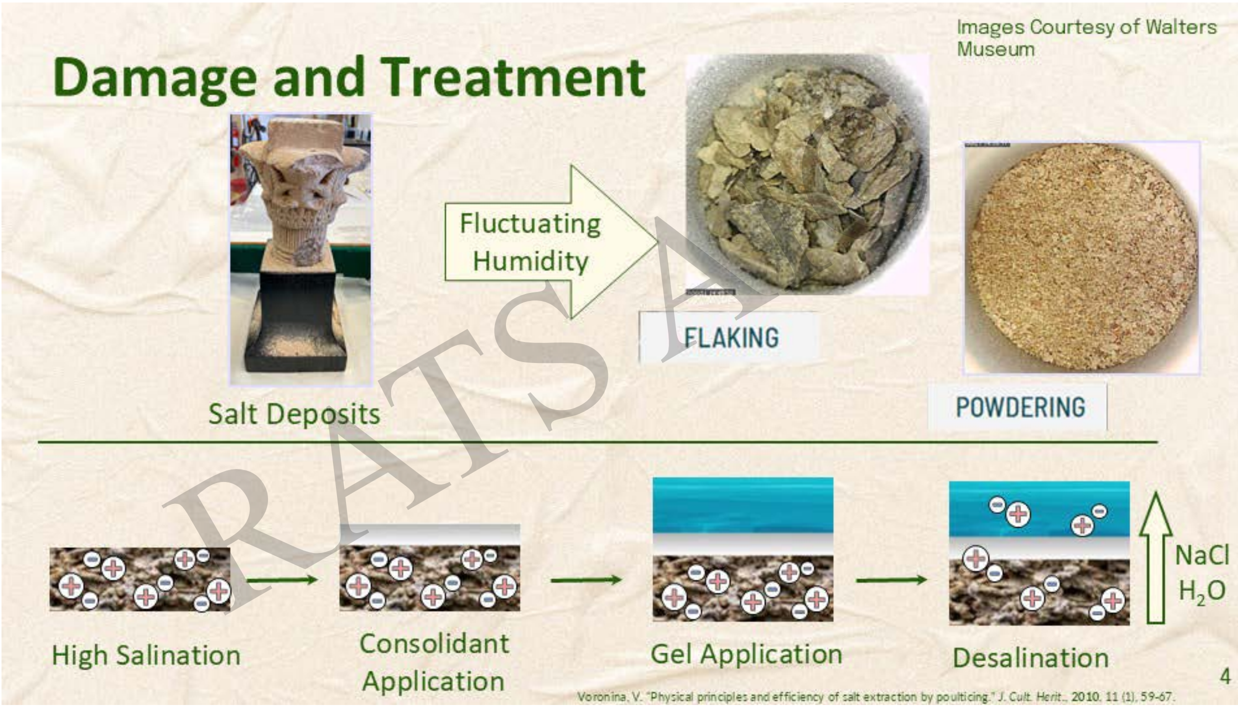
Slide 2. This research was done through the Baltimore SCIART Program at University of Maryland, Baltimore County (UMBC), an Andrew W. Mellon Foundation-Supported Summer Research Program at the Interface between Science and Art. This 10-week RUI program is aimed at high performing science and engineering undergraduate students from Baltimore area academic institutions with a diverse background and strong interest in art conservation science and engineering. The research presented here was guided by Dr. Margaret MacDonald, Research Chemist for the US ARMY DEVECOM CBC and part-time faculty at Maryland Institute College of Art (MICA), and brought together undergraduate researchers from the UMBC and MICA to engage with conservators from the Walters Art Museum in Baltimore Maryland to evaluate alternative desalination methods of limestone objects using the NMR-MOUSE spectrometer.

Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy



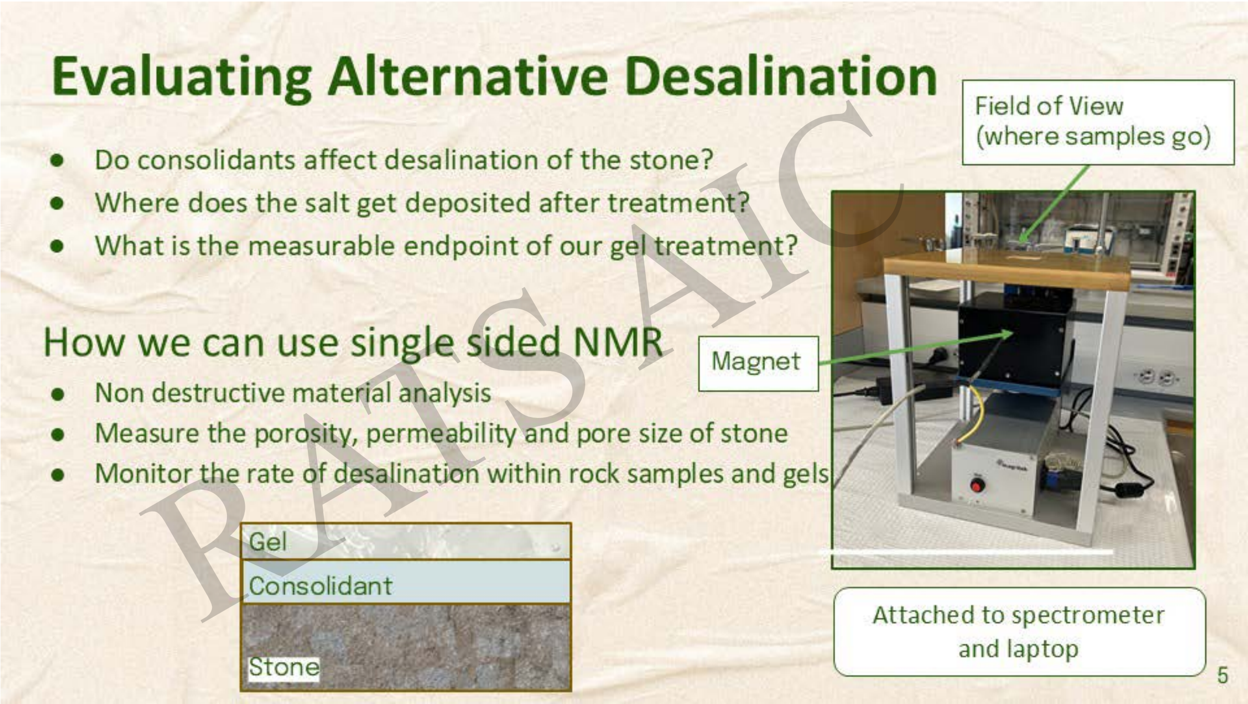
Slide 3. The University of Maryland was established upon the land of the Piscataway and Susquehannock peoples. Over time, citizens of many more Indigenous nations have come to reside in this region. We humbly offer our respect to all past, present, and future Indigenous people connected to this place.

Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy



Slide 4. The presence of soluble salts have been a major challenge in the cultural heritage field, and conservators at the Walters Art museum are facing this challenge with some Egyption limestone objects. When present in these objects, soluble salts can migrate under conditions of fluctuating humidity, resulting in flaking and powdering at the surface of the object when salts deliquesce and crystallize. Traditionally, objects are submerged in a water bath for desalination. However, alternative desalination method is required for these Egyptian limestone objects, as they are too fragile to undergo this traditional method of desalination. This process involves the application of a hydrogel poultice to the surface of the object, which gradually draws salt ions out of the stone and into the gel. A consolidant layer may be added to protect the surface of the object during treatment.

Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy



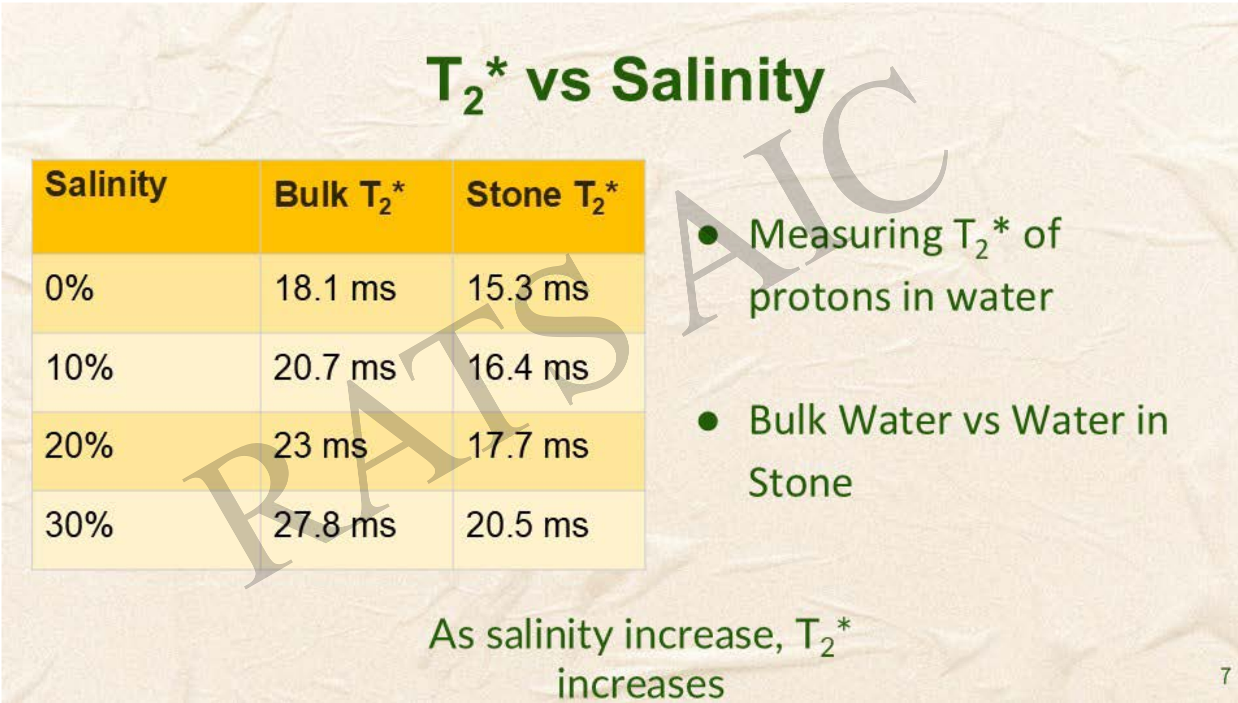
Slide 5. The goal of this research is to evaluate the effectiveness of this alternative desalination method. Several questions must be answered regarding treatment, including: Do consolidants effect desalination of the stone? Where does the salt get deposited after treatment? What is the measurable endpoint of our gel treatment? To evaluate the egress of salt from the stone to the gel, we utilized a single sided NMR technique known as NMR-MOUSE (MObile Unilateral Surface Explorer). This is a non-destructive technique that allowed us to measure the porosity, permeability, and pore size of the stone during treatment, while also allowing us to monitor the rate of desalination within rock samples and gels.

Experiments were conducted on mock samples consisting of a slab of Indiana limestone, a consolidant layer, and a thin sheet of hydrogel. The NMR-MOUSE consists of a magnet/radio frequency coil fixed to a mechanical lift that is connected to a spectrometer.

Investigating Hydrogel Desalination of Egyptian Limestone Objects
Using NMR-MOUSE Spectroscopy

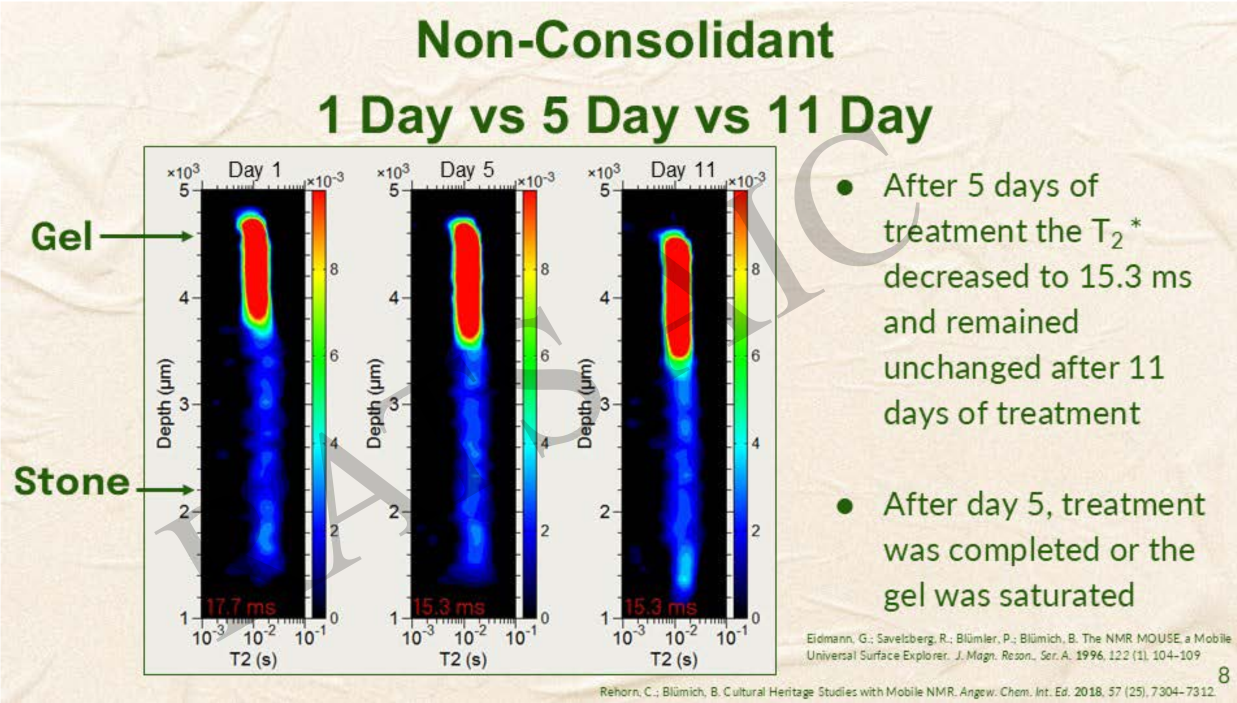
Slide 6. Samples were prepared by first drying mock stones under vacuum, soaking stones in a salt solution, and applying two coats of consolidant.

Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy



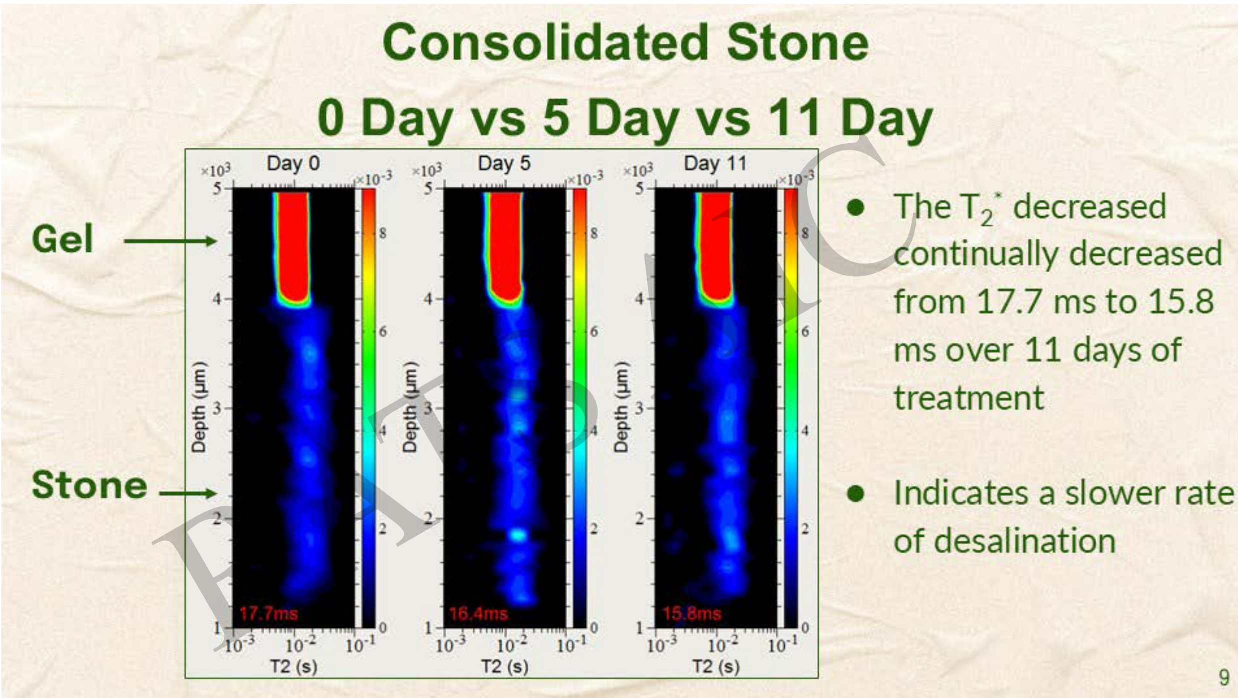
Slide 7. Stones were soaked in salt water solutions of varying salinity. Using the NMR-MOUSE, we analyzed both the salt water solutions themselves (bulk) and the saltwater that was in the stone samples (stone). The T2* relaxation times of hydrogen atoms in the water in the stone and in bulk showed that as salinity increased, the T2* relaxation time increased as well. This allowed us to determine salinity in the stone by measuring the T2* relaxation time.

Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy



Slide 8. This a spatially resolved T2* experiment over day 1, day 5, and day 11 of a non-consolidated stone. The x axis is the T2* and the y-axis is the depth into the sample. The top area of the graph is the gel and the blue is the salt water saturated stone. The color correlates to the strength of the signal collected. The more protons present, the stronger the signal. As such, the gel is red, as the hydrogel contains more protons than the water in the stone. Overall, as the treatment progresses, we are looking for a shift in T2* of the hydrogens of the water in the stone to a faster time. At day 1, the relaxation time was 17.7 ms, and by day 5, the time shifted to 15.3 ms, where it remained until day 11. Compared to the previous slide, our T2* measurement of 0% salinity that we calibrated was 15.3 ms. This indicates that the stone desalinated by day five.

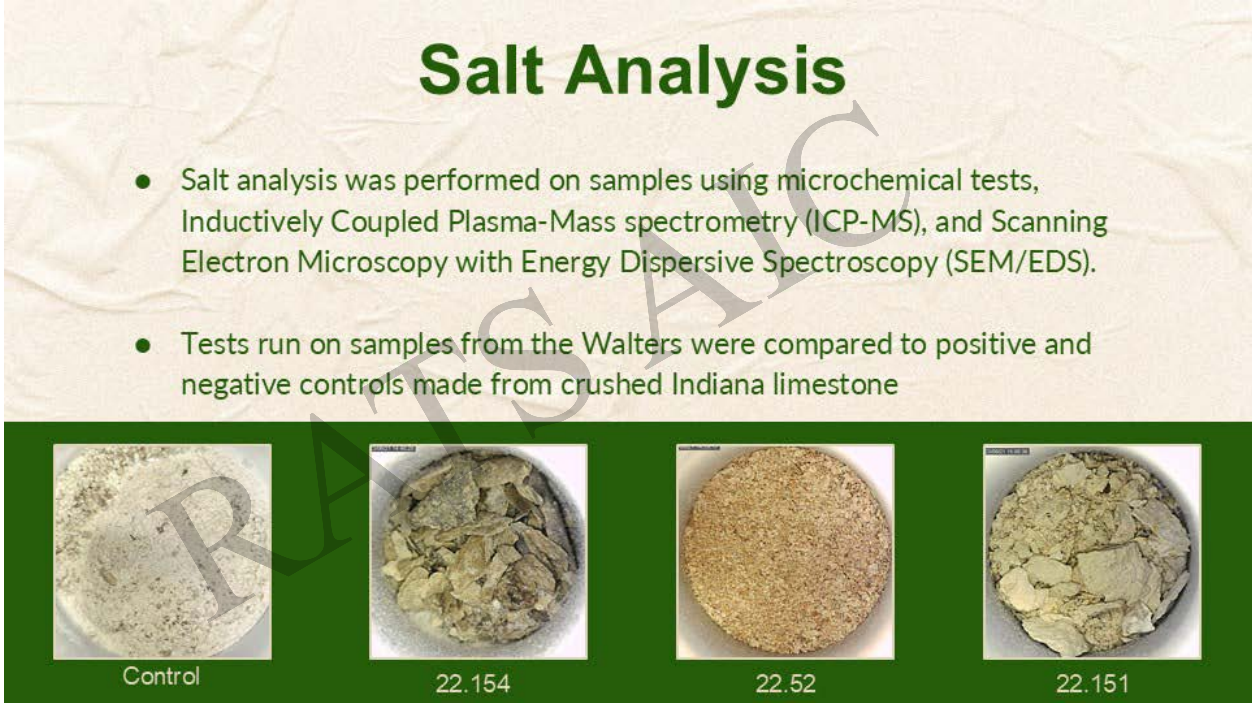
Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy



Slide 9. This is the T2* resolved data of a B-72 consolidated stone. Again, we are looking for a shift in T2* relaxation time. On day 5, the T2* time is 16.4ms which is slower than the non-consolidated stone, and then we see on day 11 the stone reached a endpoint of 15.8ms which is similar to the 15.3ms endpoint of a 0% salinated stone. What we can conclude is that the consolidated stone is slower at desalinating than the non-consolidated stone but it is still possible.

A potential question that arises from this experiment is, does this desalination technique only work because it is a thin stone sample? To determine this larger samples would have to be tested. Our current set up may deal with surface water and only be efficient due to the size and shape of the stone samples used. As a result, more tests need to be done with whole objects or thicker objects to determine the effectiveness of this agarose gel treatment.

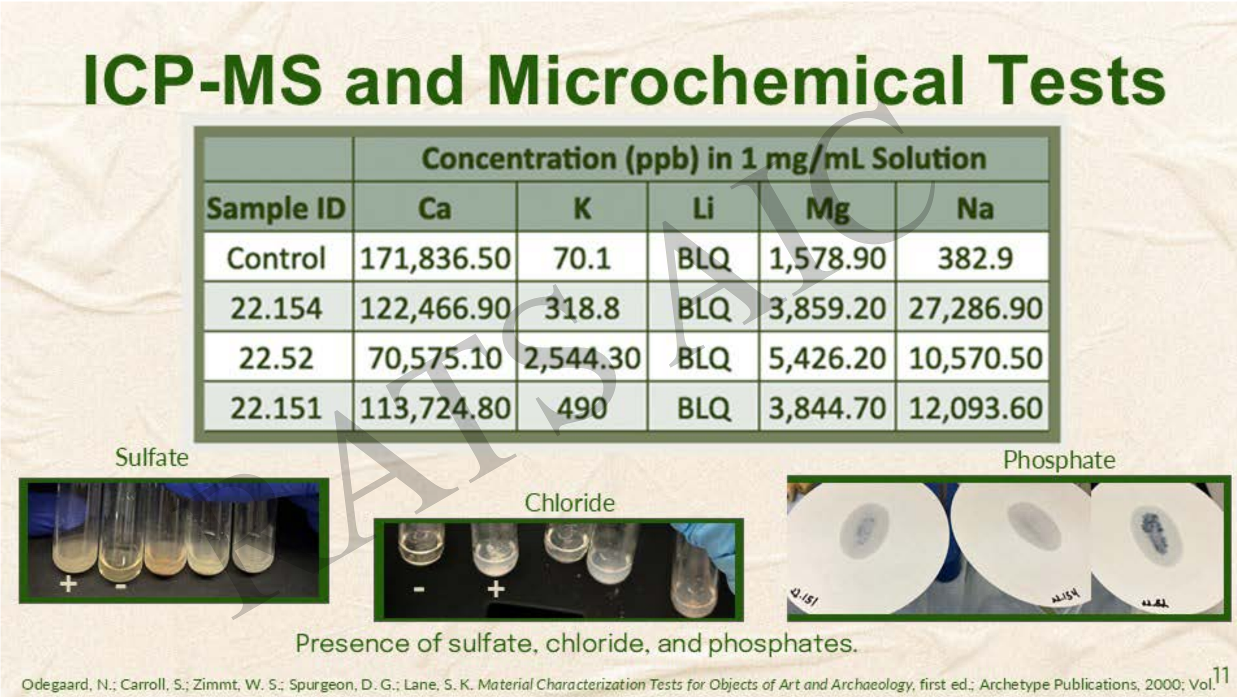
Investigating Hydrogel Desalination of Egyptian Limestone Objects
Using NMR-MOUSE Spectroscopy



Slide 10. We did additional salt analysis to determine the makeup of the Walter's samples to compare and contrast from our mock up samples. From left to right, the control sample has a light beige color with a powdery consistency with small particles. The Walter's sample 22.154 has a darker color and has chunky flakes. Sample 22.52 has a tan brown color with a powdery consistency. Sample 22.151 has a light grey color with very large chunks and flakes.

An important note is that we used very conservative amounts of the samples. And that the samples collected from the Walter's objects were already flaked off.

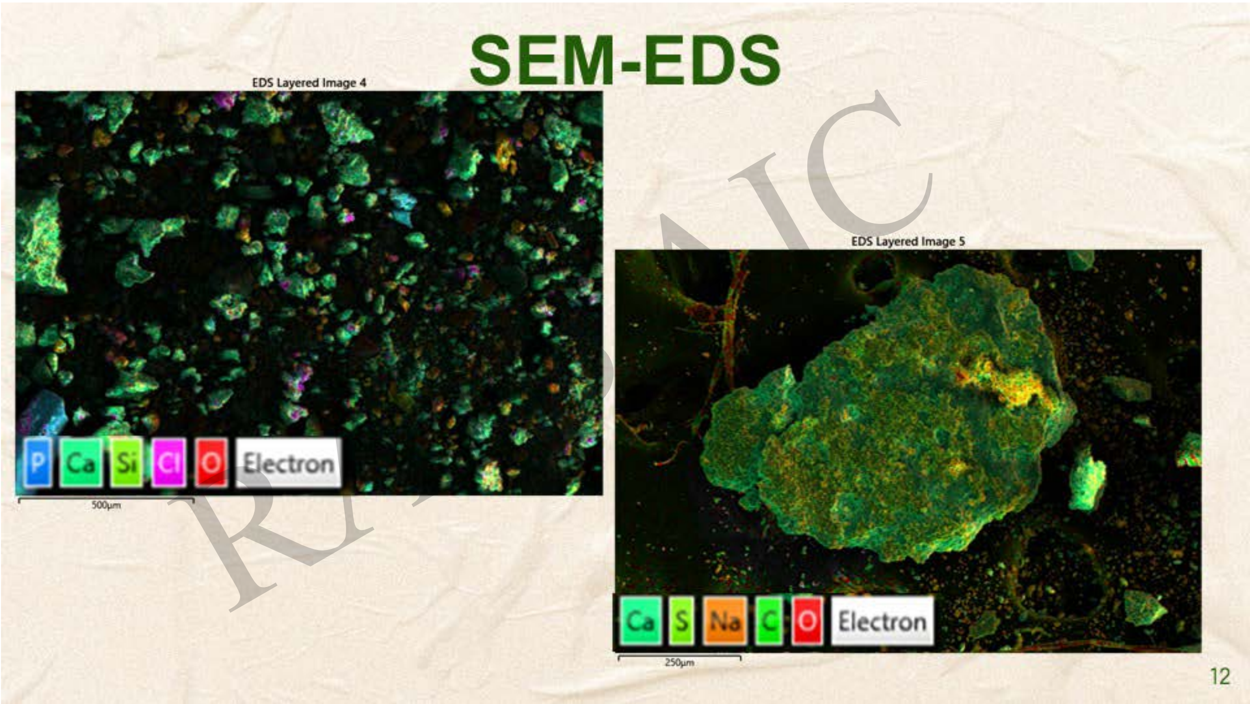
Investigating Hydrogel Desalination of Egyptian Limestone Objects
Using NMR-MOUSE Spectroscopy



Slide 11. In the ICP-MS data, we found all Walters samples to have high concentration of sodium and magnesium. Microchemical tests were also done on the samples, which confirmed the presence of sulfate (through the appearance of a cloudy brown precipitate), chloride (a cloudy white precipitate), and phosphate (a blue precipitate).

Knowing that salts are present other than sodium chloride raises the question, how do those salts affect the T2* time? Future tests would need to be done with combinations of salts to determine if they alter the T2* times and the rate of desalination.

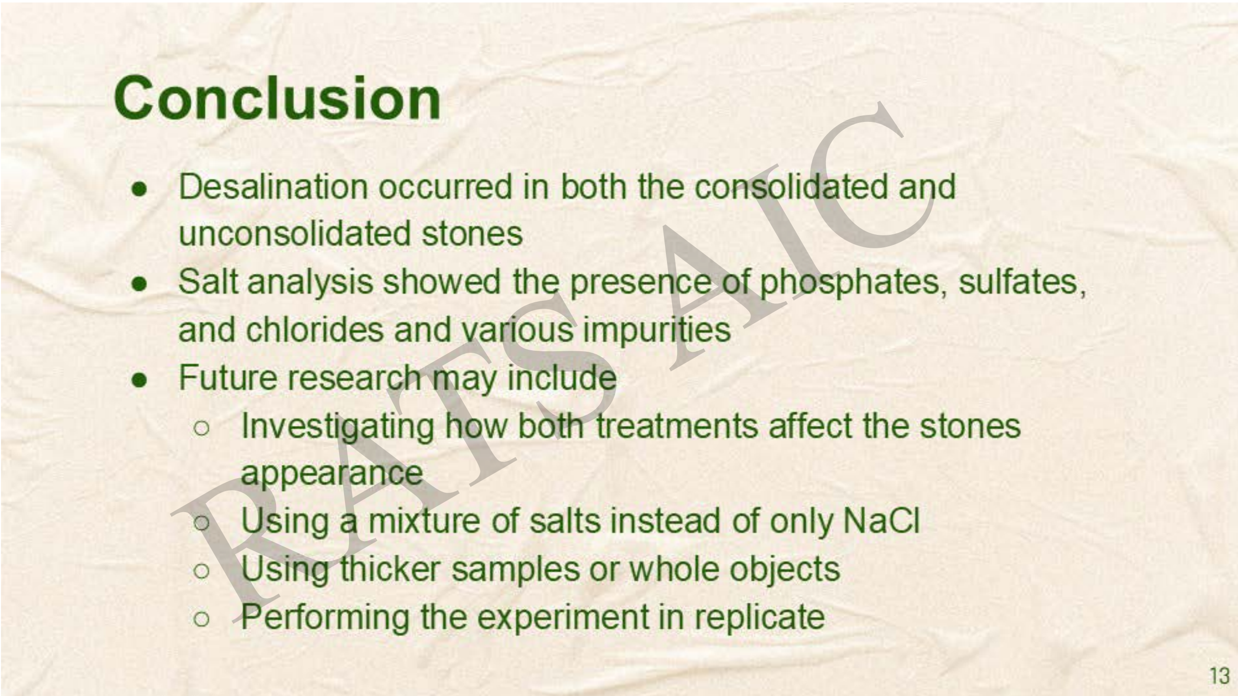
Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy



Slide 12. Scanning Electron Microscopy with Energy Dispersive X-Ray Diffraction data showed us the elements present in the Walters samples to give us a idea of what salts are present.

Both stones show up as green, which is calcium, normal for limestone makeup. We see in the left image, 22.52, there are traces of chlorides (magenta) and phosphorus (blue). In the right image sample, 22.154, there are traces of sulfur (yellow) scattered all over the stone.

Investigating Hydrogel Desalination of Egyptian Limestone Objects
Using NMR-MOUSE Spectroscopy



Slide 13. This study examined the efficacy of using agarose gel poultices for desalinating fragile limestone objects. While desalination occurs at a slower rate in consolidated stones, treatment is still viable. Additionally, the salt analysis performed were able to determine the presence of phosphates, sulphates, and chlorides in the Egyptian limestone samples as well as other common impurities.

Moving forward this information could be used to continue research by testing with a mixture of salts instead of only NaCl. Other steps forward in research could be investigating how the treatment affects the stones appearance, using thicker samples of stone or whole objects that are not flat, and performing the experiment in replicate.

Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy

Slide 14. This research was performed as part of the Baltimore SCIART Program, which is supported by the Andrew W. Mellon Foundation under Award 41500634.

Thank you to our research advisor, Dr. Margaret MacDonald, Research Chemist for the US ARMY DEVCOM CBC and part-time faculaty at MICA

Dr. Zeev Rosenzweig, Professor of Chemistry, Department of Chemistry and Biochemistry at UMBC and Director of the SCIART program

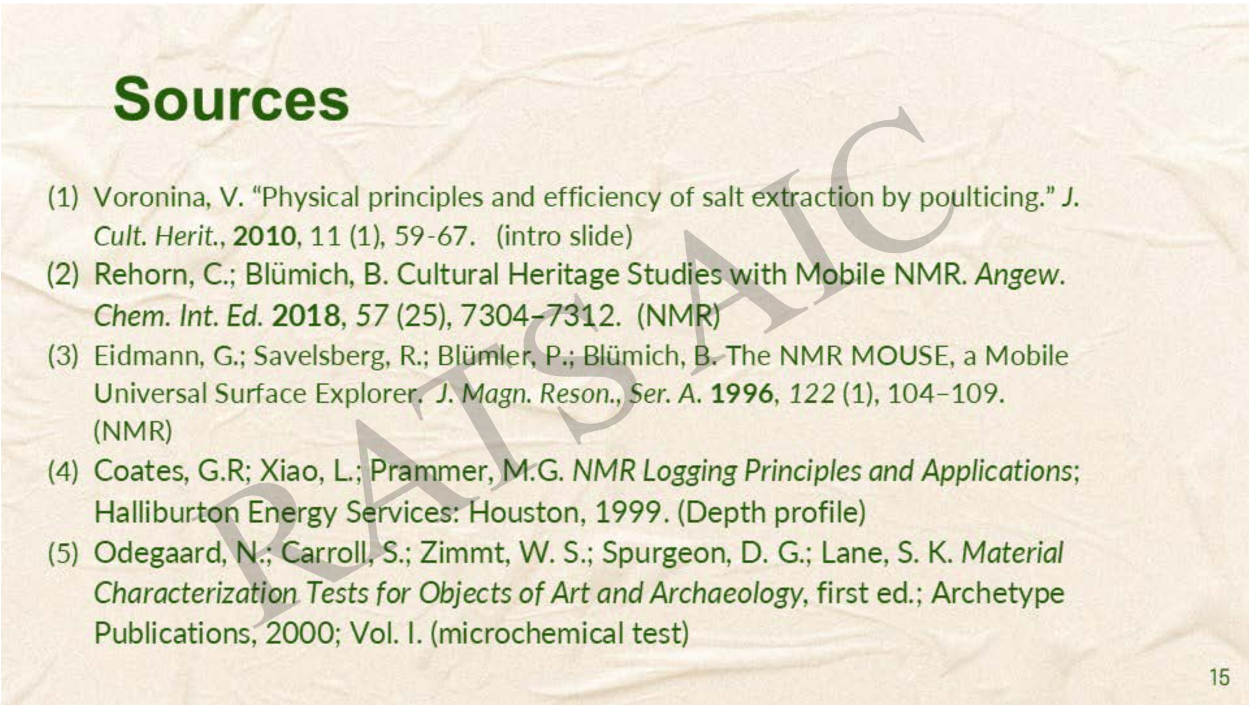
Dr. Joseph Bennett, Assistant Professor of Chemistry, and Dr. Jessica Heimann, the SCIART Postdoctoral Fellow in the Department of Chemistry and Biochemistry at University of Maryland, Baltimore County (UMBC).
Thank you to UMBC for the use of the laboratory space and equipment.

Special thanks to Angela Elliot, Head of Objects Conservation, Gregory Bailey, Senior Objects Conservator, and Katharine Shulman, Graduate Intern from the Walters Art Museum

Thanks to Dr. Cynthia Niedermaier, Molecular Characterization and Analysis Complex Facility Manager at UMBC, Dr. Tagide deCarvalho, Director of the Keith. R. Porter Imaging Facility (KPIF) at UMBC

And thank you to the US Army DEVCOM Chemical Biological Center for use of their equipment and SCITECH Services Inc. for their assistance with travel to the conference.

Investigating Hydrogel Desalination of Egyptian Limestone Objects Using NMR-MOUSE Spectroscopy



Slide 15. Resources for this project are as follows:

Voronina, V. "Physical principles and efficiency of salt extraction by poulticing." *J. Cult. Herit.*, 2010, 11 (1), 59-67. (intro slide)

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Evaluating the Light-stability of Roasted Arsenic Sulfide Pigments

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[1] Beal Family Postdoctoral Fellow in Conservation Science, Harvard Art Museums

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Original Abstract

Arsenic sulfide pigments, broadly ranging in color from red to yellow, have been used since prehistoric times in their natural, mineral form.[1] The most widely known of these arsenic sulfides are orpiment (As_2S_3), realgar (α-As_4S_4), and the light-induced alteration product of realgar known as pararealgar (γ-As_4S_4). The poisonous quality and reactivity of such pigments has been known for centuries, with Cennino Cennini warning that "there is no keeping company with [the arsenic sulfides]" and to "look out for yourself" when working with them. Although arsenic sulfides lost popularity and became commonly replaced by less-toxic yellow colorants over time, they are heavily used in works of art dated prior to the 19th century. Much research has been carried out on understanding the alteration of realgar into pararealgar, both from an atomic-level perspective[2] and from a museum perspective.[3] Nevertheless, there are many other mineralogical arsenic-bearing phases that have scarcely been identified in works of art, including dimorphite (As_4S_3), bonazziite (β-As_4S_4, which is the high-temperature counterpart of α-As_4S_4), and alacranite (As_8S_9).[4] As a result, the light-stability of these pigments has not been fully assessed from a conservation viewpoint.

Recently, as part of Harvard University's 'Mapping Color in History' project, an arsenic sulfide pigment identified as β-As_4S_4 was collected from the workshop of the traditional Indian painter, Mr. Babulal Marotia, based in Jaipur, Rajasthan. It is known that β-As_4S_4 can be obtained from realgar by heat-treating the mineral at temperatures approximating 250 ºC.[5] Considering that naturally occurring bonazziite is particularly rare, the identification of this arsenic sulfide phase suggests that the pigment was procured by roasting natural realgar. In the current study, the lightfastness of the Indian pigment will be evaluated and compared to paint outs of natural realgar, orpiment, pararealgar, and artificial realgar from the Forbes Pigment Collection housed at the Harvard Art Museums. The limitations of using a microfading tester on realgar-type pigments will be explained and compared to results from fading experiments carried out in natural lighting conditions. The light-induced alteration of the Indian pigment will be further assessed in-situ using a combination of Raman spectroscopy and photocrystallography. Insights on the photochemical reactions taking place will be evaluated against the natural light fading colorimetry measurements, providing a thorough review on the light-induced degradation pathways of the roasted pigment, and its implications for art conservation.

Evaluating the Light-stability of Roasted Arsenic Sulfide Pigments

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Using Projection Mapping to Reduce Damage to Light-sensitive Paintings

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Original Abstract

Relevance and background

Preserving the integrity of historical artifacts remains a paramount concern for cultural heritage. However, stewards of heritage grapple with the material degradation over time catalyzed by environmental conditions, such as air quality, humidity, and light. Light can cause photochemical damage when directed onto light-sensitive artwork like textiles, paper-based works, or oil paintings, resulting in color fading, varnish yellowing, or undesirable color shifts.

While light is an imperative medium for human visual perception, the dichotomy it presents—between enhancing visibility and inducing damage—is at the crux of conservation endeavors, exerting a critical influence on art display within museums. The "visibility-damage dilemma" shapes the lifetime of artworks, governed by the antagonistic relationship between prolonged exposure and longevity. While prevailing museum lighting guidelines underscore the importance of curbing light exposure, it is important to acknowledge that stringent light reduction measures, while mitigating damage, may not uniformly cater to human visual perception. Under dim lighting (often 50 lux or lower), paintings may lose their inherent vibrancy, owing to the decreased sensitivity of the human visual system. Such conditions can render objects visually muted, prompting the re-evaluation of universally adopting reduced light levels as a catch-all solution for both conservation and visual appeal.

Purpose and hypothesis

A promising novel application is the optimization of light using projection mapping techniques, which can improve the viewing experience while simultaneously reducing degradation caused by light. Previous studies show that light source spectra can be spectrally optimized to reduce light absorbed by materials, only emitting light that is reflected off of surfaces. We hypothesize that light projection systems can be used to go beyond visual enhancement, embracing the mitigation of photodegradation-induced color desaturation or compensating for low light levels.

Using Projection Mapping to Reduce Damage to Light-sensitive Paintings

Methods and outcomes

Our research started with computational simulations aimed at quantifying reduced damages. Linear optimization methods gauged the appearance of 15 color samples under different illuminants, yielding energy savings up to 71% without perceptible color shifts. Extending this exploration into heritage conservation, we used a seven-channel LED system targeting the preservation of monochromatic oil paintings, demonstrating the feasibility of halving damage and energy consumption without inducing discernible color shifts. In a follow up study, an absorption-reducing light projection prototype was tailored for Joaquín Sorolla's painting "Walk on the beach". This RGB projector-based system utilized point-by-point light projection to curtail damage by up to 49% compared to daylight, and up to 67% compared to incandescent illumination, all the while preserving color fidelity. Finally, we conducted a vision experiment to test the appearance of artwork under light projection to test user acceptance.

These advancements herald the path toward spatially and spectrally precise light optimization, culminating in prototypes attuned to the spatial complexities of multi-colored artworks. This comprehensive exploration not only underscores the intricate interplay between light, preservation, and visual aesthetics but also supports evidence for the potential of light projection systems as transformative tools within the realms of conservation.

Alteration of Materials and of Meaning in an Early 16th c. Upper Rhenish Devotional Manuscript

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Original Abstract

Non-invasive micro-scale analyses are bringing a revolution to the scholarly understanding of the texts and images of medieval manuscripts, unlocking new information about their current condition, original making, and meaning. A dramatic example of this was recently found in a diminutive devotional miscellany manuscript written ca. 1518 in the Upper Rhine region, currently part of the Library of Congress's Lessing J. Rosenwald Collection.

Rosenwald Ms 13, *Betrachtungen des Leidens Christi und Gebete für Klosterfrauen* (Contemplations of the Passion of Christ and prayers for nuns) is a particularly interesting example of a manuscript crafted for devotional purposes, used and re-used over several centuries within the context of a female religious community in Germany. The hand-written text is decorated with red initials and highlights throughout, and small hand-colored woodcuts pasted into the book. These vary considerably in style, format, and palette, suggesting that they derive from multiple sources and may have been purchased already painted. One image stands out as exceptional: the Holy Face on folio 58v (**fig. 1**), which presents the face of Christ in shades of dark gray and black.

Technical study of the woodblock was conducted to learn whether the present appearance of the Holy Face is intentionally black due to deliberate material choices, or due to deterioration of the materials used. Synergistic application of x-ray fluorescence spectroscopy, reflectance spectroscopy, and multispectral imaging revealed that the present appearance is a combination of alterations and intent. Quite unexpectedly, the small painted image includes uncommon and novel material uses to render the unexpected palette. Identifying its present appearance as (largely) intentional fundamentally alters the meaning of the image, linking it not just to private devotional practice centered in the text on the page, but to the practices of pilgrimage, spiritual pilgrimage, and exchanges of relics and devotional images in the intellectual, social and spiritual lives of cloistered women of the era.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures

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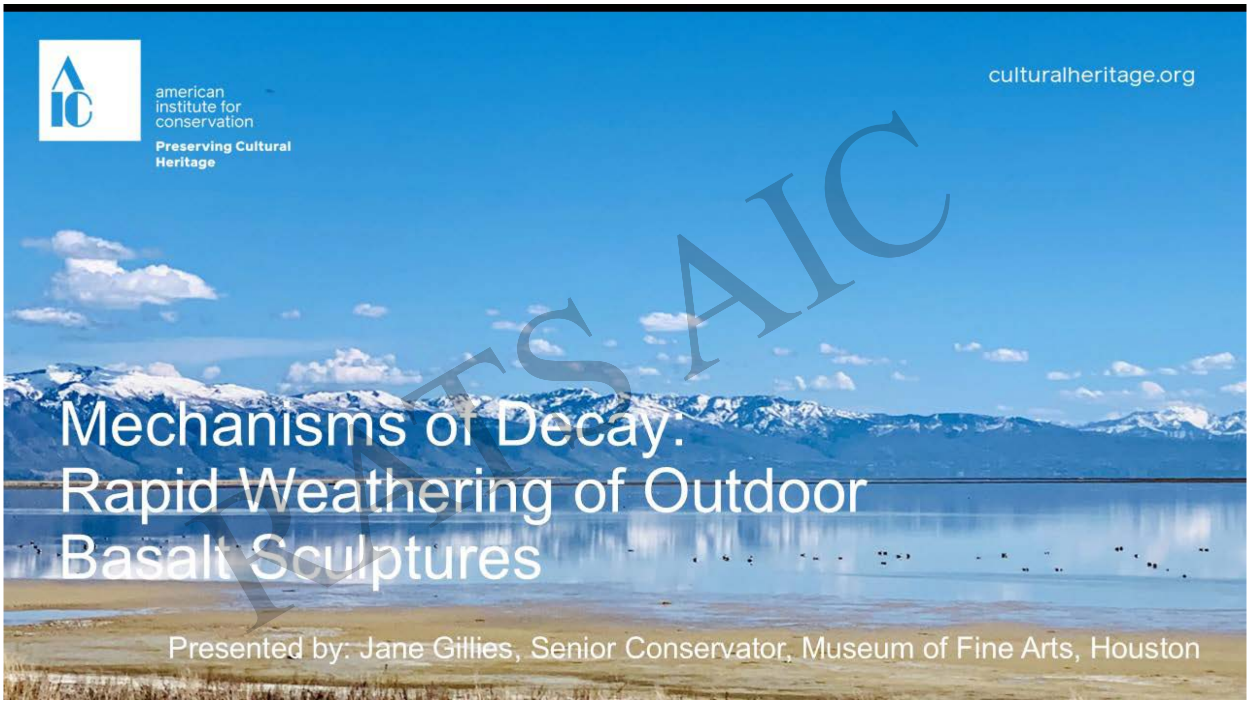
Original Abstract

Three basalt sculptures by the South Korean Artist Byong Hoon Choi called "Scholar's Way" were installed in a pool of water outside the new Kinder building for Modern and Contemporary art at the Museum of Fine Arts, Houston in 2020. The sculptures are carved from naturally occurring columns of basalt sourced from Indonesia, with most of the surface being highly polished to a black mirror-like finish. Parts of the sculptures around the bases and at projecting elbows of the abstract forms retain a weathering crust. Before the installation, conservation had concerns about what effect the surrounding environment and the addition of chemicals, to control the water quality, would have on the sculptures. In a short time, the polished surface had dulled and granules of the crust were falling off. Although the artist has worked with this material for forty years, only a few of his sculptures are installed outside in water. Despite his assurance about the material durability, we obviously had a problem whose mechanisms needed to be more fully understood.

Conservation collaborated with students and faculty at Rice University to determine the geochemistry of the basalt and weathering crust, as well as to analyze the water quality and its chemical composition. Surface measurements of the columns with near infra-red, energy dispersive spectroscopy (EDS) and electron probe microanalysis (EPMA) showed that the base rock that was used was already in a highly altered condition before installation. The degree of alteration on the surface was accelerated by weathering in humid conditions. The weathering crust is largely made up of clay and some remnant basaltic igneous minerals. The EPMA showed that the basalt contains orthopyroxene, Ti-augite, plagioclase, and Ti-magnetite and is thus an iron-titanium basalt. Secondary minerals are widespread and make up more than 90% of the crust. These minerals are mainly clays such as ferripyrophyllite, ferrisepiolite, and kaolinite. The presence of these minerals proves that the rock was altered by hydrothermal processes prior to human intervention. The effect of weathering in humid conditions affects the surface of the rock. The porous clay aggregate readily absorbs water and the other remnant minerals are somewhat soluble in the chemically treated water. The civil ordinance governing water features which had been used to justify the use of harsh chloride containing bleach and acid in the water was deemed inapplicable to this non-interactive feature. The clay minerals occur over the entire surface of the sculpture including previously polished portions, consistent with recent weathering in addition to the original weathering crust. This study is ongoing. A protective wax has been applied to the polished areas. We have not decided on whether a consolidation treatment can be applied to the weathering crust as this may cause greater damage. We are removing the additive acid/alkali mix from the water and are investigating replacement with a copper salt to prevent algae growth.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



Slide 1. I would like to acknowledge that Greater Houston was built on the unceded lands of many indigenous tribes including the Atakapa and Karankawa.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures

Slide 2. "Scholar's Way", by Choi, Byung-Hoon, comprises three black basalt columnar sculptures, which stand in several inches of water, which were installed at the Museum of Fine Arts Houston in 2020.

The title of the installation "Scholar's Way", references the concept of Scholar's Rocks, which are found in several Asian cultures. Despite its recent installation, deterioration of the surface was noticed as early as 2021. A unique aspect of these sculptures is that they were carved from already heavily geologically weathered basalt. Here we can see the black basalt and an off-white weathering product, both of which are incorporated into the sculpture. The fragile weathering crust is a result of chemical reactions over geologic time, whereby waters circulating through fractures in the rock reacted with the minerals comprising the original basalt. However, further degradation has occurred since the sculptures were installed. The sculptures are exposed to Houston's warm humid climate and also to chemicals that were added to the water to prevent algae growth. After three years fragments of the sculptures have fallen off, the rich black polished appearance has dulled, and salt-like minerals regularly precipitate on the sides of the sculptures. Understanding the reasons why the sculptures are degrading is imperative for preservation efforts.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures

Slide 3. The creator of "Scholar's Way", Choi, Byung-Hoon, was born in 1952 in South Korea. A pioneer of modern design in Korea, he works as a sculptor, an artist and as a furniture designer, combining traditional Korean aesthetics with modernism. His influences include both Zen Buddhism and Taoism, philosophies which center on paradox, and the harmony of unifying differences. He said "East Asian cultures have long held that the energy of the universe is immanent in water and stone". In this installation they form a procession of three separate but related columns, as can be seen here in his studio outside Seoul. Choi has been using this material for forty years.

He wrote to me:
"The basalt I chose are columnar joint from the mountains in Java, which is suitable for planning works because it has various forms, and since it has been buried in soil for a long time, the outer surface is rough, and the inner black is very hard, so it has a high gloss effect, which can obtain a dramatic contrast of surface texture in the finished work. If it is not critical, the change on the surface from the weathering will add natural effect.. Getting marks from time passing is natural and will bring more depth to the work."

In other words, some aging is acceptable, but the contrast must be preserved.

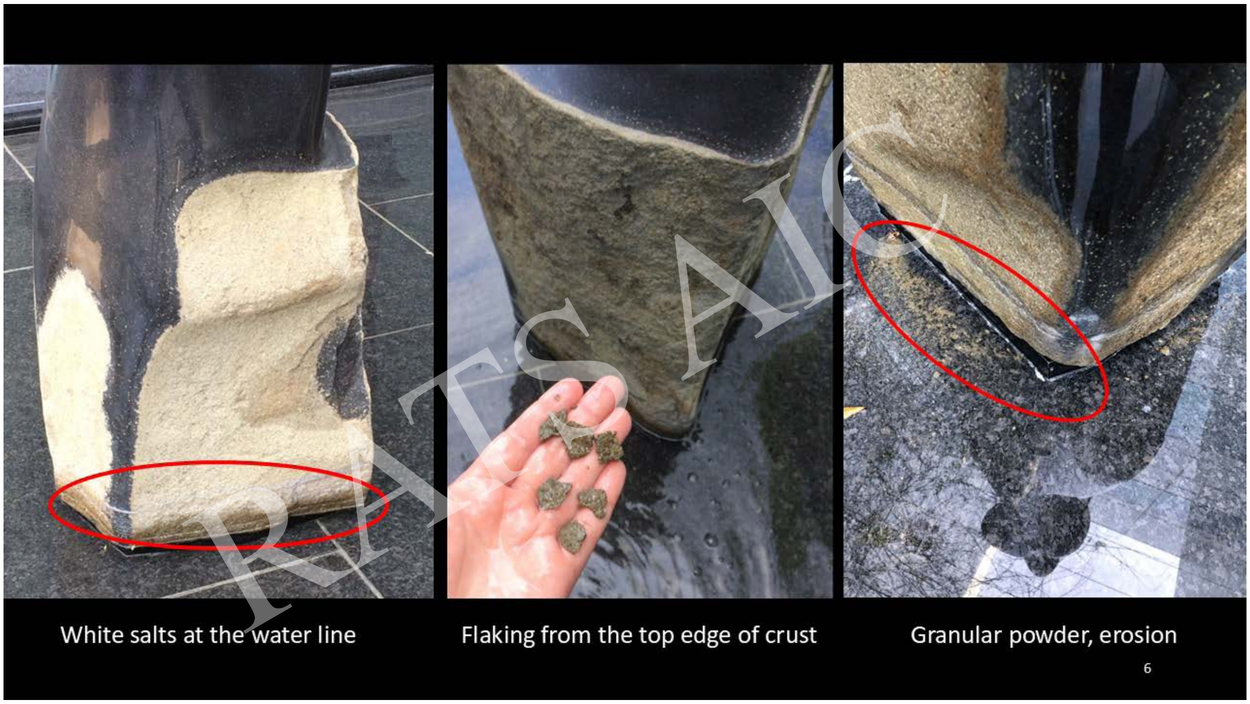
Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures

Slide 4. Two images from 2020 and 2022, show that In two years the surface is no longer so highly polished, and the black color is turning gray.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures

Slide 5. The water wicks up the weathering crust , which becomes much softer when wet. Rapid evaporation of the pond mixed with added chemicals affect the surface.

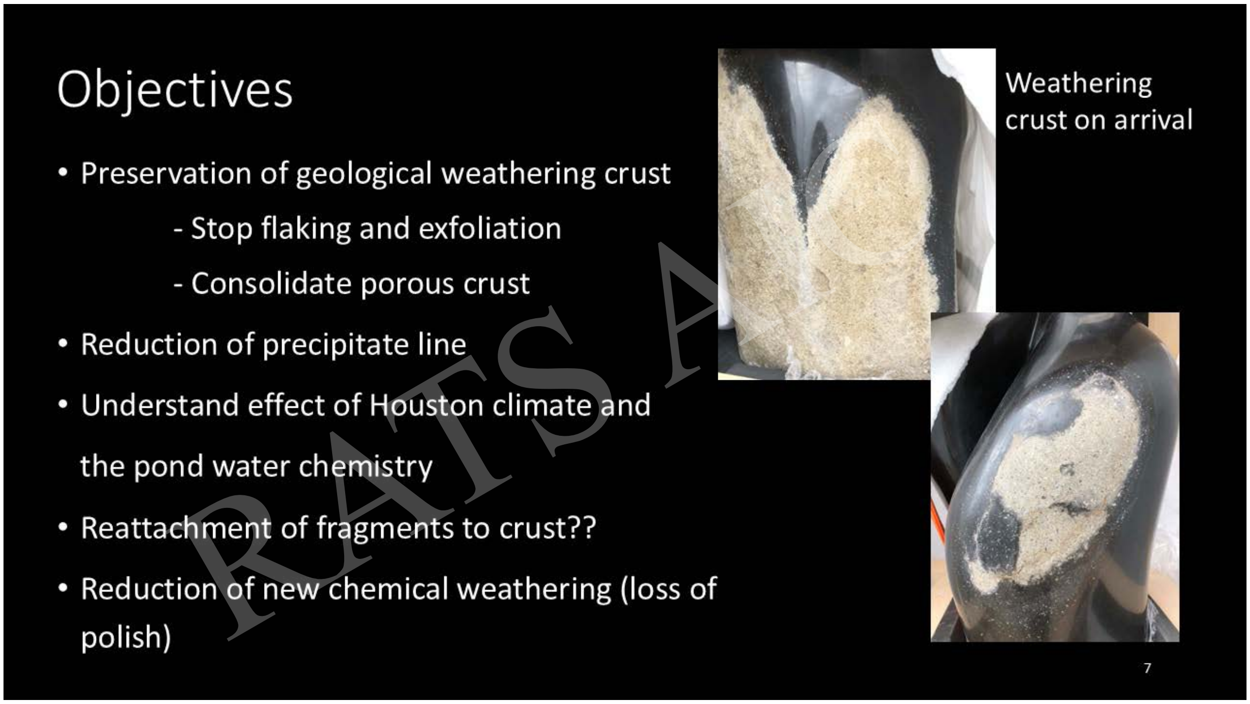
Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



Slide 6. In the left image, there is a white line of precipitate that forms at the water level. In the middle image, we see flakes that had come from the top edge of the weathering crust. In the right image, we see granular powder collecting at the base of the column.

The extreme winter freeze occurring in Houston in 2021 was blamed, due to possible ice wedging of the porous crust when water-saturated, but other possible contributors should be considered. We hypothesize that this results from dissolution of minerals into the pond water and later precipitation as a powder, as concentrations increase due to water evaporation.

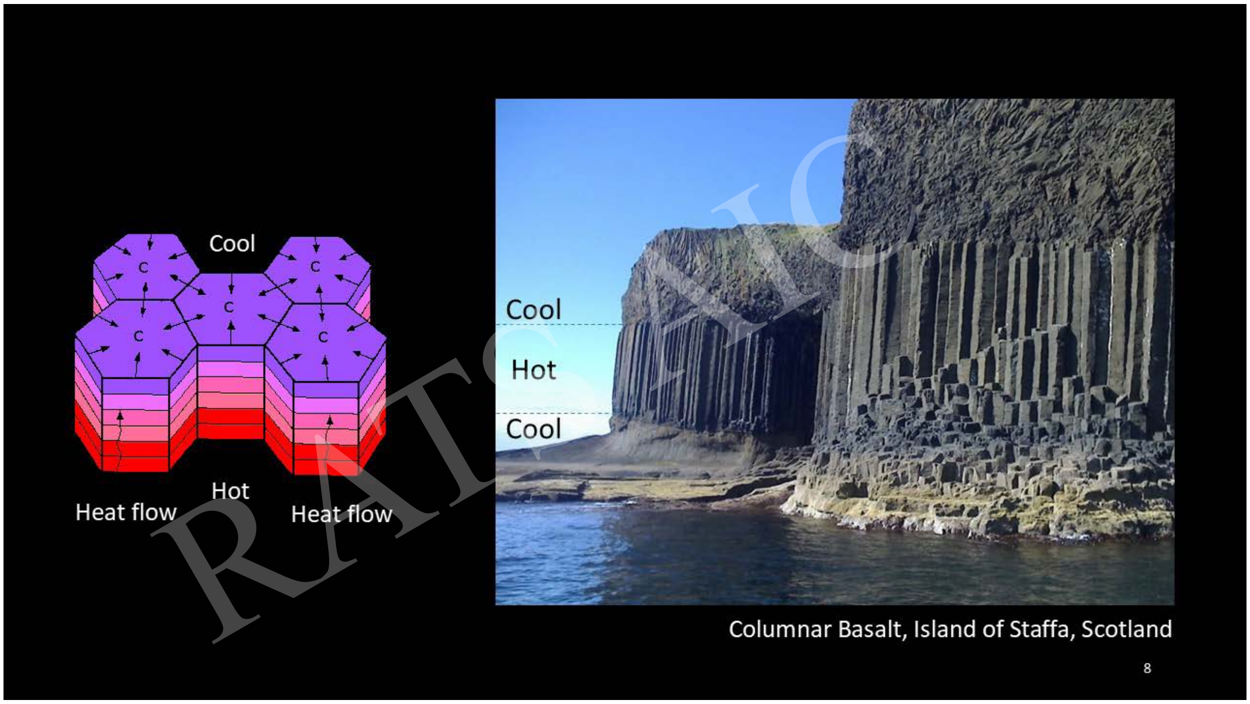
Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



Slide 7. Details of the original geological weathering crust and the carved surface of the sculpture.

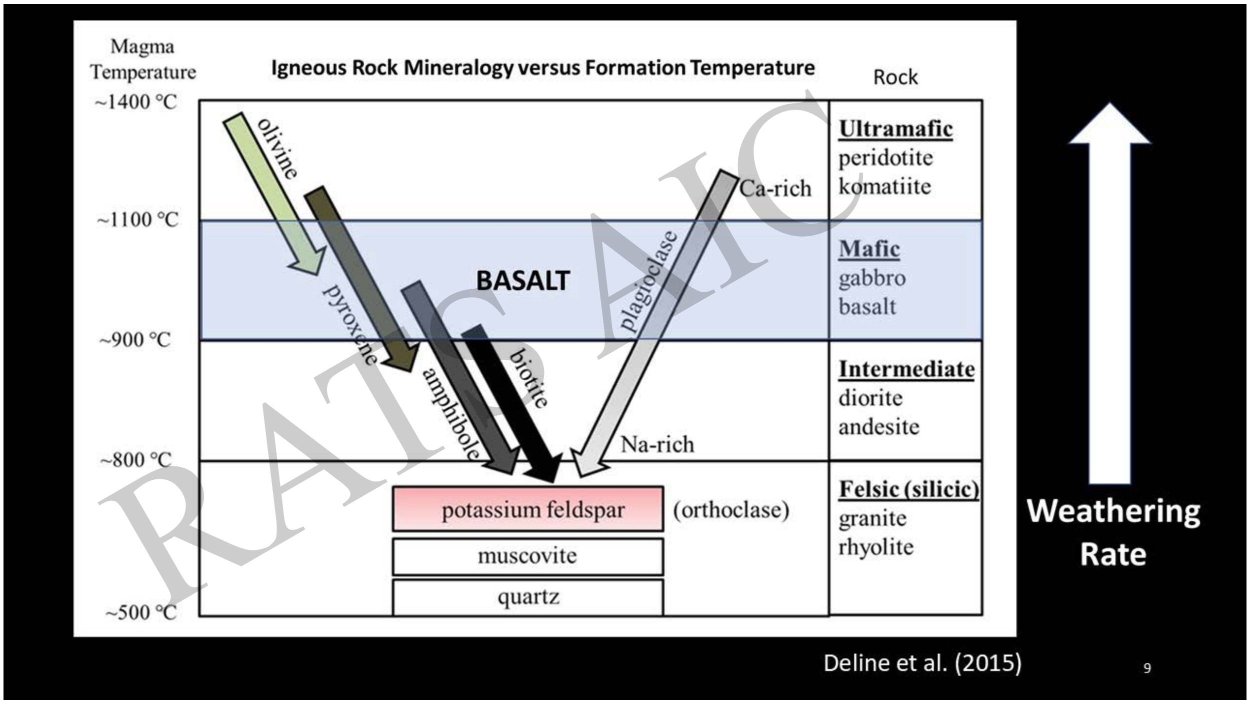
Conservation was aware that the weathering of the rock was unknown, and that adding chlorine containing additives would probably have a detrimental effect on the rock. We suspected that conservation would have problems down the road but were surprised that the changes turned out to be so rapid.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



Slide 8. These sculptures are made from naturally occurring columnar basalt from Sumedang, Jawabarat, in Western Java, Indonesia. These columns form at the top part of the lava or magma as it cools fastest here. Cracks form which often form hexagons in x-section. The melt cools faster at the edges and at the top, and the solidified melt takes up less space than the molten melt, because it contracts as it cools. This generates cracks in the lava as the whole surface cools, much like dried mud.
This is a hard rock that can be polished but these Indonesian basalts have calcium-rich plagioclase feldspars which weather relatively rapidly.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



Slide 9. Bowen's reaction series in this diagram showing rocks formed at a range of magma temperatures, where minerals formed at high temperature weather more quickly than those formed at lower temperatures.

The minerals forming basalt weather more rapidly than those in granitic rocks. Plagioclase feldspar is volumetrically usually the most important constituent in basalt. The Scholar's Way basalts contain calcium-rich plagioclase that forms at high temperature and weathers particularly rapidly with significant volume reduction over a human life span when immersed in fluids under certain pH conditions.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures

Slide 10. Kirsten Siebach, a Martian Geologist from Rice University, who specializes in the study of basalt on Mars and two of her students, using a portable Visible Near Infra-Red spectroscopy (VNIR) to collect data from the sculptures.

Spectra taken from the sculpture can be compared with spectra from known minerals. Her students also used computational modeling from water chemistry data, Electron Dispersive X-Ray Spectroscopy (EDS), and Electron Probe Micro-analysis (EPMA), to learn about the sculptures' composition, the "bathtub ring" precipitation from the pond, and the dissolution of materials from the sculpture.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures

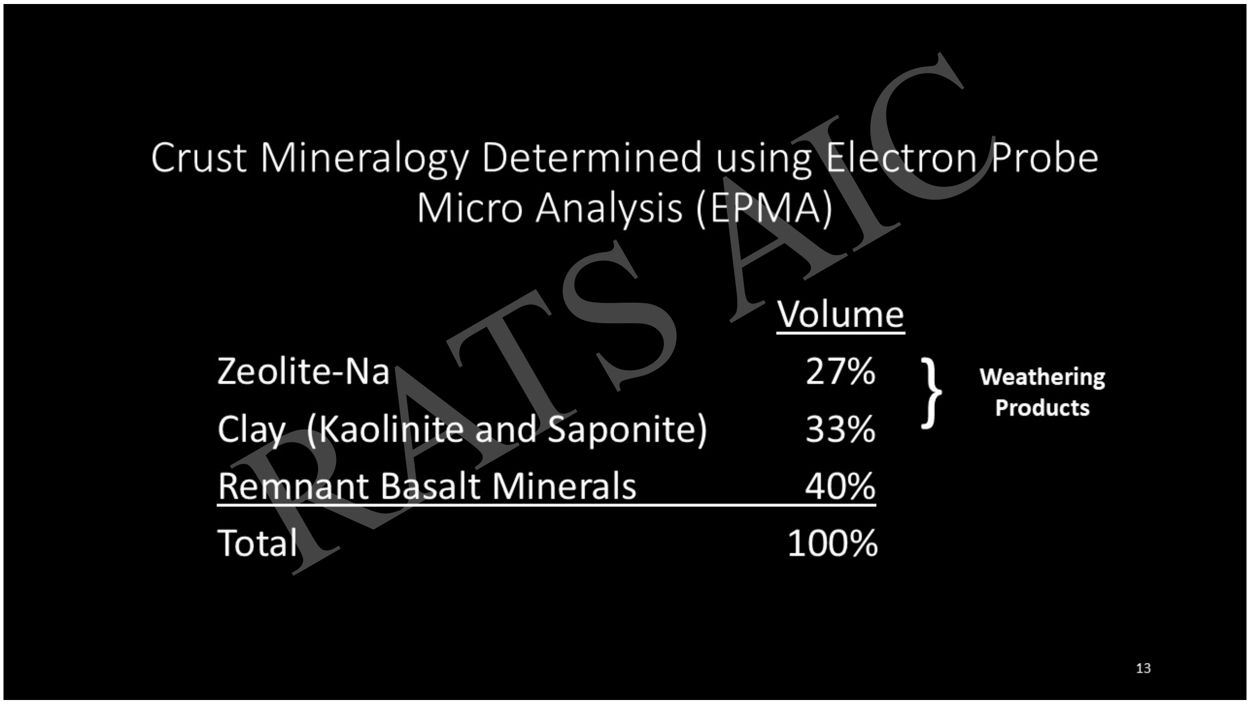
Slide 11. Fragment of the weathering crust in 20% hydrochloric acid.
The fragment did not fizz.
It is rich in clay that is a silicate and less reactive and less soluble.
The pond water is very rich in chlorine and oxygen negative ions that will combine with metal ions in the rock and crust to form salts and oxides.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures

Slide 12. Rock fragments and scrapings of deposits from the pond walls.

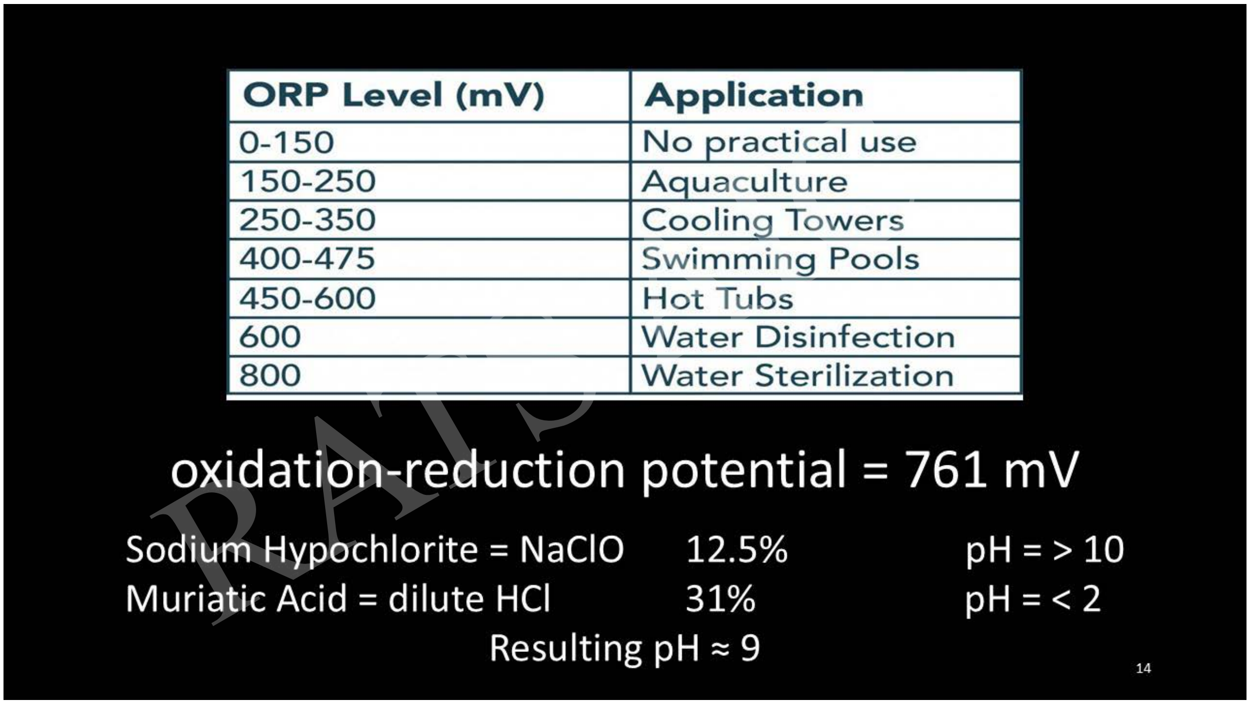
EDS (Energy Dispersive Spectroscopy) was done for the scrapings from both the pond wall and the sculptures. These were chemically identical and were identified as amorphous silica-based products. Elevated silicon dioxide by wt% was associated with an anomalously high chlorine wt% percentage of up to 2%. This implies an interaction with the chemical additives to the water.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



Slide 13. Electron Probe Micro-analysis allows high spatial resolution for small grains and micropores showing that the crust is sixty percent weathered minerals and forty percent remnants from the original basalt.
And this 40% can continue weathering.
The zeolite and clay are microporous and fragile.
Saponite swells with water which can contribute to exfoliation and flaking.
The crust shows a high amount of interstitial amorphous material, which is very prone to deterioration.

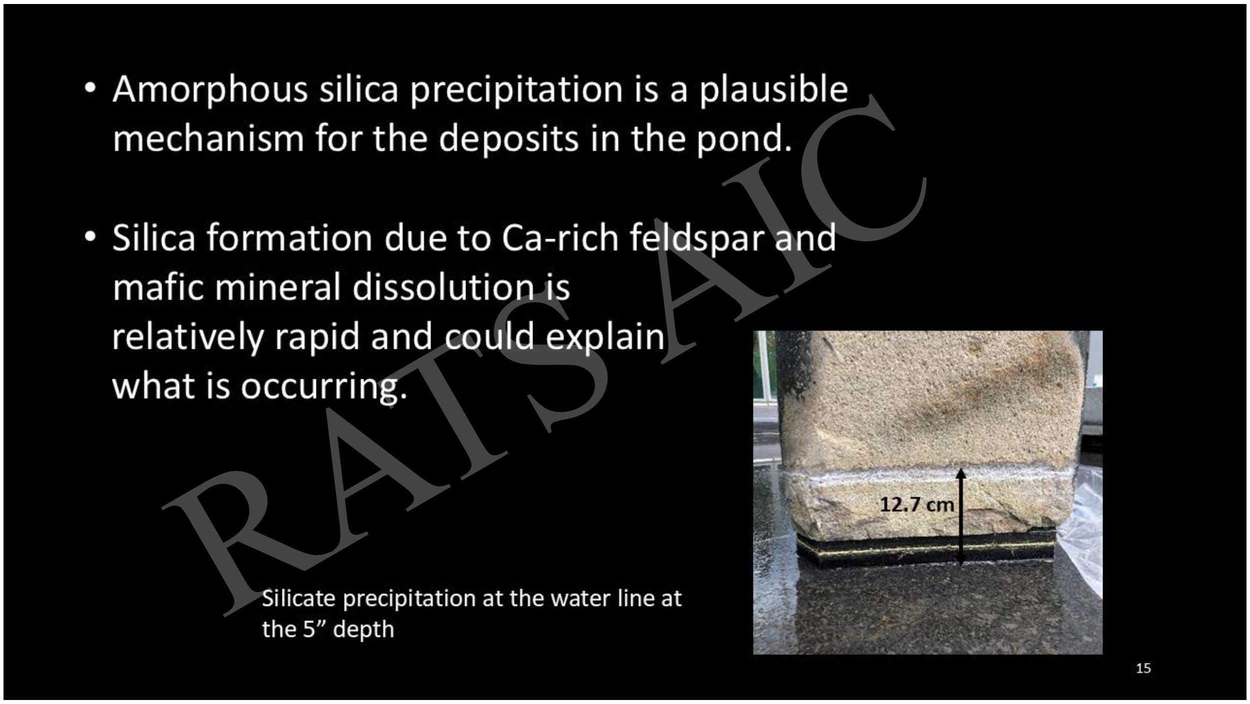
Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



ORP Level (mV)	Application
0-150	No practical use
150-250	Aquaculture
250-350	Cooling Towers
400-475	Swimming Pools
450-600	Hot Tubs
600	Water Disinfection
800	Water Sterilization

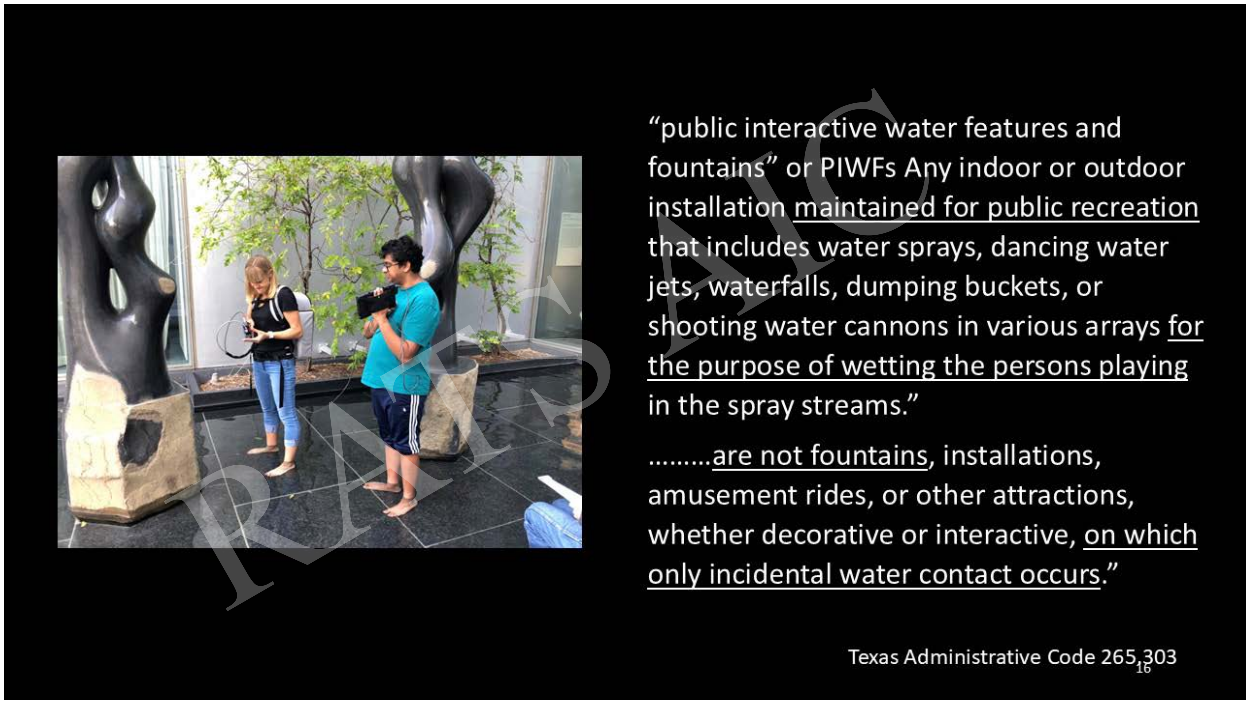
Slide 14. The sculptures were intended to be in five inches of water. The underlying granite paving stones being dark and with hot sun, evaporation is significant. The pools have an automatic top up, but that is insufficient to keep the water at a constant depth and regular manual filling has been irregular, increasing the concentration of added chemicals. Our administration had said that the addition of chemicals was necessary from a legal standpoint as the purity of the pond water needed to be the same as a municipal swimming pool. The chemical additives to the pool water were sodium hypochlorite and muriatic acid. The oxidation-reduction potential, ORP, of the pond was recorded as seven hundred and sixty one millivolts, which is much higher than it needed to be, even for a swimming pool which is roughly 400-475 mV. Solutions of twelve and a half percent sodium hypochlorite (which has a high pH) and thirty one percent muriatic acid which is added to bring the pH down to a pH of eight (although we recorded a pH of nine). Both of these products contain chlorine, which is well-known to be detrimental to most sculpture, as chlorine reacts with metal ions. The high ORP suggests a high concentration of reactive anions in the treated water which may leach metals out of the basalt and the weathering crust.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



Slide 15. Amorphous silica precipitation sourced by calcium rich feldspar and mafic mineral dissolution followed by precipitation plausibly explains the origin of the white precipitate. Our analysis of the kinetics of the reaction suggests that the reaction is rapid, even at neutral pH, but it is often triggered by changes in pH, and that could explain what has occurred in a short period of time.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



Slide 16. It does not appear that the chemicals were necessary from a legal perspective, but it took until a year ago until everyone was ready to accept that we might not have needed to add the chemicals and in such large quantities.

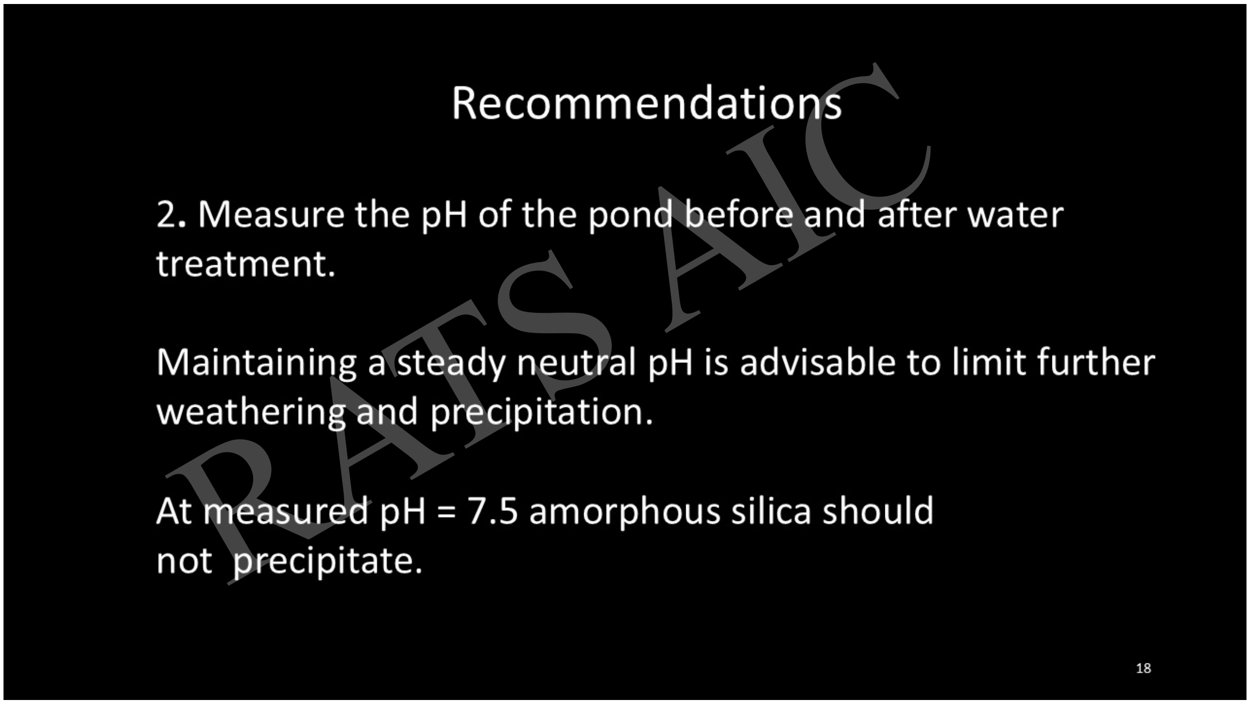
This was the end of October 2022, and the Rice team are standing in several inches of cold water.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures

Slide 17. These recommendations are from Bavan Rajan who based his Bachelor of science, B.Sc. thesis at Rice on this problem.

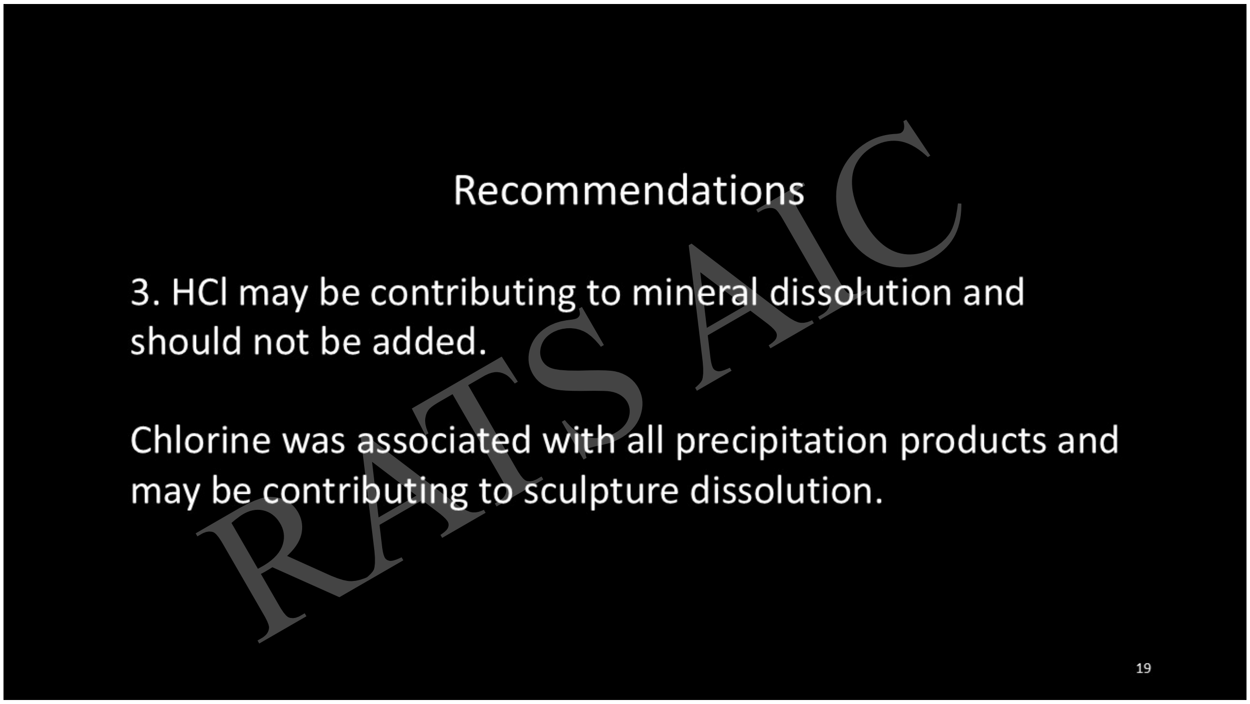
In terms of coating the black polished surface, the artist recommended that the polished surfaces of the sculptures be coated with a commercial stone wax, which has helped to restore the polished appearance, and helps to seal the stone from humidity and chemical action. However, this does not address the more serious issue of the protection of the weathering crust Adding a coating to the crust could cause serious spalling with a barrier coating on an absorbent material that is constantly wet and humid, so we were looking for a material that would change the physical chemistry of the crust. We sent samples of some larger losses of the crust to Professor Pietro Baglioni in the Physical Chemistry department at the University of Florence. He has developed several consolidants based on nano-technology, including nano-silicates, and is leading the “Green Art Initiative”. The MFAH is a partner and is testing and evaluating new sustainable conservation products.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



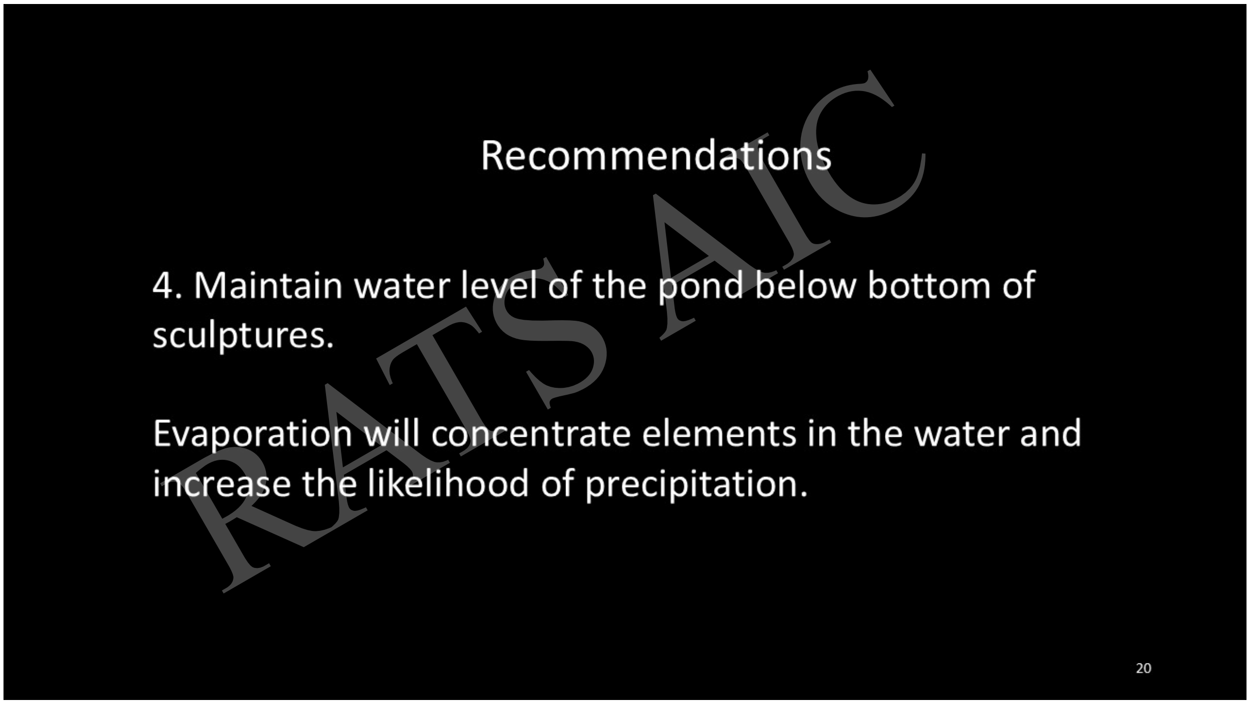
Slide 18. The water is treated and the pH monitored by an outside contractor, but conservation will also monitor this to maintain a neutral slightly alkaline pH.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



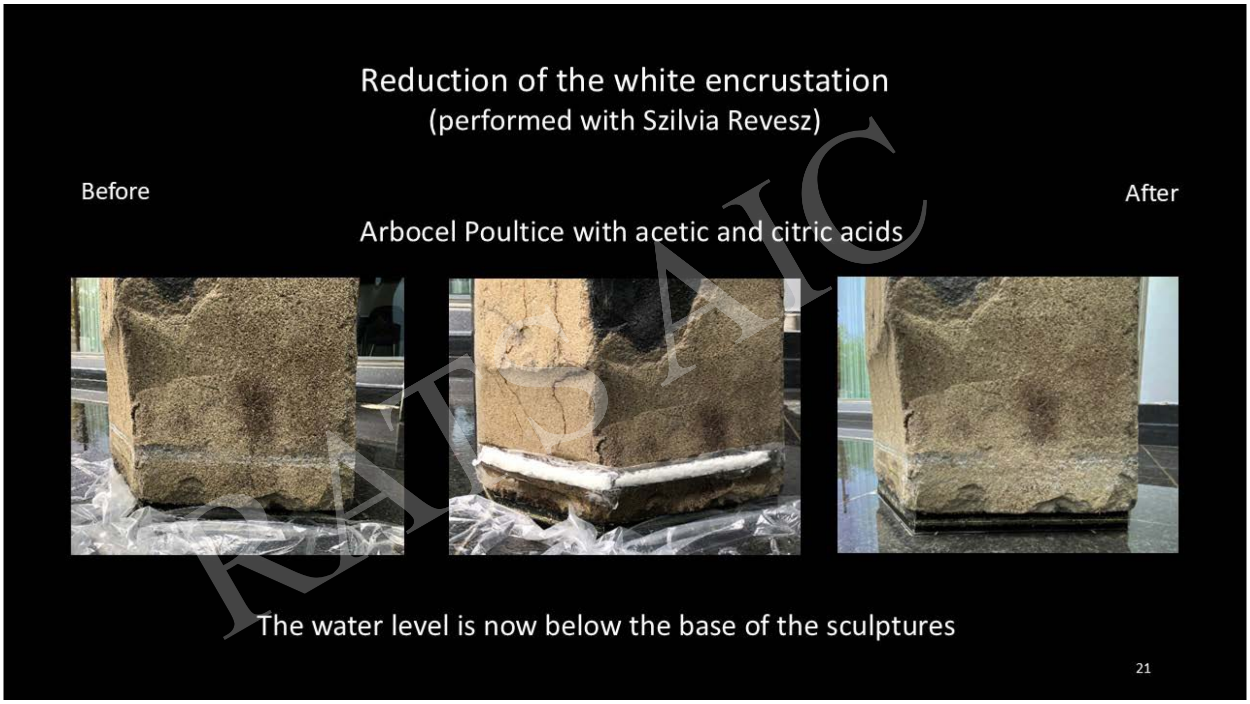
Slide 19. The equipment that regulated the water treatment that was originally installed was not under warranty and it broke down frequently. It was recently replaced in September 2023 and the new system offers greater chemical control over the ranges. Whilst the old system was broken we tried switching to copper sulphate, an additive which is used in pools to control algae, which is not harmful to the sculptures. This has proved to have worked well in the connected ponds without the sculptures, but algae is still forming in this pond The water quality monitoring company that the museum used had recommended changing the chemicals to concentrated sulphuric acid and another chlorine containing products, but the results were, of course, worse and now no harsh additives are being added. This has now been replaced with more regular cleaning to remove algae, together with “EarthTec”, a copper sulphite product with lower copper content which was recommended by Michael Fus, and is in use for water in the Buckingham fountain in Chicago.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



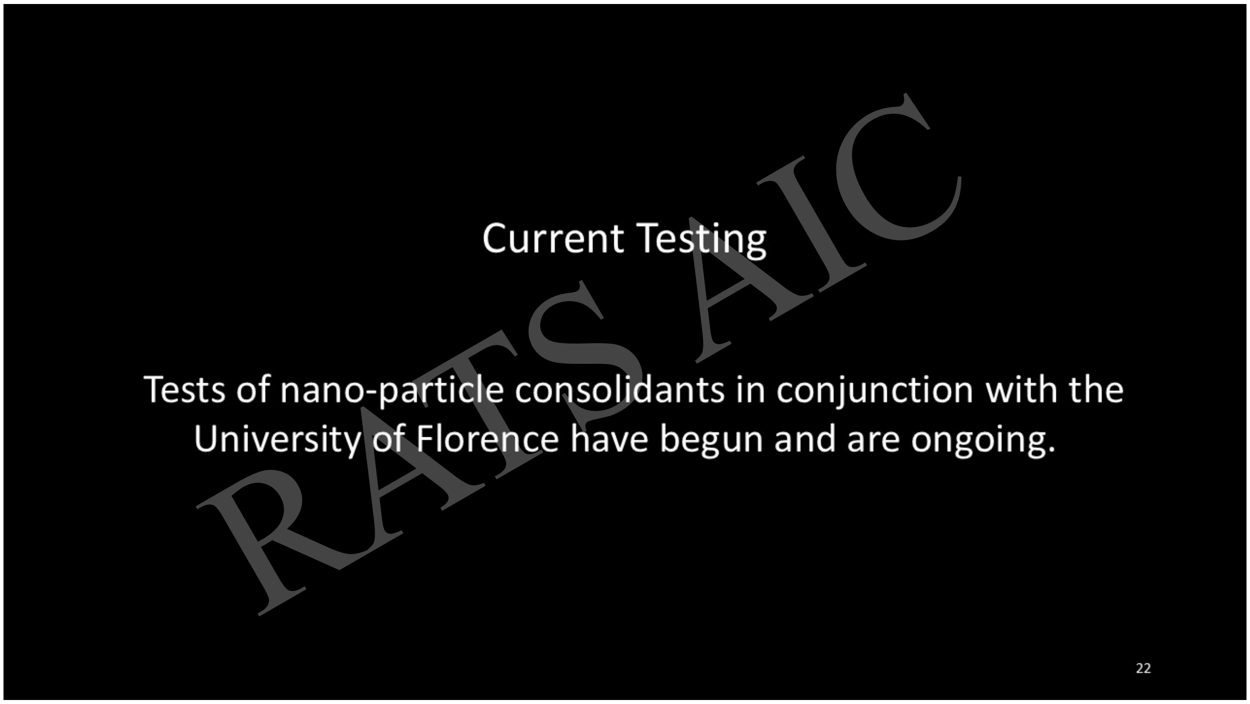
Slide 20. The water level is now below the base of the sculptures as opposed to the original plan of having the bottom of the sculptures in the water.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



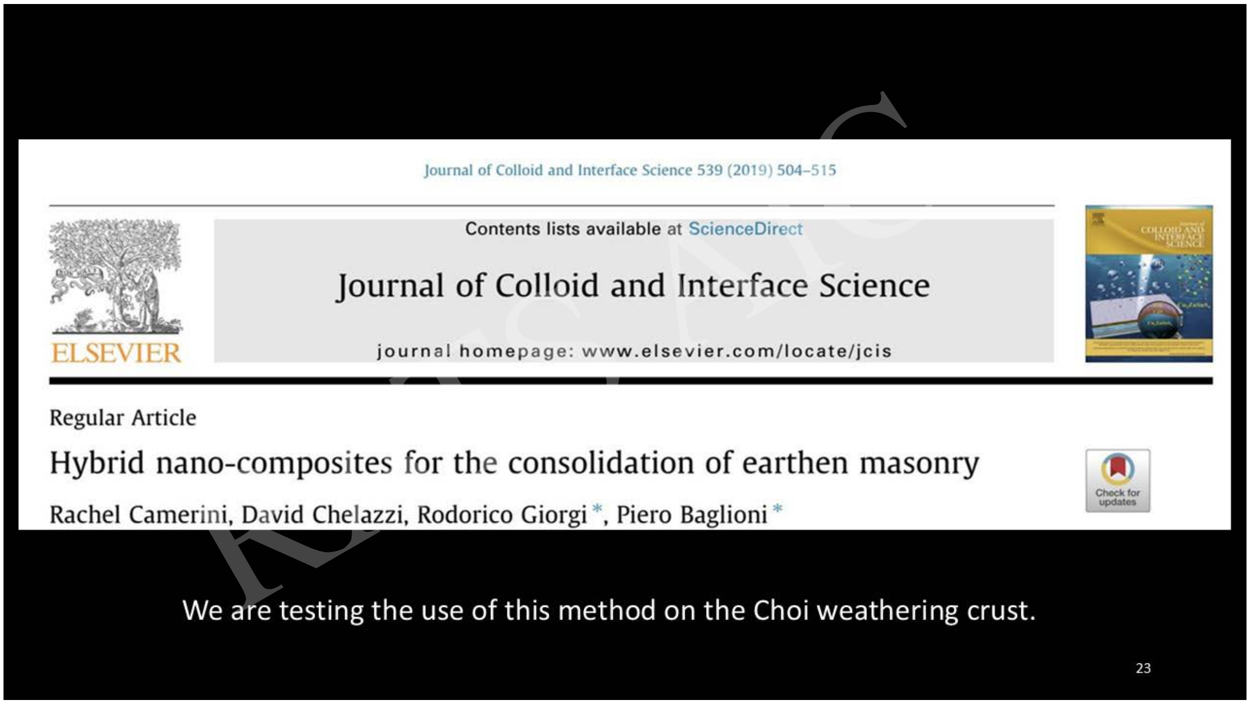
Slide 21. Before and after images showing partial removal of the precipitate line at the water level. Each side had two applications of a poultice of fifty percent “Arbocel forty” and fifty percent “Arbocel two hundred” wetted with distilled water, in between layers of Japanese tissue, with six milliliters of sixty percent acetic acid in water, and ten milligrams of one hundred percent citric acid crystals
The encrustation was not completely removed as not all of the components are soluble in mild acids. New silicate precipitation should not be a problem.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



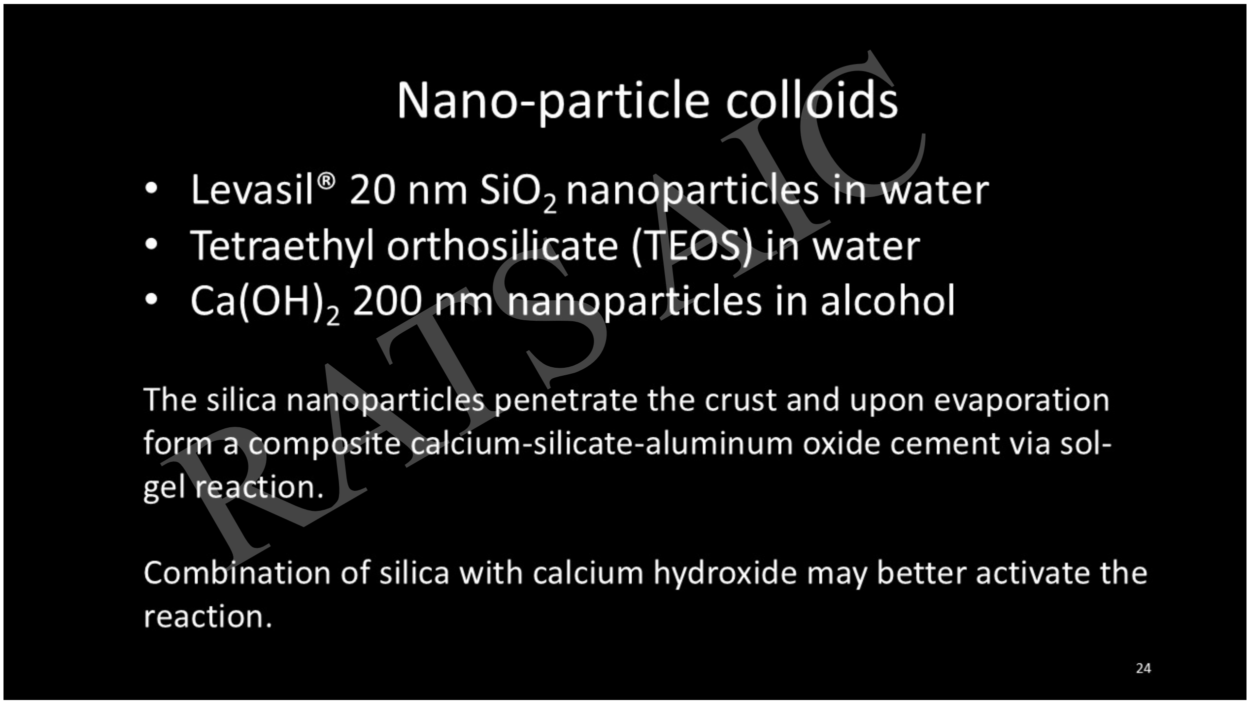
Slide 22.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



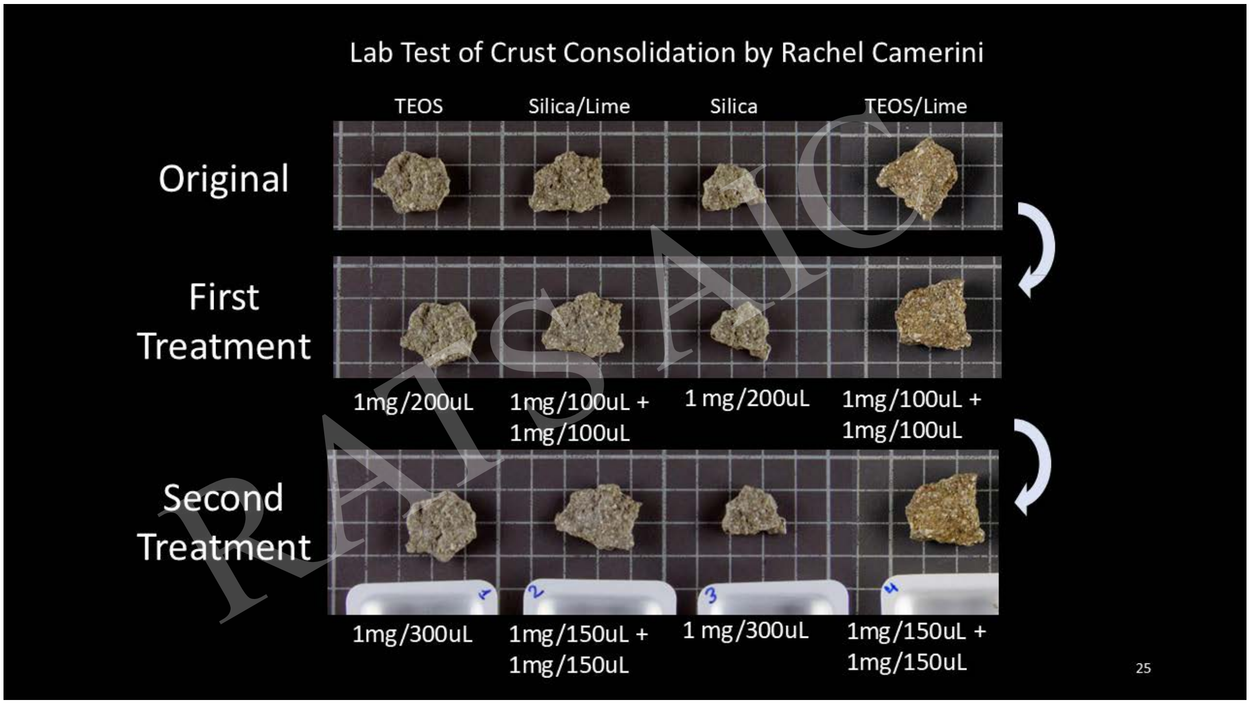
Slide 23. In a paper by Camerini et al. (2019) on consolidation of adobe masonry, it was shown that nano-particle colloids of silica and lime can be used to penetrate microporosity and form cement.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



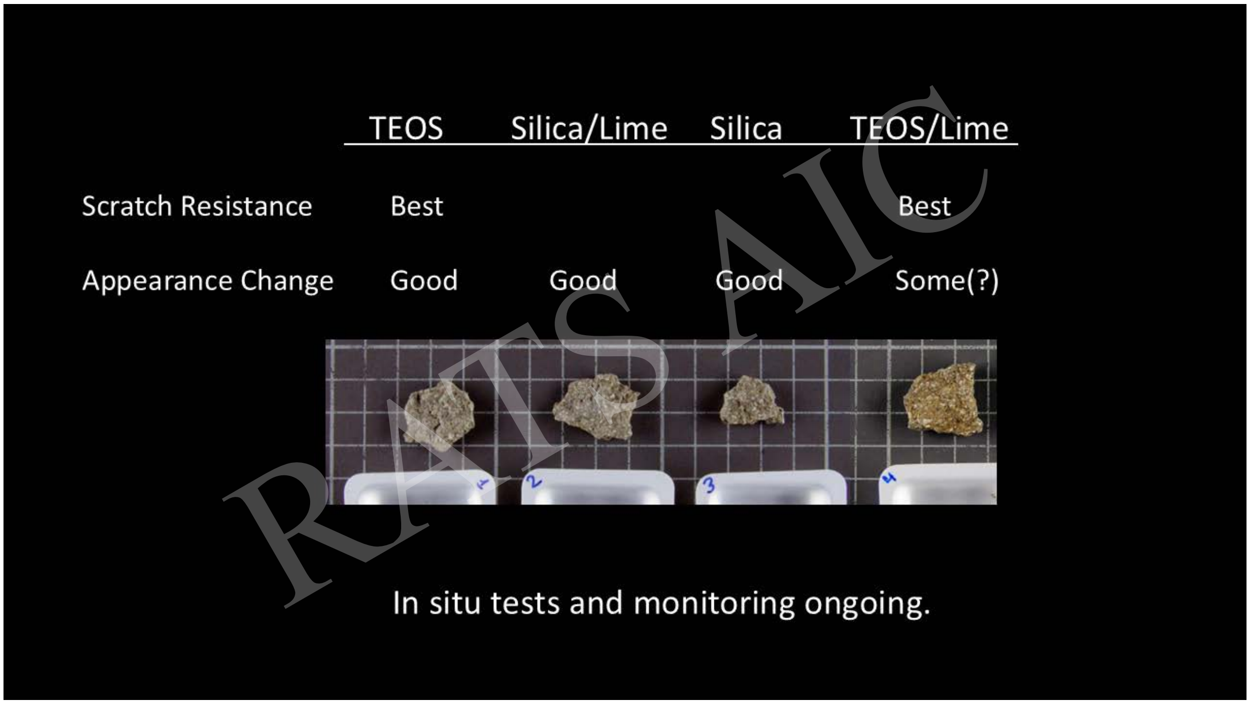
Slide 24. Nano-particle colloids to be tested are Levasil® silica nanoparticles in water and tetraethyl orthosilicate (TEOS) both tested with or without mixing with calcium hydroxide nanoparticles in alcohol as a catalyst.
The silica nanoparticles penetrate the crust and form a composite calcium-silicate-aluminum oxide cement upon evaporation via sol-gel reaction. The sol-gel technique transforms a colloidal suspension into a solid network. The combination of silica with calcium hydroxide may better activate the reaction.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



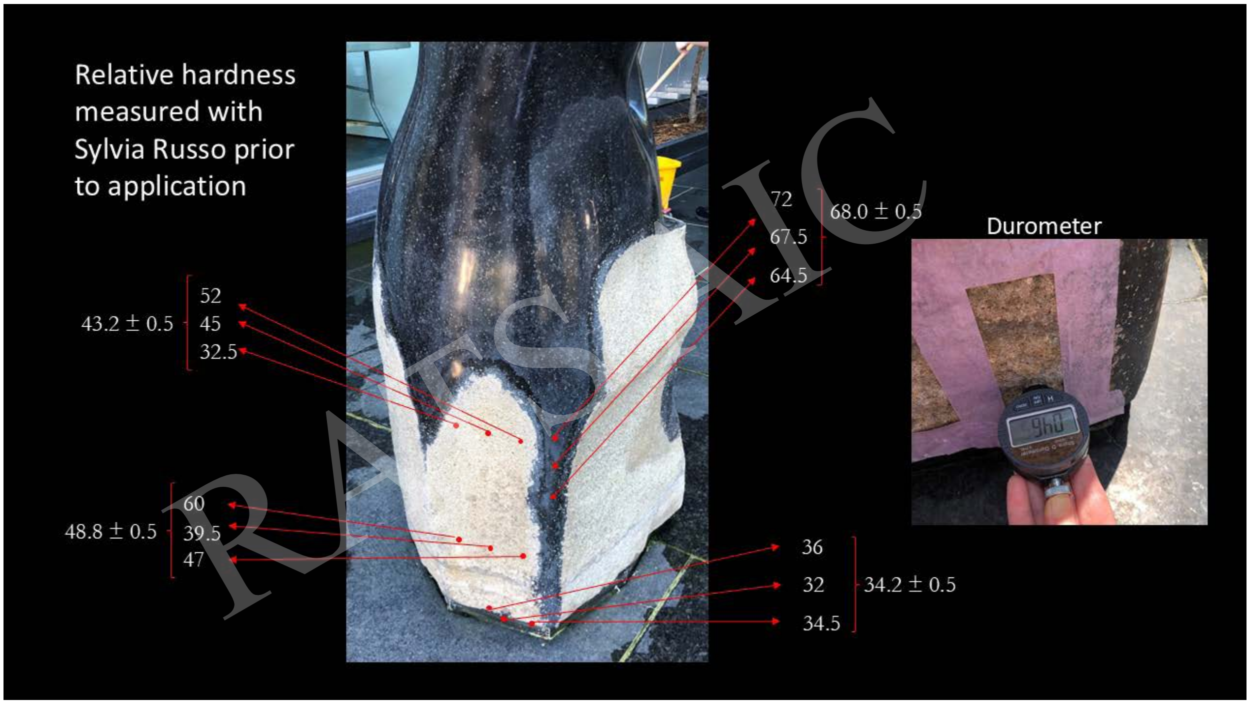
Slide 25. On the top row are crust fragments prior to treatment.
They were first treated with dilute suspensions of TEOS or silica with or without the calcium hydroxide.
An additional second treatment was applied with fifty percent greater concentration.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



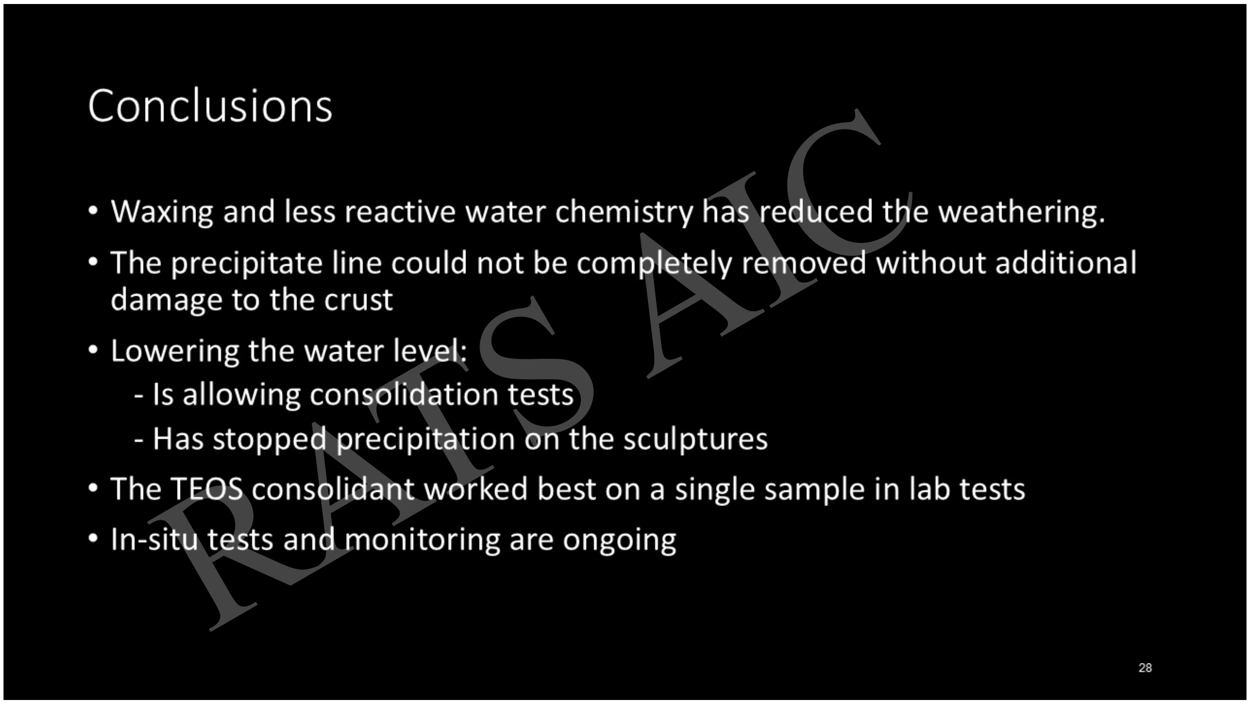
Slide 26.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures

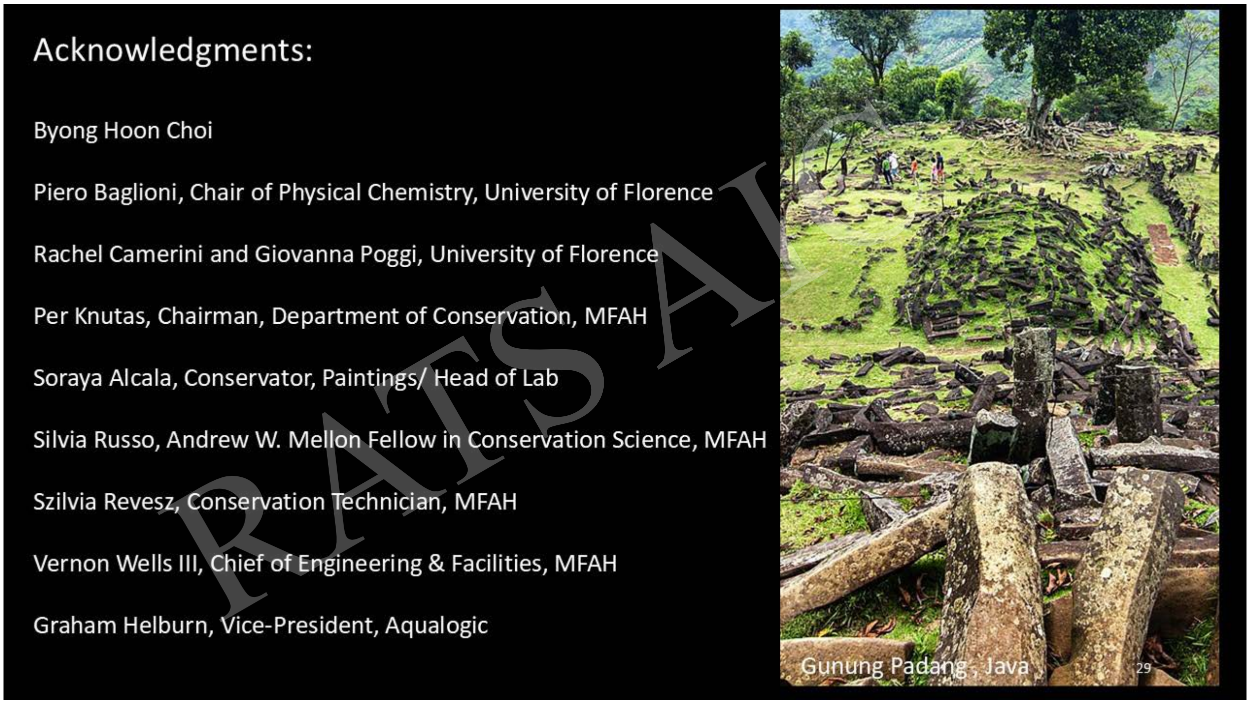


Slide 27. Relative hardness was measured with Sylvia Russo using a “Shore D Durometer” prior to application of the consolidant. Tests after consolidation of the crust have not shown significant differences so far. The hardness meter may not be sufficiently sensitive to see the change. Frequent rain and high humidity may also have hampered our results.

Mechanisms of Decay: Rapid Weathering of Outdoor Basalt Sculptures



Slide 28.



Slide 29.

Not All That's White is Salt: Encountering Lead Corrosion on Glazed Ceramics

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Original Abstract

The revenues from the salt trade were of great significance to the Bavarian electors until the late 18th century. The 'white gold' was transported via waterways from Hallein and Berchtesgaden to the town of Hof near Regensburg, with so-called salt ship convoys being used on the Danube. These were convoys of ships specially designed for salt transport, which were pulled upstream with the help of horses, a process known as "towing". In the ducal Bavarian salt trade logistics, salt ship convoys played a central role as cost-effective and easily calculable means of transportation, thanks to reliable cargo quantities and rates for all participants in the trade. This importance increased even more in the 18th century, so it is not surprising that these ship convoys became worthy of depiction in the last third of the 18th century. The only known sculptural representation of a Palatinate salt ship convoy is housed in the Bavarian National Museum (BNM) in Munich. The group of objects has so far been dated to the second half of the 18th century. As an object, it has no parallel in Wittelsbach possession and is culturally a piece of regional historical significance.

This representation of a salt ship convoy is made of glazed ceramics, leather, metal, and wood and consists of three ships and three skiffs, accompanied by 17 riders and a servant. It was already transferred from the Munich Residenz to the Bavarian National Museum before 1869. Since 1956, the object had been on permanent loan outside the museum. However, it was selected for permanent exhibition at Schloss Obernzell near Passau, so it returned to the BNM in 2022 for examination and restoration. Initial investigations revealed a notable pattern of damage on all figures and ships: sporadically growing "needles" from the surface. Initially, it seemed likely that these could be salt efflorescences, but a closer examination held a surprise. The white material always had its origin in a metallic core. Knowledge of the exhibition conditions during recent years led to the assumption that the white material is indeed lead corrosion, which was confirmed by SEM-EDX and X-ray diffraction. The lead had reacted with formic and acetic acid emissions from display cases to form lead hydroxycarbonate (lead white) and lead formate. The question of the origin of the lead accumulations was investigated through CT scans. It became evident that the lead did not originate from impurities in the body but was formed from the lead glaze during firing.

The restoration of the salt ship convoy involved dealing with various options for treating active lead corrosion and discussing their applicability to an object made of mixed materials. The decision was made

to mechanically remove the lead corrosion products and apply a protective coating to the lead accumulations. Aspects of preventive conservation were also considered because the new display case is made again of wooden materials that can lead to an accumulation of acetic acid. Therefore, options for retrofitting an existing display case to reduce emissions are also being discussed.

A Study of the Use of *Acacia Nilotica* Seed Pods to Produce a Distinctive, Black Paint for Bwa and Mossi Polychrome Wood Masks in Burkina Faso

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Extended Abstract

Introduction

Exposure to an unusual plant-based black paint during conservation treatment of Bwa masks in 2000 and 2022 inspired this black paint investigation of Bwa and Mossi polychrome wood masks, which we published in the double-volume of *Technè* (2023) dedicated to the meaning and substance of black materials (Hornbeck and Newman, 2023). Focus on six Bwa and Mossi masks in the collection of the University of Iowa's Stanley Museum of Art (SMA) draws on field observations of the making of such paint by Christopher Roy (1947-2019), scholar of Burkinabè material culture and art history professor at the university. Four of the masks (**fig. 1**) were collected directly by Roy in Burkina Faso, two for C. Maxwell and Elizabeth M. Stanley's important private collection of African art bequeathed to the University. Roy's intriguing description of the paint's derivation from processed *Acacia nilotica* seed pods (**fig. 2**) and its distinctive appearance led to this effort to corroborate Roy's field observations by characterizing the composition via analytical methods. Moreover, few if any scientific studies of black pigments used in African art appear to have been carried out to date, a further motivation for this technical study.

Cultural Use

While red, white and black colors are found on masks throughout Africa, the color symbolism is especially important in the Western Sudan, which extends south of the Sahara from the Niger River in the east to the west coast. Community ceremonies are occasions for public mask performances by initiated men and women. Often oversize, these masks depict hybrid creatures or animals and are made by multiple cultural groups, including Bwa, Mossi and Nuna people, collectively described as Burkinabè, in the greater Burkina Faso region. The performances reenact historical encounters between the ancestors and protective spirits, represented by the form on the mask. Costumes of dyed fibrous hemp material conceal the bodies of masqueraders. The white and red paints are applied to masks in thin layers with binders stated to be egg or gum arabic; thin black paint, in the same media, was also sometimes used. However, a heavy-bodied black paint is used for raised linear designs. While commercial paints with modern binding media can sometimes be found, natural plant-based binders remain common.

A Study of the Use of *Acacia Nilotica* Seed Pods to Produce a Distinctive, Black Paint for Bwa and Mossi Polychrome Wood Masks in Burkina Faso

Figure 1: (left to right) 1. *Luruya* (dwarf mask), Bwa, Burkina Faso (X1990.633). The Stanley Collection of African Art, University of Iowa Stanley Museum of Art. © S. Hornbeck. 2. *Bayiri* (mask with hooks), Bwa, Burkina Faso (X1990.634). The Stanley Collection of African Art, University of Iowa Stanley Museum of Art. © S. Erickson. 3. *Wan Nyaka* (antelope mask), Mossi, Burkina Faso (2022.70). The Stanley Collection of African Art, University of Iowa Stanley Museum of Art. © S. Hornbeck. 4. Crocodile and Hornbill mask, Bwa, Burkina Faso. William N. Nehring Collection. © W. N. Nehring.

In a 1987 description[2] Roy explained that making the thick black paint "requires an expensive process called *gbonkahû*…made by boiling the seed pods of the *Acacia nilotica* tree, which the Mossi call *pernenga* and the Bwa call *nyaoh*, into a thick 'tarry' liquid." Roy noted that *pernenga* was also used by most other Burkinabè peoples to paint masks and by the Asante in Ghana to stamp adinkra cloth. *Acacia nilotica* pods are particularly rich in hydrolyzable tannins, and have been used as brown or black dyes on leather and textiles. Yet, the use of *Acacia nilotica* seed pods for black paint appears to be localized to the Burkinabè.

During field research Roy established relationships with Burkinabè makers and practitioners. The Konaté family in Ouri have been carving and painting masks for more than six generations. In the village of Boni wood masks are used by individual families; initiated Bondé men are eligible to wear the masks owned by this family, sometimes purchased from the Konaté workshop. A Bondé family member, potentially carver and chief of Boni Yacouba Bondé, owned three of the masks in this study. For comparison, black paint of similar appearance from two additional SMA objects (not directly collected by Roy) were also sampled.

A Study of the Use of *Acacia Nilotica* Seed Pods to Produce a Distinctive, Black Paint for Bwa and Mossi Polychrome Wood Masks in Burkina Faso

Figure 2: left - *Acacia nilotica* seed pods (stock image); right - In Boni, Abdoulaye Ouedraogo makes black paint (n.d.). Photo J. Gaasch, in Gaasch J., 2016, p. 122 *African Masks from the Collection of James Gaasch*, Humboldt State University Press, Humboldt [https://digitalcommons.humboldt.edu/monographs/3].

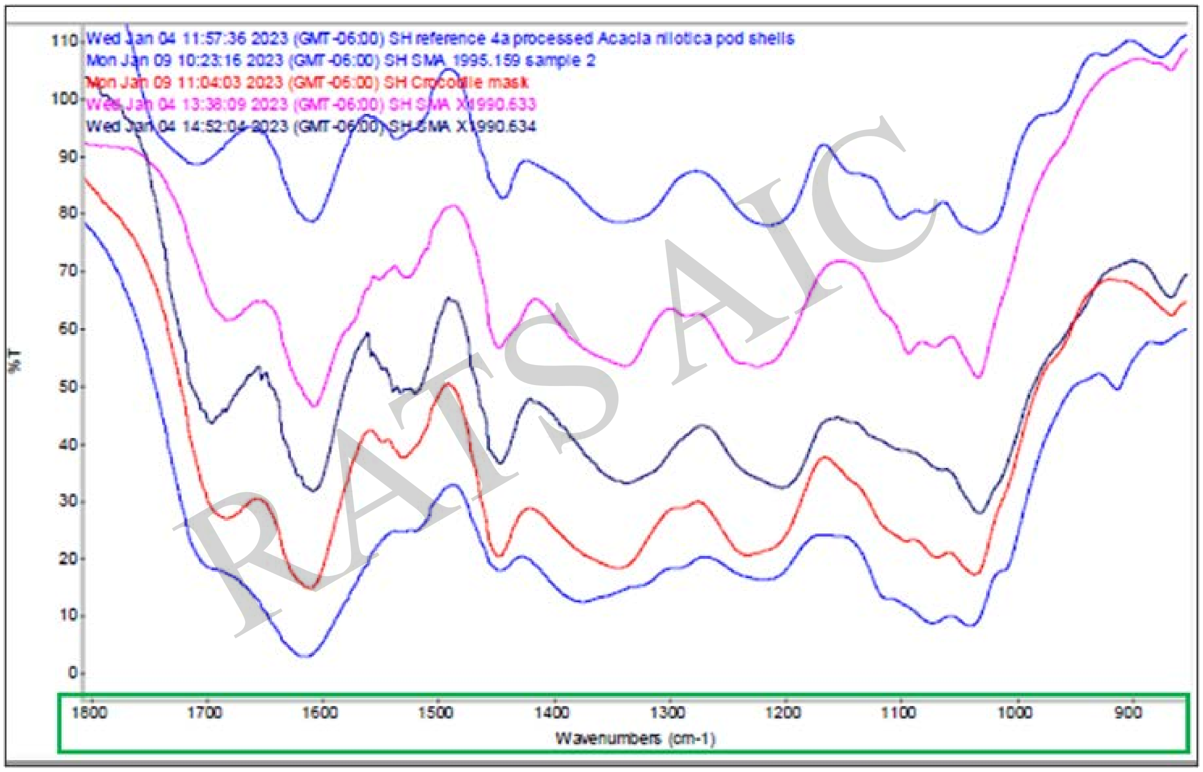
Scientific Analysis

Multiple analytical techniques were applied to the lab references and object paint samples to elucidate their nature and to confirm Roy's description. As initial FTIR analysis did not yield a close match to materials in the database, production of lab reference samples from known raw materials was needed for comparison. Following Roy's description, an abbreviated version of processing *Acacia nilotica* seed pod shells, seeds and a mixture of both was undertaken in the lab. The goal was to achieve through processing an approximation of the material composition, if not its exact consistency.

Examination with SEM-EDS indicated the very dark coloration of the paint samples could be mainly due to carbohydrate pyrolysis products that were created during extended processing of raw materials. All object paint samples, dry films from water-solubility tests, and lab references were analyzed by transmitted FTIR. While the match indices to at least one of the three references were better than any in the database, they still were less than 90 in a match index of 100. Most of the spectral features are in the 1800-650 wavenumber range. Differences in the higher wavenumber peak positions between the spectra of paint samples and the processed pod shells suggest that the lab processing did not produce exactly the same changes in composition or polysaccharide structures as were present in the paints. Spectra from three paint samples closely resembled each other and exhibited many similarities to the lab reference sample prepared from seed pod shells (**Table 1**). They were less similar to the material from a mixture of pods and seeds, and least similar to material from only seeds.

A Study of the Use of *Acacia Nilotica* Seed Pods to Produce a Distinctive, Black Paint for Bwa and Mossi Polychrome Wood Masks in Burkina Faso

Table 1: Transmittance FTIR spectra, spectral features in the 1800-650 wavenumber range. Top blue spectrum = lab reference material 4a: processed seed pod shells, as compared to spectra of paint samples from objects. MFA Boston Scientific Research Lab Analytical Report, SR Lab project number: 2023-3, Feb. 8, 2023.



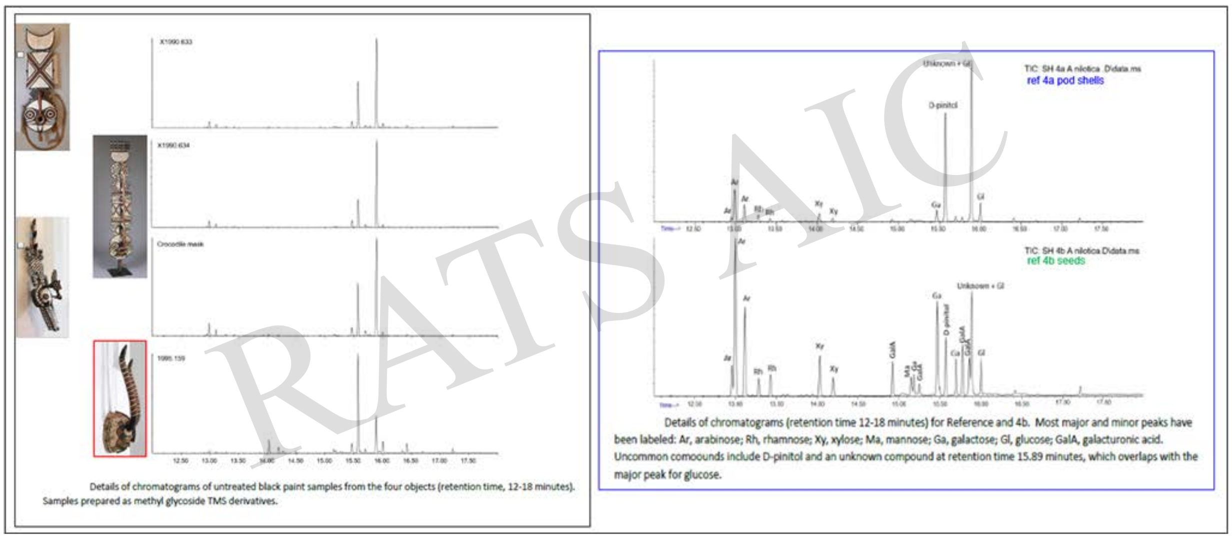
Given the significant carbohydrate content, analysis by GC/MS was undertaken. Confirming what was implied by FTIR, chromatograms from three of the objects closely resembled one another and the lab pod shell reference material (**Table 2**). The major monosaccharide in all samples was glucose, which co-eluted with an unknown compound that is not a monosaccharide. In all paint and lab references, small amounts of arabinose, rhamnose, xylose and galactose were detected; galacturonic acid was detected in all samples except one. On the right of the table, the major ions for monosaccharides (m/z 204 and 217) and another major compound detected in all samples, D-pinitol- a common component of many plant seeds and other parts- are plotted as well as the major ion (m/z 281) of an unknown compound.

The GC/MS monosaccharide profile of the paint samples closely matched results from analysis of processed pod shells. Paint from a fourth object- the antelope crest mask- showed a somewhat different composition, although *Acacia nilotica* is almost certainly the raw material used to make it. As noted, *Acacia nilotica* pods contain hydrolyzable tannins, and compounds from these components are likely present in the black paints and lab-prepared samples but were not directly detected by the GC/MS procedure utilized. Further analysis to characterize the tannins present is planned.

Conclusions

A Study of the Use of *Acacia Nilotica* Seed Pods to Produce a Distinctive, Black Paint for Bwa and Mossi Polychrome Wood Masks in Burkina Faso

Table 2: The left side shows GC-MS chromatograms from analyses of a sample from each object. All four samples show the same peaks, large and small. The relative peak heights in the top three chromatograms are quite similar. The sample from object 3, at bottom, however, is distinctly different. The right side shows chromatograms with individual peaks identified for samples of lab reference materials – Reference 4A processed pod shells above and Reference 4B processed seeds below. The two extracts clearly contain the same compounds, but in quite different relative amounts. The chromatogram for Reference 4A is very similar to those for the first three samples shown on the left side. For these samples the chromatograms show the same strong link to Reference 4A as the FTIR spectra did. However, the sample from object 3 does not closely resemble either Reference 4A or 4B. MFA Boston Scientific Research Lab Analytical Report SR Lab project number: 2023-3, Feb. 8, 2023.



The study of the compelling biographies and materiality of the masks illuminates a long cultural tradition in Africa's Western Sudan region. Christopher Roy's 40-year engagement with Burkinabè communities afforded direct object collection from makers/practitioners and yielded abundant scholarly material. This technical study supports Roy's field observations that the unusual, thick black paint on Bwa and Mossi masks from Burkina Faso was prepared by extensive boiling of *Acacia nilotica* seed pod shells. The results from one object, the Mossi antelope mask- the oldest in the study- indicated variation in how paints were prepared, even if all were based on extracts from the same acacia species. The continued use of this natural paint, time-consuming to produce and enduring even as commercial paints similar in appearance are also available and used, highlights the importance of cultural tradition. Collaborations with Burkinabè researchers and artist/makers will advance understanding of cultural use, materiality, and sourcing of local plant materials.

A Study of the Use of *Acacia Nilotica* Seed Pods to Produce a Distinctive, Black Paint for Bwa and Mossi Polychrome Wood Masks in Burkina Faso

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Endnotes

[1] The species *Acacia nilotica* has been recently re-classified as *Vachellia nilotica*. *Acacia nilotica*, still a widely used synonym, is used in Roy's publications and consequently this paper, as well.

[2] Roy 1987, p. 40.

When One's Upbringing Guides Scholarly Research: the Technical Examination of a (Purported) Mexican Religious Painting

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Original Abstract

Historical objects are key to understanding the context that led to their creation – cultural, social, and technological. The growing interest in studying overlooked collections has aided in shedding light on certain periods and places, such as the transition from New Spain to (independent) Mexico. This is the case of a painting donated in 2022 to the Winterthur Museum, Garden & Library, an institution known for their American decorative arts collection. Originally referred to as a "Mexican Retablo", the object depicts ten figures commonly associated to the Catholic religion. This term was used despite lacking provenance, bibliographic information, or a thorough description.

Our interest in this work is multifaceted, both professionally, and personally. The objectives were (1) giving a more informed attribution and significance; and (2) adding technical information on Mexican artists, outside those once endorsed by the Spanish Monarchy. Spanish being the native language of most authors, who, in addition, were raised into Catholic traditions in a predominantly Catholic country, played a central role in this study. For example, it was possible to rapidly identify most of the religious figures portrayed, later confirmed through iconographic cross-referencing. As well, we realized that it was incorrectly described as a "retablo" but instead it was a "devocionario". Devocionarios are painted collections of Catholic icons that emulate retablos, which are comprised of both sculptures and paintings. In addition, as Spanish speakers, we could access primary sources, catalogs, and existing published studies in this language. Instrumental analyses included X-ray fluorescence (XRF), Raman, and fiber optic reflectance (FORS) spectroscopies; cross-section microscopy, and scanning electron microscopy (SEM) with elemental mapping (energy dispersive X-ray spectroscopy, EDS). This technical examination revealed the work's relative simplicity (e.g., no preparatory drawing), and limited pigment palette (e.g., white lead, ochres, etc.). Of particular interest was the presence of arsenic and sulfur suggesting orpiment, a pigment traditionally used in Mexico. This study contributes to the limited knowledge of painting traditions in present-day Latin America, as it evolved from being of European influence to finding its own identity by incorporating local materials and practices and owning its iconographic style.

Eh, voilà! Encountering the Unexpected in the Treatment of Gustave Caillebotte's 'Young Man at His Window'

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Original Abstract

Sometimes things are not what they appear to be. A thorough investigation of 'Young Man at His Window' by Gustave Caillebotte using broadband UV, visible light, infrared, and X-ray imaging showed that the painting had multiple varnish layers applied over significant losses to the original paint and ground which had been extensively overpainted. However, the unexpected happened during what was anticipated to be a relatively straightforward treatment: newspaper print and gauze were discovered along one of the edges of the painting when a small window was opened in the paper tape. Was this evidence of a transfer? A closer visual examination supported by a full technical investigation into the composition of the previously applied conservation materials using scanning macro X-ray fluorescence spectroscopy (MA-XRF), scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS), Fourier transform infrared (FTIR) spectroscopy and gas chromatography- mass spectrometry (GC-MS) confirmed that the painting was, in fact, a transfer!

Painted in 1876 on a finely woven canvas, the work likely suffered significant damage from shrinking after exposure to water. Presumably, the damage to the original canvas was sufficiently great to warrant transferring the painted image to a new support. The materials used in the ensuing structural treatments, as well as their sequence of application, were deduced from the material evidence still present on the painting. First, the damaged painting was faced using newspaper and stiff cardboard. The original canvas was then removed from the paint and ground layers. A new priming layer - composed of barium sulfate, zinc white, and gypsum bound in linseed oil - was then applied to the exposed ground. Next, gauze was laid over the dried priming layer. The newly transferred painting was then lined using starch and animal glue to affix it to an auxiliary canvas support, and re-stretched. The final step in the transfer process would have been to remove the temporary facing. Small islands of paint affixed upside down and rotated with respect to the surrounding weave suggest that additional damage occurred during this step, necessitating further conservation treatment. Large areas of the painting were covered using a chalk-based filler and overpainted using pigments bound in modern resins. Multiple varnish layers containing pine resin, dammar, bleached shellac, drying oil, and a UV-absorber were identified on the surface of the painting.

Eh, voilà! Encountering the Unexpected in the Treatment of Gustave Caillebotte's 'Young Man at His Window'

The results were contextualized through archival research and studying textual sources.[1] The materials associated with the transfer and lining coupled with their order of application are a close match with published Parisian recipes and documented workshop practices. In this case study, the materials used in the previous treatments functioned to hide the complete extent of damages, rendering many losses invisible using standard broadband imaging techniques. This treatment and scientific examination serve as a reminder that we should expect the unexpected in every work of art.

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What's On The Bag? Technical Analysis of the Colorants and Printing Techniques Utilized in Frank Stella's 1984 Tyler Graphics Bag

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Original Abstract

In 1991, the Nevada Museum of Art presented an exhibition of shopping bags belonging to the private collection of J. Scott Patnode. The exhibition, titled 'It's on the Bag', aimed to bridge the gap between 'functional' and 'fine' art by celebrating the shopping bag as a ubiquitous and accessible reflection of consumerism and pop culture at the close of the 20th century, and many of the bags on display were commercially printed with reproduced or commissioned imagery made by popular artists. One such artist represented in the exhibition was the American painter, printmaker, and sculptor Frank Stella. Commissioned by the now-closed chain of Dayton's department stores to promote the 1984 expansion of the Walker Art Center in Minneapolis, MN, Stella's bag was titled Tyler Graphics Bag for the purposes of the exhibition.

Tyler Graphics Bag is named for the Tyler Graphics Studio, where the bag was produced. Under master printer Kenneth Tyler, the studio collaborated with numerous other artistic luminaries of the 1970s and 1980s, including David Hockney, Helen Frankenthaler, Ellsworth Kelly, and Roy Lichtenstein, and was actively exploring new technologies for digital printing. Stella's Tyler Graphics Bag is printed on all five sides, with compositions by Stella on the two largest panels and promotional information about the Walker Art Center's new galleries written on the smaller side panels. Prints from the same edition are described inconsistently in the market and in institutional collections, contributing to a lack of clarity around the media of the original design and the methods of production.

Two of the Dayton's Stella bags are in the collection of The Conservation Center of the Institute of Fine Arts, New York University, where, in partnership with the Museum of Modern Art, technical analysis of the bags was carried out to characterize the colorants and printing techniques employed in their manufacture. The bags were analyzed using multiband imaging, portable Raman spectroscopy, and reflectance

What's On The Bag? Technical Analysis of the Colorants and Printing Techniques Utilized in Frank Stella's 1984 Tyler Graphics Bag

Fourier-transform infrared spectroscopy (rFTIR) to characterize the media and colorants used in their production. Microfade testing (MFT) was also used to classify the light sensitivity of the identified colorants to establish possible display recommendations. The manufacturing processes were explored through microscopic examination, which revealed evidence that the images on the shopping bags were created using offset printmaking techniques to mimic diagnostic characteristics of other printing methods; there is a faux woodgrain in the background of the printed composition, while the overlapping marks in the center suggest stone lithography and screenprinting techniques, all of which are ersatz, produced instead with halftones of combined gray spot color and CMYK color separation.

This research sheds new light on printing techniques during a transitional period in printing and digital technology, and on collaborations between one of the foremost American artists and printing studios of the 1980s.