RATS

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Virtual Meeting
May 21 – September 2, 2020

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Research and Technical Studies Specialty Group Sessions

A Closer Look at School of Rembrandt's *Portrait of a Young Man in an Armchair* at the Memorial Art Gallery

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Keywords: Rembrandt, Analysis, Technique, Materials, Multi-modal Imaging, Attribution

Extended Abstract

Portrait of a Young Man in an Armchair at Rochester's Memorial Art Gallery (MAG) is a painting with a troubled past. Attributed to Rembrandt and also demoted several times, it has been difficult for curators and conservators to determine how the painting fits into Rembrandt and his school's greater oeuvre. With a recent focus on Rembrandt paintings and conservation histories at institutions worldwide, updated information is now available to better characterize Rembrandt's use of materials as well as the cumulative effect of conservation campaigns. As such, the armchair painting was worthy of a closer look. Faculty at the Patricia H. and Richard E. Garman Art Conservation Program collaborated with the MAG to conduct technical imaging and analysis. The goal was to use current knowledge in the field and compare it with information obtained from the painting.

According to the MAG, the provenance of the painting is as follows: "by descent to Charles Robert Wynn, Earl Carrington (1843-1928), Wycombe Abbey, Buckinghamshire, England; purchased from him by Charles J. Wertheimer, London, 1895; Alfred Beit (1853-1906), London, ca. 1899 - 1905; to his brother, Otto Beit (1865-1930), London; M. Knoedler Galleries, New York; George Eastman (1854-1932), Rochester, 1911; his bequest to the University of Rochester, New York, 1932; transferred to the Gallery in 1968". The provenance leaves 183 years unaccounted between 1660 and 1843.

Today, Rembrandt and his paintings have been extensively researched. The Rembrandt Research Project (RRP), an initiative of Netherlands Organization for Scientific Research, details the designation of many Rembrandt attributions. It is important to recognize that the MAG painting is not included as attributed to Rembrandt in the RRP, though it has been labeled as such in several catalogue raisonnés including those by Smith (1831) and Bredius (1969) among others. The MAG historical records contain a letter dated Aug. 8 1930 to George Eastman from art historian Dr. Wilhelm R. Valentiner, director of Detroit Museum of Art stating that in former catalogues "…it was fully signed and dated 1660; but now neither the signature nor the date is anywhere visible". The MAG has since indicated that this might have been stated in error.

The painting has also suffered extensively, causing it to be conserved by the hands of several restorers, including four prominent American restorers. The records at the MAG indicate several 20th century treatments. The files included: treatment reports by Thomas Agnew & Sons, 1930; quote and treatment proposal by Stephen Pichetto, 1935; treatment reports by William Suhr, 1936; treatment reports by Caesar Diorio, 1950 and 1960; and a treatment report from the Intermuseum Conservation Association (ICA), Oberlin, by Richard Buck and Delbert Spurlock completed after the painting was recovered from theft in 1968. The numerous treatments include glue and wax-resin linings, lining removals, numerous varnish removals and inpainting, and an application of copaiba balsam. The painting was also analyzed in 1991 by Harvard Art Museums.

The number of treatments and the painting's history indicate that the painting experienced considerable damage.

The methods of analysis for this study include multi-modal imaging, x-ray fluorescence spectroscopy (XRF), Raman spectroscopy, cross-sectional analysis, Fourier-transform infrared spectroscopy (FTIR), x-ray diffraction (XRD) and scanning electron microscopy (SEM-EDS). Of particular interest was whether the ground contained quartz and if a specific plumbonacrite compound recently found in Rembrandt's impasto was also present. Imaging revealed considerable damage and overpaint present and very little composition planning. X-radiography revealed a

significant change in the position of the sitter's hands. SEM of the cross-sections revealed regions rich in silicates, with the specific chemistry of these particles indicating a good match for quartz. Optical microscopy of the ground layer was consistent with showing quartz-like particles. XRD indicated that the impasto samples contain a mixture of cerussite and hydrocerussite, though plumbonacrite was not identified. XRF mapping was performed on the painting in the areas of the hand and face, indicated a palette consistent with 17th century Dutch painting materials. FTIR indicated the presence of kaolinite, quartz and lead white. The results indicate that where sampled, quartz was identified in significant quantities within the ground layer and plumbonacrite was not identified in the impasto. The palette and working method were consistent with the Harvard analytical report completed in 1991 and is typical of a 17th century painter in Holland, including that of Rembrandt.

Portrait of a Young Man in an Armchair has now returned to display at the MAG. There is still opportunity to find out more about the painting, as a gap in the provenance remains present and the materials are typical of many 17th century painters. The results are planned to be displayed in an interactive exhibition at the Memorial Art Gallery, enticing visitors to also have a closer look.

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Archaeological Plant Fiber Identification through DNA Extraction and Sequence Match

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[1]Associate Professor, Eastern Carolina University

Submitted Abstract

It is commonly recognized that identification of different bast fibers and leaf fibers of archaeological objects can be very challenging. One such example is the debate between the research teams led by Kvavadze (2009) and the team by Bergfjord (2010) about the identification of 30,000 year-old wild flax fiber. DNA analysis can be a potential new tool in dealing with this challenge. Murphy, *et al* (2011) identified flax and hemp fiber present in the rope and fabric samples from the Christmas Cave in Israel through DNA analysis; and some of the samples were dated as early as the "fourth millennium BCE." This new technology can only work, however, when the plant fiber material contains other plant cells, such as parenchyma, because the dead fiber cells do not contain any plastids.

In this paper we present DNA extraction and sequence matching results of two textile fragments recovered from *Mary Rose*, an English Tudor navy ship of King Henry VIII which sank in 1545. Before using the limited archaeological samples, we first replicated and tested the sample preparation method by Dunbar and Murphy (2009) with commercial rope samples (Chen and Mayer 2018). In addition to the rbcl primers used by Murphy, et al (2011), we explored matK and psbA3 + trnHf primers which are recommended for addressing the limitation of overlapping rbcl genes between species. The extracted DNA were sequenced using BigDye v.3.1 on an Applied Biosystems 3130 XL Genetic Sequencer. The sequences were used as a query for a BLASTn through the Geneious software package. Three DNA extraction experiments were made with two rope samples and ten sailcloth samples prepared from *Mary Rose*. DNA extractions were successful with the two rope samples and six out of the ten sailcloth samples using rbcl primers, and other primers failed to work with these samples. The results of DNA sequence matching revealed the rope sample (marling twine) from *Mary Rose* being cannabis sativa (hemp), rbclF2: ID = 130/136 or 96% and rbclR3a: ID = 138/140 or 99%, along with other two high percentage identities such as Humulus lupulus (a flowering plant of hemp family). These matches do indicate the limitation of rbcl gene for plant identification. However, it is known that hemp is the fiber plant cultivated for textile production.

Among the six sailcloth samples' DNA matching results, three showed one directional identity match at 98% and 99% with Urtica family members (nettle fiber); one showed two different identities matching of Urtica family at 98% and Populus at 93%; and the remaining two showed matches lower than 90% with other plants, including flax. These results demonstrate that DNA extraction and sequence matching are possible with archaeological plant fiber material, but the sequence matching results need to be examined and interpreted carefully due to overlapping rbcl gene region between plants and contaminations which could produce a false matching.

Comparing DART Analysis to Traditional Wood Anatomy for the Identification of West African Woods: Research at the Smithsonian National Museum of African Art and Museum Conservation Institute

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Keywords: Wood Identification, DART, Anatomy, African Art, Smithsonian

Annotated Powerpoint

ABSTRACT

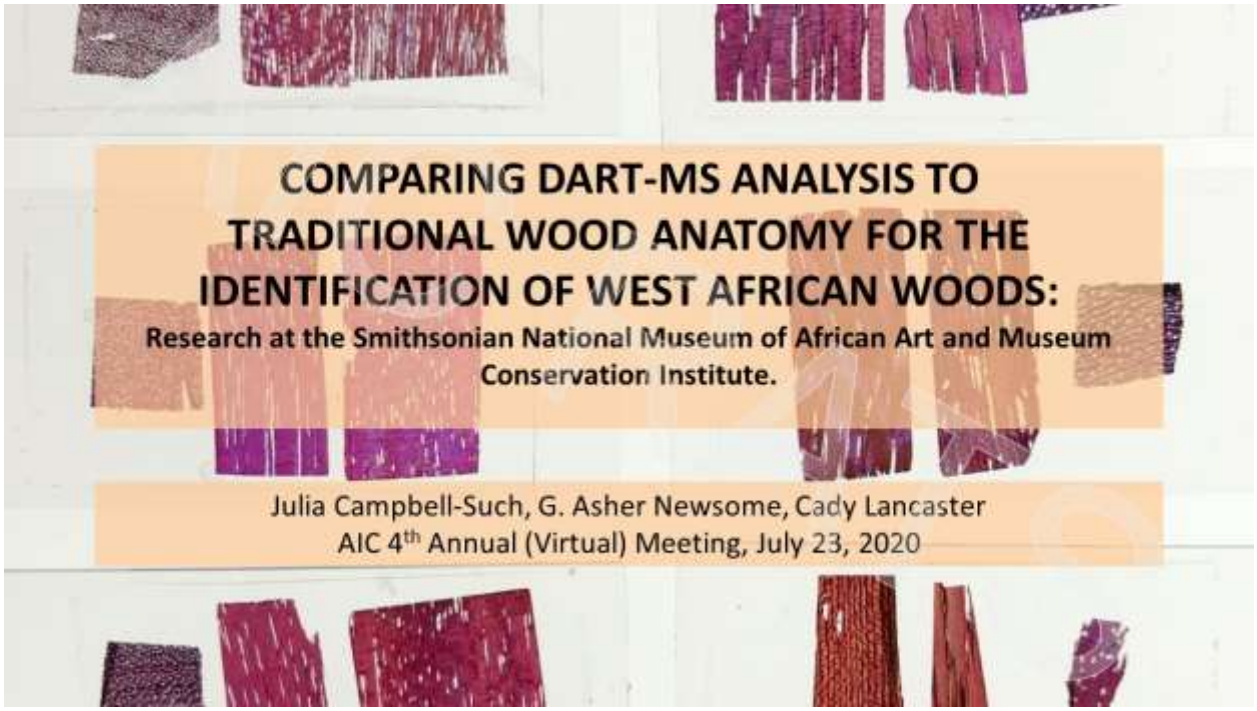
In the field of African Art Conservation, understanding which species of wood was used to construct an artwork enriches our understanding of the object; it may help us develop a provenance for a piece of artwork, connect it to a particular cultural community, or help us determine the historical time in which it was made. In addition, museums must comply with increasingly strict regulations on the international transport of goods made from endangered plant species; reliable species identification of the woods used to make art will help to protect art objects when they travel. Wood genus and species are traditionally identified by anatomic and micro-anatomic features, but to do this with accuracy requires specialized training, access to reference materials and databases, and many years of experience. A relatively large sample must be taken from the object, and, most often, woods cannot be distinguished beyond the genus level by their cellular anatomy.

Recently, alternate methods of wood species classification have been developed that rely on the chemistry of different species rather than on their anatomical characteristics. Wood identification by Direct Analysis in Real Time (DART) Mass Spectrometry is currently being used by the National Fish and Wildlife Service's Forensic Lab as a practical technique to aid in the prevention of trade in endangered woods; the Smithsonian National Museum of African Art, in collaboration with Smithsonian's Museum Conservation Institute, is currently researching the potential of this tool to aid in the species classification of woods used in African art.

In 1998, the conservation lab at the Smithsonian National Museum of African Art received a donation of 62 wood samples from Ghana, labelled with botanical and local names. These samples

were donated for use in the identification of woods in the museum's collection; current research compares DART analysis with traditional microanatomical identification by performing both techniques on the same sample set. The primary goal of this project is to provide an initial, practical assessment for working conservators of the potential of the DART technique for the identification of wood species in art and cultural heritage collections.

The project is also investigating the compatibility of the US Fish and Wildlife technique with the Smithsonian's own instrumentation to determine how easily this technique can be transferred to facilities with slightly different capabilities. This comparison demonstrates how useful the database of DART spectra for wood species managed by US Fish and Wildlife may be for analysis done in other contexts. The larger goal of this project is to contribute to the database of DART spectra of known woods, which is still being developed, and which has the potential to be a valuable resource not only for cultural heritage research and preservation but also for researchers in other fields such as plant biology, ecological conservation, and the protection of endangered species.



Thanks to AIC for having me here.

I am grateful to be standing on Dish with One Spoon territory right now. This is land shared under treaty by Haudenoshaunee of the Six Nations, Anishinaabe and Huron Wendat peoples. These peoples shared the land for generations before European settlers came here and called it Toronto, Canada. I want to acknowledge that settlers like myself have, too often, not been good treaty partners on this land, and that it is time to be better.

I also want to acknowledge the many Indigenous cultures who created the art in our museum, the Smithsonian National Museum of African Art. I want to remind us of the United Nations Declaration on the Rights of Indigenous People, which asserts that: "Indigenous peoples have the

right to maintain, control, protect and develop their cultural heritage, traditional knowledge and traditional cultural expressions." As we care for art and historical objects from these cultures and communities, I believe we should strive to account for the perspectives of those who created them.

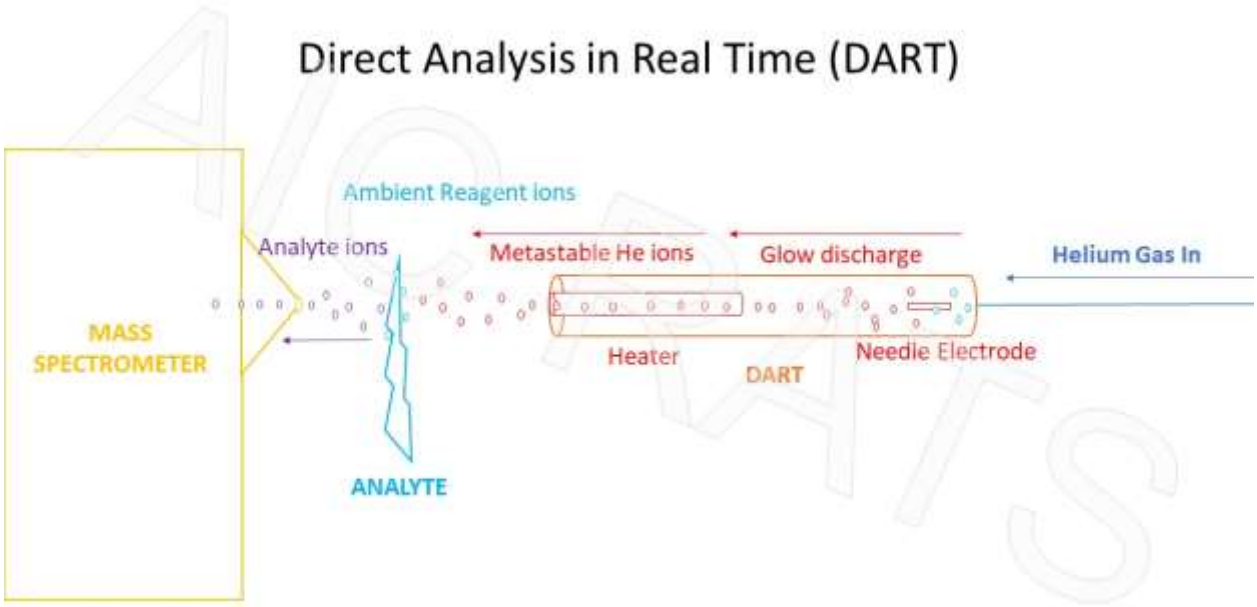
In the field of African Art Conservation, understanding which species of wood was used to construct an artwork can enrich our understanding of it; it may help us develop a provenance for a work of art, connect it to a particular cultural community, or help researchers understand the symbology of the work and its creators in relation to the natural world.

In the field of African ecological conservation, rapid and accurate identification of wood species can help protect endangered trees and forests listed under international conventions such as CITES, aiding in the enforcement of treaty regulations and in supply-chain tracking.

Photos: Parisladouce.com (Dec. 2019)

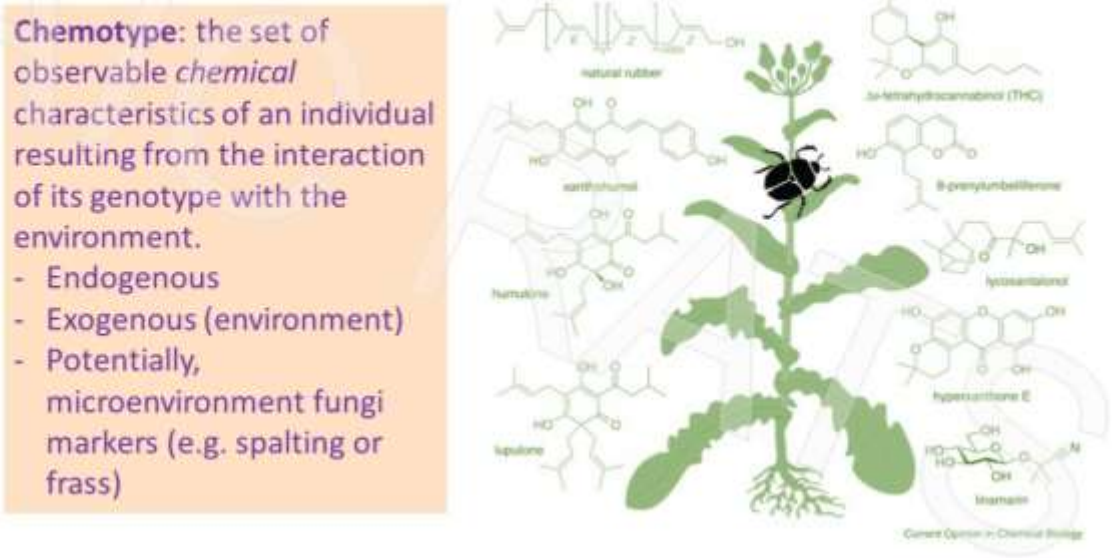
These two conservation fields interconnect as museums must comply with increasingly strict regulations on the international transport of goods made from endangered plant species. A reliable method for species identification of the woods used to make art will not only help to protect

art objects when they travel, making them less likely to be confiscated by customs officials, but will also help to protect African forests.



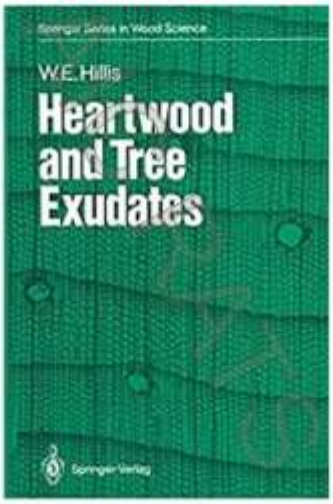
Direct Analysis in Real Time, or DART, an ambient ionization technique coupled with mass spectrometry, distinguishes species by looking at their phytochemistry rather than their anatomy. This technique works by desorbing infinitesimal amounts of material from the surface of a sample. This material is then reacted with metastable ions that protonate, ammoniate or directly ionize it. Analyte ions are then transferred to a mass spectrometer, producing a series of spectra which are then compared to spectra of known members of botanical taxa.

DART, in combination with a Time of Flight Mass Spectrometer, has been used, for example, to successfully differentiate between red and white Oak (*quercus*), various species of *Dalbergia* (rosewood) and *Swietenia* (mahogany), and wild versus cultivated Agarwood. This technique is currently used by the forensics lab at US Fish and Wildlife on a day-to-day basis as a law enforcement tool in their fight against the trade in endangered plant species.



When used for wood identification, the DART technique relies on an analysis of the tree's chemotype, the set of observable chemical characteristics of an individual that results from the interaction of its genotype with the environment. The chemistry of heartwood is a result of products left over from the natural growth of a tree and the events that have occurred in its life. For example, a tree may produce chemicals in response to an insect attack, and these small molecules are left behind in the secondary tissue as it grows.

Hillis, W. E., *Heartwood and Tree Exudates.* Springer-Verlag: Berlin, 1987; Vol. 4.



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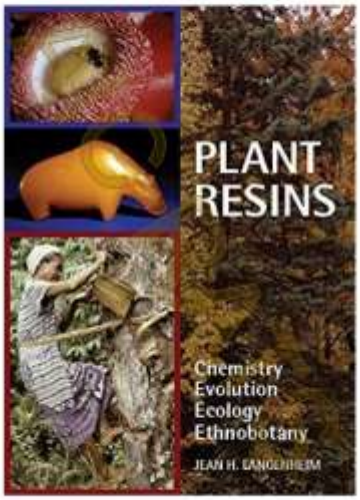


These molecules, sometimes called exudates or extractives, may be gums, resins, or other phytochemicals produced by the tree during its lifetime as it responds to its environment and other organisms in a variety of ways. It is these small molecules, rather than the lignocellulose matrix itself, that are useful for identifying the species of a tree.

Heartwood is used for identification rather than sapwood, which has a much higher content of starches and a lower content of these smaller and more distinctive molecules. Heartwood and sapwood of the same tree will tend to have very different chemistry, so it is important that heartwood be compared to heartwood.

Historic and Ancient Woods Identified by DART-MS at the Fish and Wildlife Forensic Lab

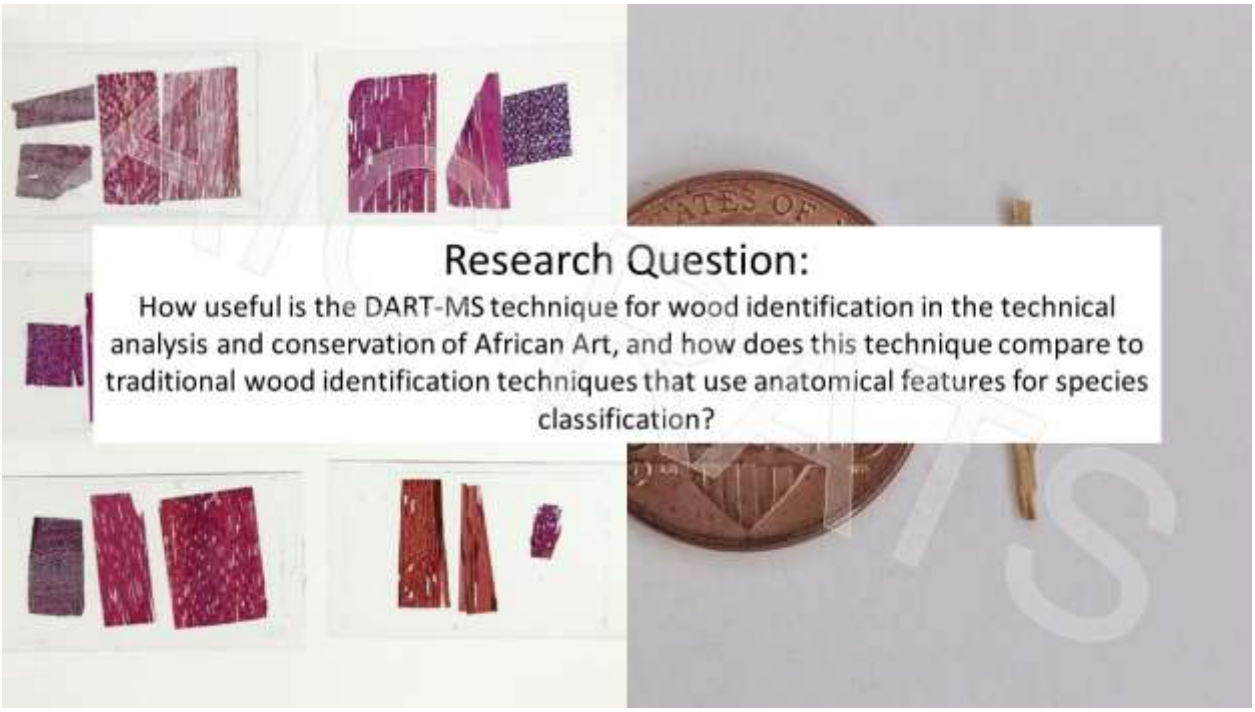
Species	Source	Years BP
Swietenia mahagoni	Sunken torpedo boat, Florida, US	~ 50**
Dalbergia spp.	Madagascar	~ 220*
Swietenia mahagoni	High chest, Princeton Art Museum, US	~ 245**
Aquilaria spp.	Imperial Vault of Heaven, China	~ 262**
Quercus faginea	Sunken Spanish galleon, Portugal	> 500**
Agathis australis	Kauri wood, New Zealand	> 50,000*

* Radiocarbon dating
** Historical context

Research by: Ed Espinoza & Pam McClure, Office of Law Enforcement Fish & Wildlife Forensic Laboratory (Ashland, OR)
http://forseadiscovery.eu/sites/default/files/attachments/documents/poster_fsd.pdf

Environmental factors, age, life events, and position in the tree all affect the chemistry of wood but there is a discernible chemotype that distinguishes the heartwood of many or most species from one another. While intra-species and even individual variation does certainly occur and may one day be used to trace a tree to its geographic origin, interspecies variation is greater than either intra-species or individual variation. Even though each tree has its own unique chemotype, this unique chemical signature will still be more similar to signatures from other trees in the same species than to that from trees of other species.

As wood ages and degrades after the tree has been cut down, its chemistry also changes slightly, but again, not enough to prevent species identification. This consistency in wood species chemotypes over long periods of time means this technique can be extremely useful in an art conservation context.



The research we have been doing at the Smithsonian National Museum of African Art, in collaboration with the Smithsonian Museum Conservation Institute, the Botany Lab at the National Museum of Natural History, and the US Fish and Wildlife Forensic Laboratory, asks: How useful is the DART-MS technique for wood identification in the technical analysis and conservation of African Art, and how does this technique compare to traditional wood identification techniques that use anatomical features for species classification?

Example of a Hand Sample Block from the
Jane Smith (JS) Collection of West African Woods

To answer this question, I have been investigating a set of 59 wood samples from West Africa that were donated to the conservation lab at the National Museum of African Art in the 1990's by a woman named Jane Smith. The wood samples in the Jane Smith collection are what is often referred to as "hand samples;" they are approximately a half inch thick, 3 inches wide and six inches long, are labelled with their country of origin (Ghana), the local name of the species, the Latin name of the species, and a short description of the wood's physical properties and ways it is used locally and commercially. The sample blocks did not have botanical vouchers accompanying them, so my goal has been to use both traditional anatomy and DART-Mass Spectrometry on all of these sample blocks to confirm (or disconfirm) their identity.

I conducted the microscopic analysis of my samples at the Botany Lab at Smithsonian's National Museum of Natural History, under the supervision of Stan Yankowski, who taught me the method he uses in that lab for making wood slides. Part of my goal here was to make a reference collection of West African Wood slides for the conservation lab, so I used methods that make larger, clearer slides than would normally be made out of samples taken from art objects.

First, I cut 1cm cubes from the hand samples. This is considered by botanists to be the minimum size of sample likely to capture the wide range of anatomical features needed for wood identification.

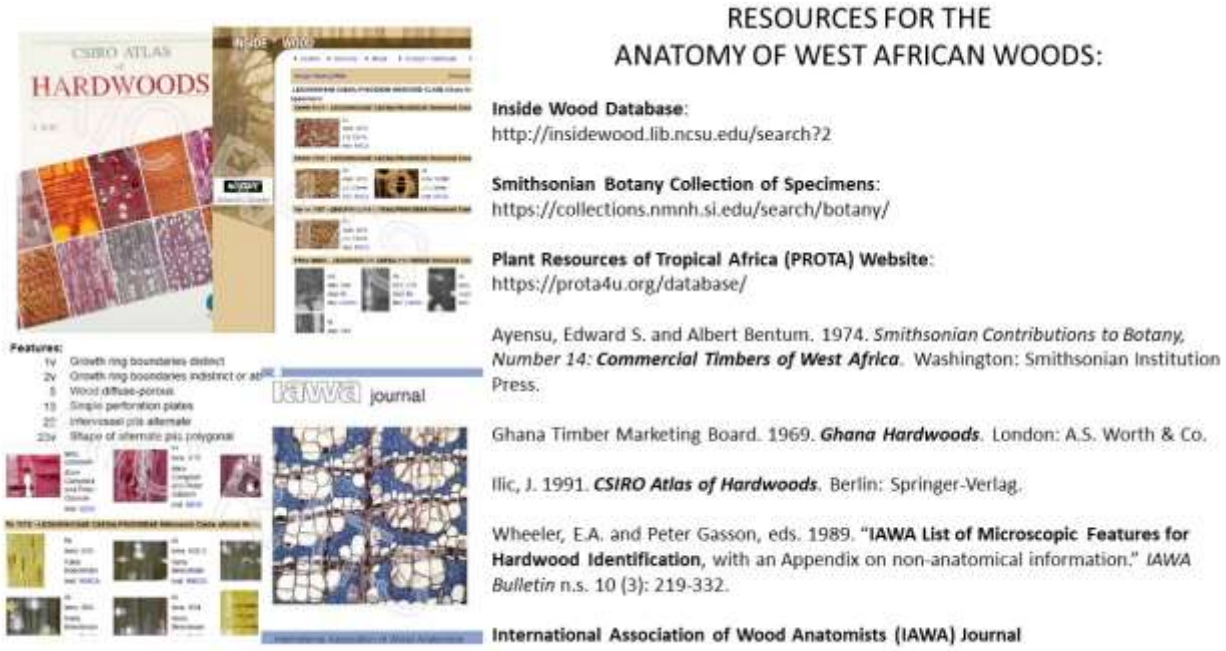
To soften my 1cm cubed blocks, I soaked the cubes in boiling water until they sank and then stored the cubes in a 1:1 solution of ethanol and glycerin to ensure they did not dry out. I cut transverse, tangential and radial sections on this Reichert Sliding microtome.

Once cut, I stained my sections with SafraBlau, a solution of 45 ml Astra Blue in 50% ethanol and 5 ml of 1% Safranin O in 50% ethanol, and then dried them in a series of successive baths, moving from 50% Ethanol through to 100% Ethanol, then Ethanol and Xylene, then two baths of xylene alone.

From the xylene bath I mounted all three sections on 1x3 slides with Thermo Scientific™ Shandon™ Synthetic Mountant, an archival mounting medium similar in composition to Paraloid B-48. I let my slides cure for several days, usually under a small amount of weight.

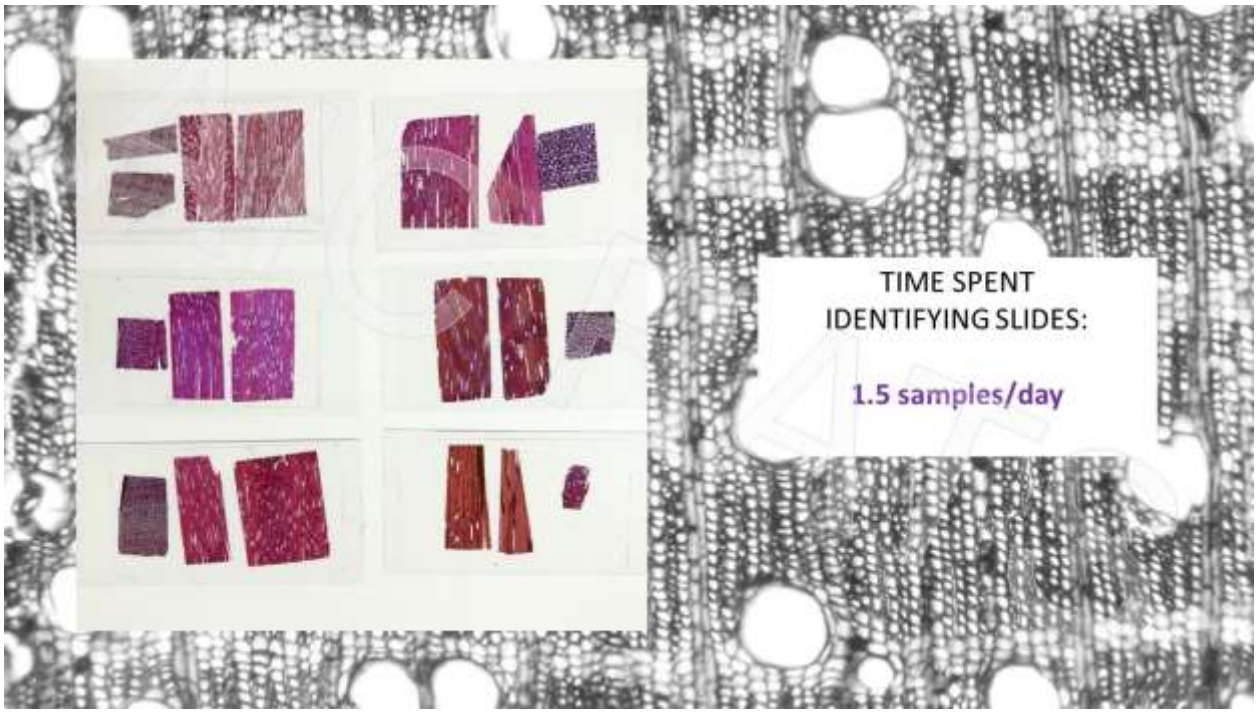
I made three slides for each hand sample; in general, I was able to do sectioning and mounting for four samples in three days.

Once mounted, I Identified the wood sections by examination under a polarized light microscope at the Botany lab. Sections were examined at 10X, 16X and 40X magnification and important features were photographed.



I compared the cellular anatomy of my sections to descriptions on the *Insidewood* database, which contains descriptions of 7,482 modern woods and 46,905 images of modern woods, many of which are micrographs of wood sections. The descriptions on *Insidewood* are coded and searchable using the International Association for Wood Anatomist's *List of Microscopic Features for Hardwood Identification* (*https://www.iawa-website.org/uploads/soft/Abstracts/IAWA%20list%20of%20microscopic%20features%20for%20hardwood%20identification.pdf*).

I supplemented the descriptions and images available on *Insidewood* with other literature as necessary, including the examination of micrographs in the Commonwealth Scientific and Industrial Research Organisation's *Atlas of Hardwoods*, descriptions and micrographs in Edward Ayensu and Albert Bentam's *Commercial Timbers of West Africa*, the Plant Resources of Tropical Africa website and various botanical articles describing individual species as needed. When possible, I also compared my sections to knowns available in the Botany Lab's vast collection of wood slides.



Identification of my slides took me between four and eight hours for each sample, depending on the species, the availability of knowns, similarity to other species, and coverage in the literature.

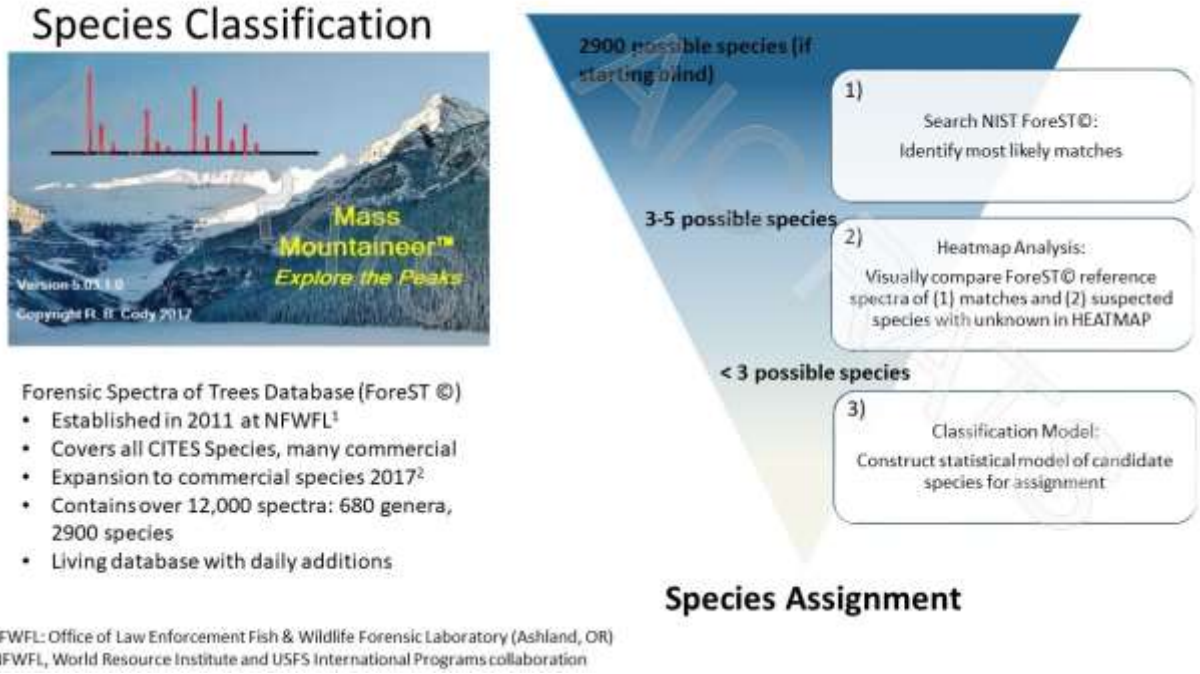
Sampling, sample preparation, and data acquisition for the DART is significantly less time consuming and complex. A small splinter of wood, about half the size of a toothpick, is all the sample that is needed for this procedure.

Our analysis was performed using a Commercial DART 100 operated by SVP controller, on a custom mount developed by Asher Newsome at MCI. Analyte ions were conducted through a differentially-pumped Vapur interface with a 40mm uncoated stainless steel inlet to a high resolution Mass Spectrometer, the LTQ Orbitrap Velos. Preliminary tests to determine optimal speed for the supplemental pump and optimal internal heating temperatures were performed before data collection began. We found the greatest abundance of signal was recorded with a total suction of 2.5L/minute and the internal heater set to 300 degrees Celsius. Data was collected in a scan range of 50-800.

Wood splinters were held in forceps clamped to a moving stage that Asher has developed to be able to introduce samples to the DART stream in a controlled way.

Samples were held in the DART stream for an average of about one minute, with time in the Helium stream dependent on observed signal output, and then withdrawn.

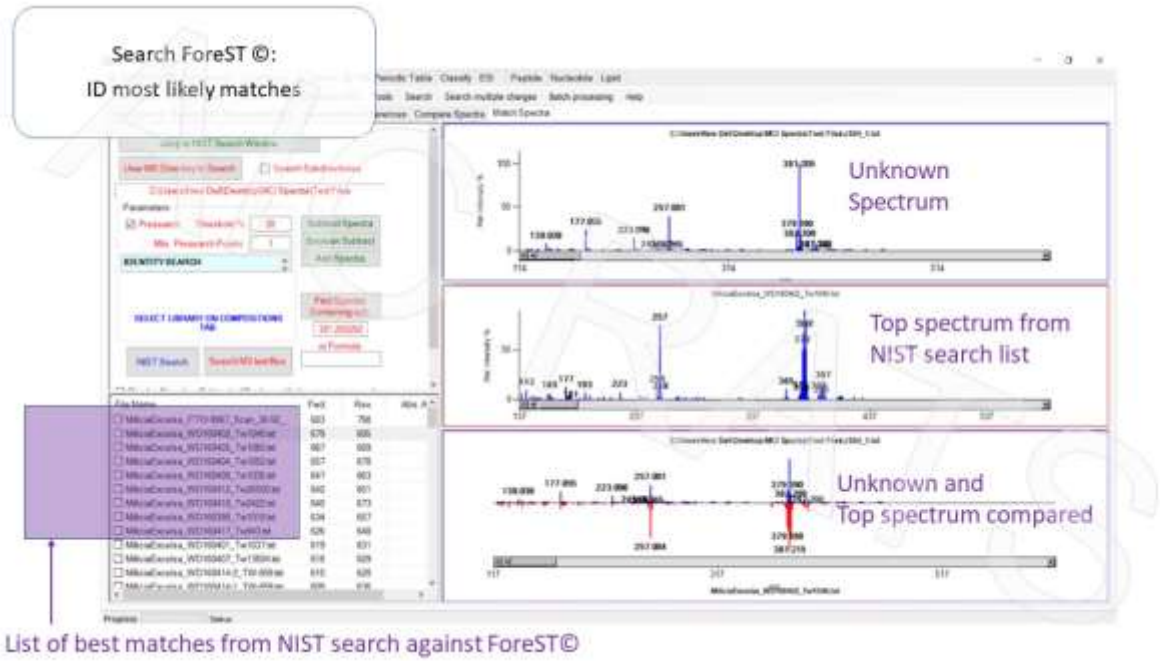
I was able to acquire data for all 59 samples in two days at MCI.



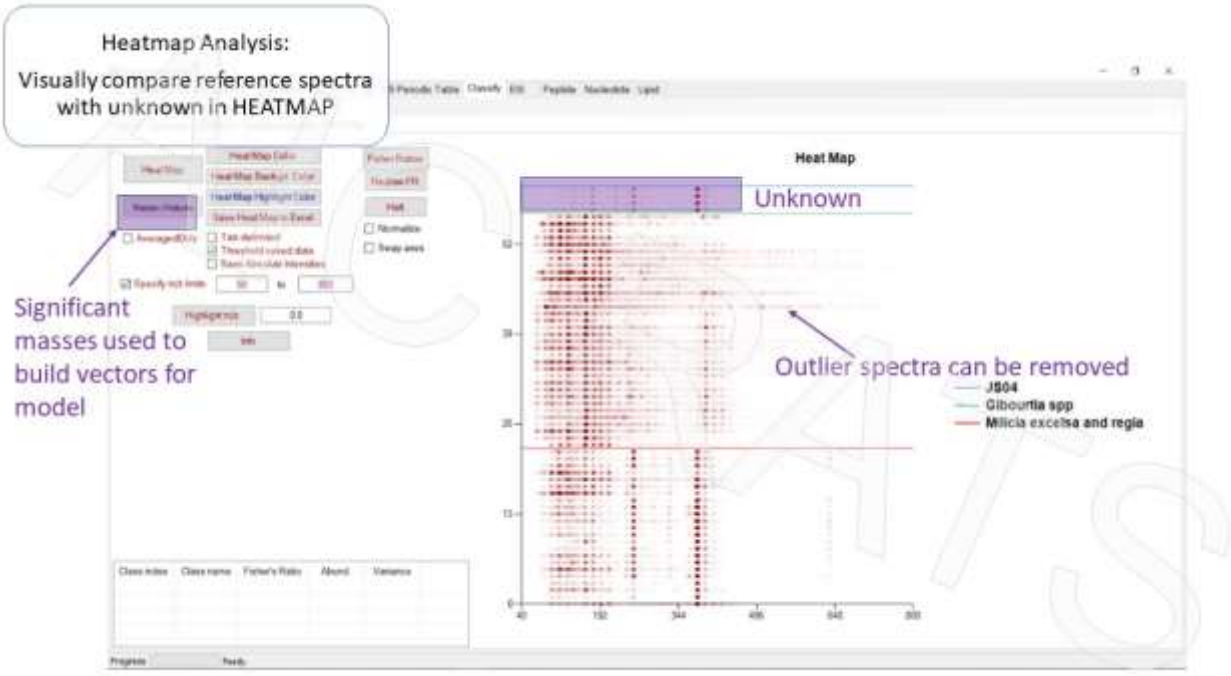
Analysis of the data was more complex, and required training on Mass Mountaineer, a software developed for examining, interpreting, and classifying mass spectra imported as text files. Cady Lancaster helped guide me through the process she and her colleagues have developed for the identification of wood species using this software to compare unknowns to spectra in a wood database. This database, called the Forensic Spectra of Trees, or ForeST, database, was compiled by Cady and Ed Espinoza at Fish and Wildlife from vouchered wood samples from *xylaria* all over the world. The database currently contains over 12,000 spectra representing 680 genera and 2900 species, but it is continuously growing, with new spectra added daily.

It took me about a week of everyday practice to feel comfortable using the Mass Mountaineer software with the ForeST database.

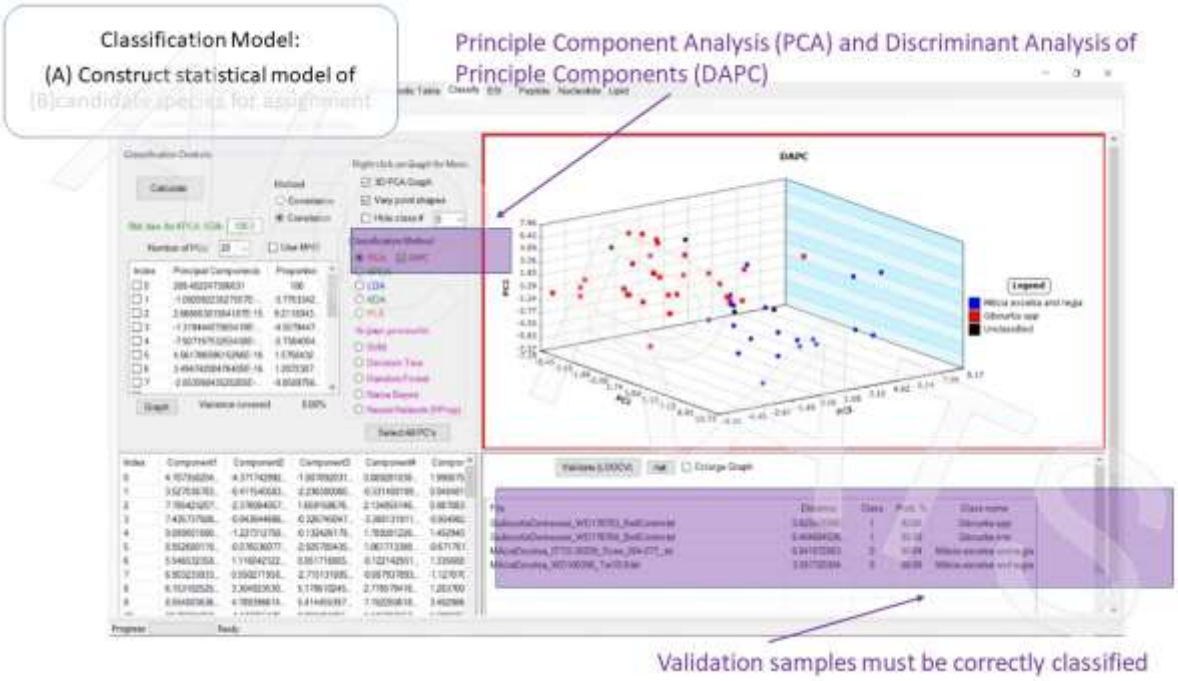
Identification was accomplished in three steps. All three steps must concur for an identification to be considered valid.



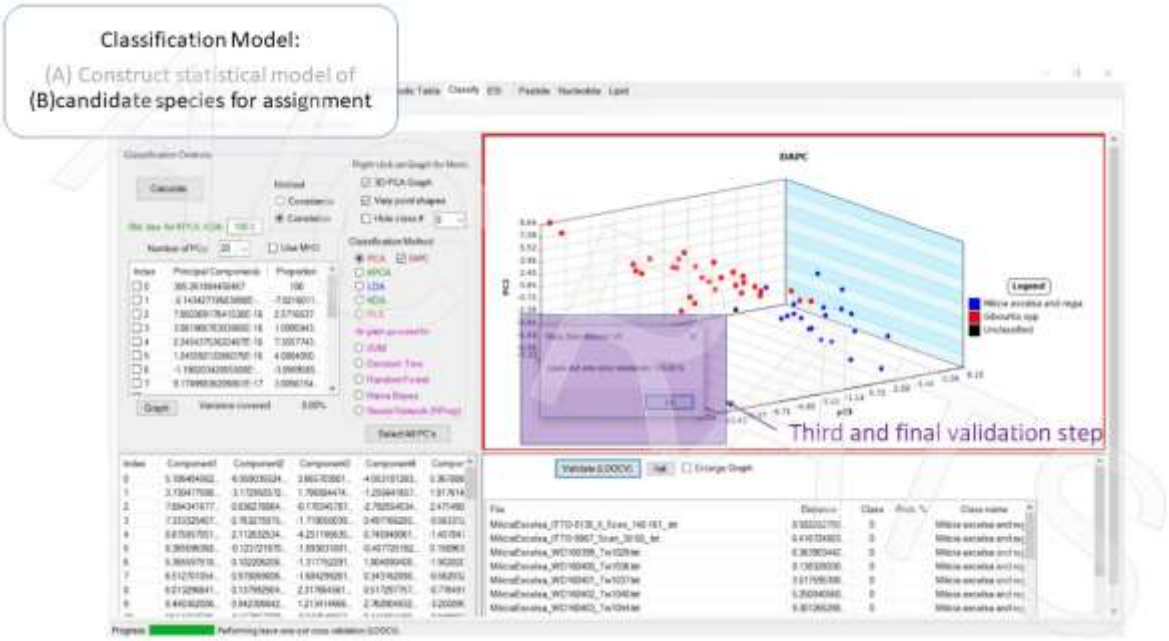
First, the unknown spectra were compared to a NIST-formatted version of the ForeST Database, which applies an algorithm to search for spectra similar or identical to the unknown. This search must provide a meaningful result- if it did not, an identification was not possible and the process stopped there. If there was a pattern, the most likely matches from this list were used for the second step.



In step two, possible species matches from the list were entered into a heatmap along with the unknown for a visual comparison. Outlier or very noisy spectra were removed from the heatmap to clean it up. The known was then removed, and with it three spectra chosen at random from each group to be used in the third step as validation and test spectra.



In the third and final step, significant masses from the heatmap were used as vectors to build a model capable of categorizing these spectra into their known species. This model was built using Principle Component Analysis and then Discriminant Analysis of Principle Components on a training set derived from the heatmap of knowns. Principle Component Analysis is a machine learning technique that can determine if there are patterns in the mass spectra that enable them to be separated into groups. It is unsupervised, meaning the categories are not provided in advance. Discriminant Analysis of Principle Components enables the categories created during Principle Component Analysis to be separated more clearly. Known spectra removed in the second step, that the model had never seen, were introduced first to validate the model and then to test it.

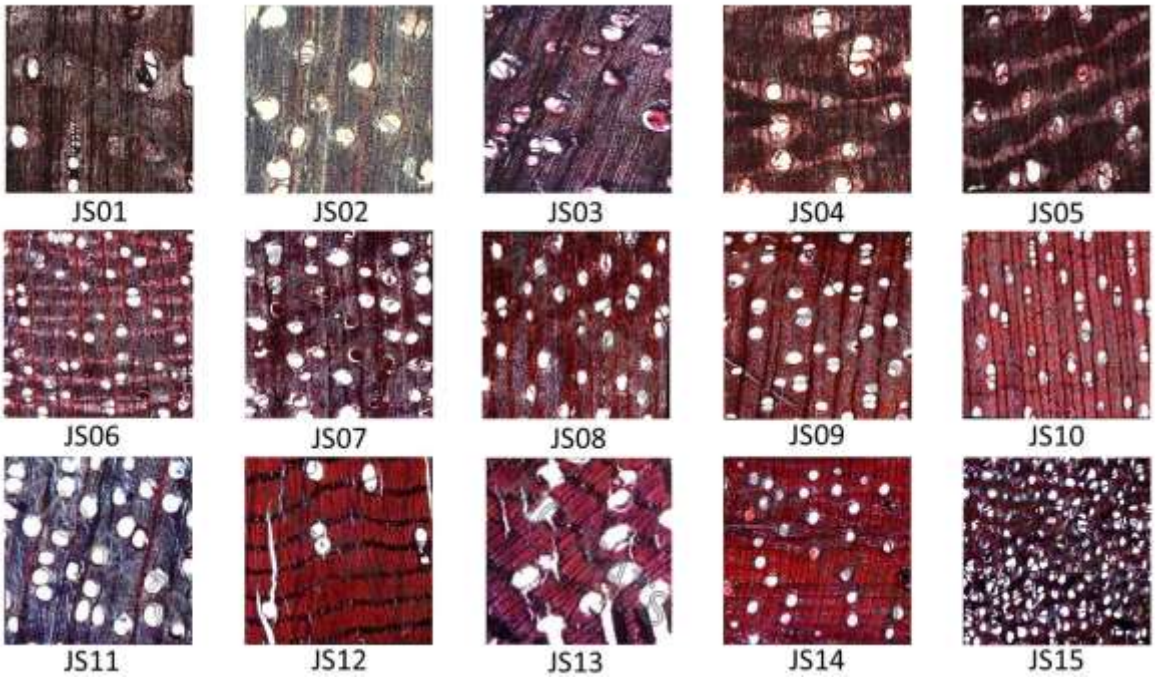


Leave-One-Out-Cross-Validation, in which the model is further validated by removing each individual member and re-classifying it, was performed as a final step before the unknown was introduced.

The time required for analysis of spectra depended on the wood analyzed, how many examples of the suspected species were in the database, and how easy the likely species were to separate, but I could usually complete a successful Identification in 45 minutes to an hour. More

experienced users of Mass Mountaineer for wood identification have told me they are often able to do identifications in about 15 minutes.

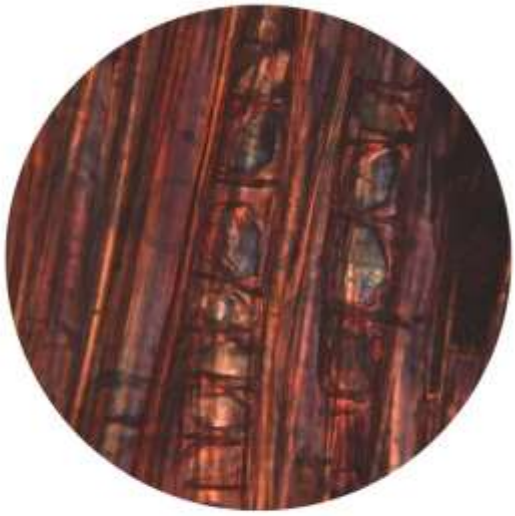
Because we have been out of the lab, my results are still preliminary, but I would like to share what I've found so far and to illustrate some interesting examples.



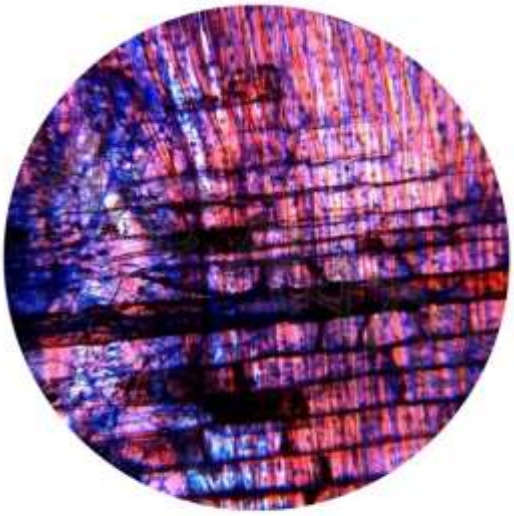
I have only made sections of 30 of my samples, which is 90 slides in total, and to examine the anatomy of 20 of these. The anatomy of all the sections I have made so far is consistent with label species- in other words, none of my results so far dramatically contradict what is on the label.

However, in several cases, my sources on wood anatomy were contradictory or information was missing, and it was not always clear which source to trust.

Botanical systems of taxonomy are not static; species previously separated are often found to be synonymous with one another and so collapsed into one, or split up when intraspecies variation appears to indicate that what was thought to be one species is in fact two. Botanists are continually revising their categories. In many cases, species are clearly distinguished by their anatomy, but in others it can be difficult to get an undisputed description. Even the world's most expert wood anatomists will rarely claim to be able to identify wood to species level with certainty, and I also cannot claim to be able to do so.



Crystals in axial parenchyma of JS01
(*Albizia* sp.)

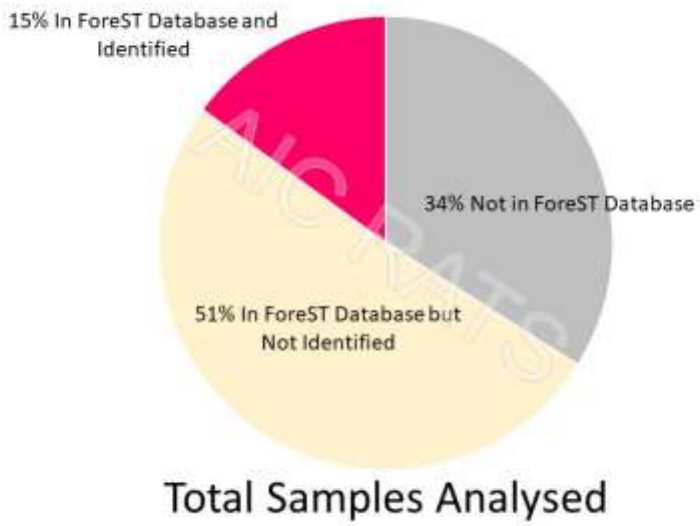


Tanniferous tube in ray cell of JS17
(*Pychnanthus angolensis*)

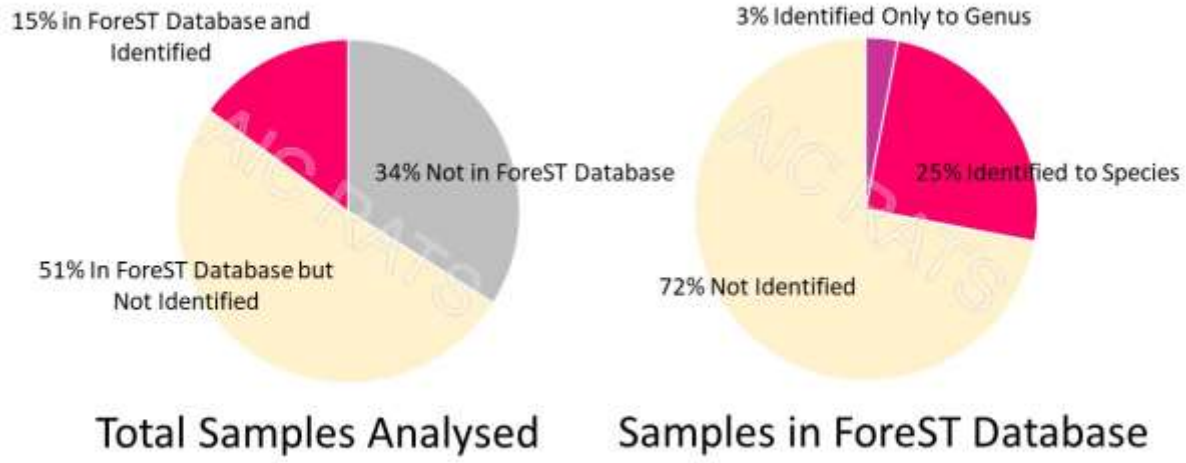
In many instances, there were distinguishing features that I could not see in my sections. Often, the presence of features such as crystals, lactifers or tanniferous tubes, can be used to confirm a species' identity, but their absence does not disconfirm it. This was the case for several of my sections, though these features were visible in others. There were also borderline cases, where slight variations from the anatomical description meant that my identification was less certain than I would have liked.

Splinters darkened or scorched on the upper end, where they entered the DART stream

I was able to analyze DART spectra from all 59 samples and compare them against the ForeST database. Many of the splinters emitted a distinct aroma when they entered the DART stream. In some cases, the splinter appeared slightly darkened or scorched around the area that had entered the stream. This effect appeared to depend on the composition of the wood rather than the amount of time the splinter was left in the stream.

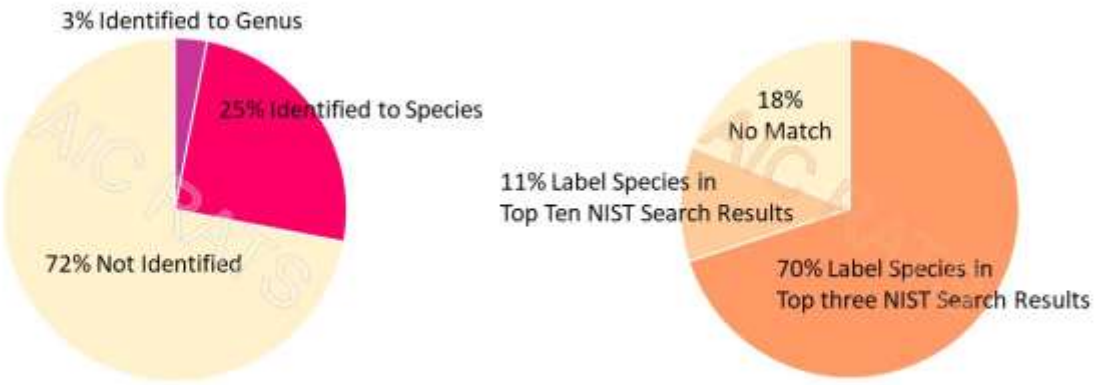


I was only able to use DART-MS to confidently identify 9 samples to genus level and 8 of these to species level- only a 15% and 13% success rate respectively. However- 27 of my samples are labelled with a genus and species that is represented by less than 10 entries in the forest database- 13 of these are not represented at all.



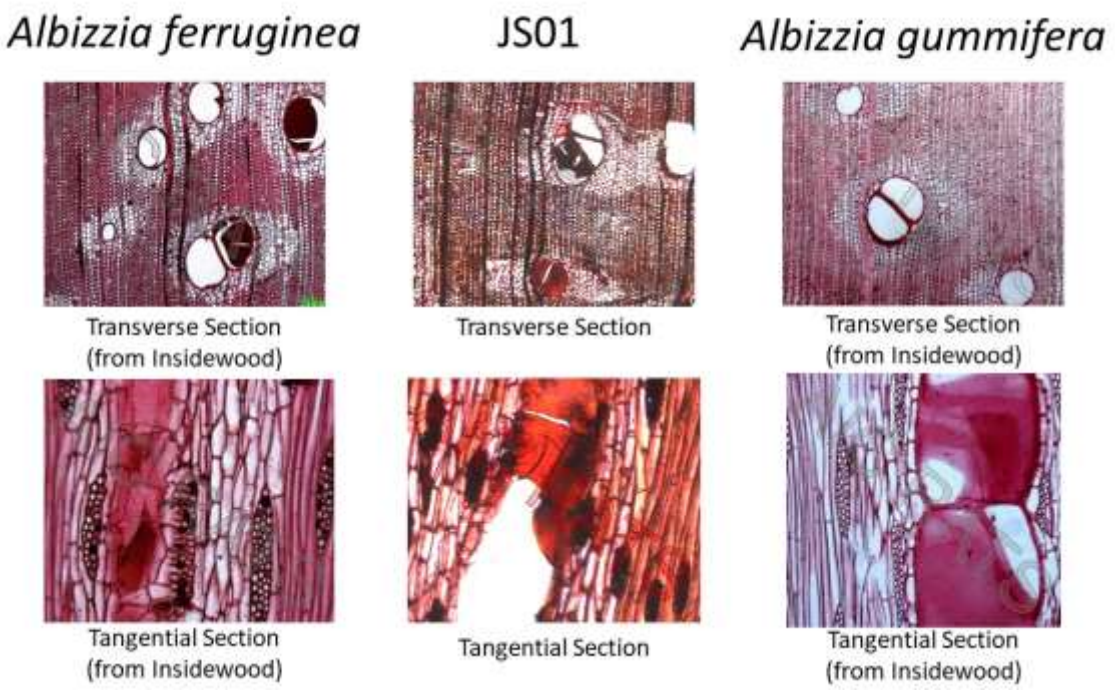
Given this, my success rate among species that are in the database is slightly better, at 28% for genus level identification and 25% for species level identification. Notably, one of the easiest

species to identify was JS15, *Pericopsis elata*, or *Afromorsia*. This species is the most endangered out of all the species represented in my collection.



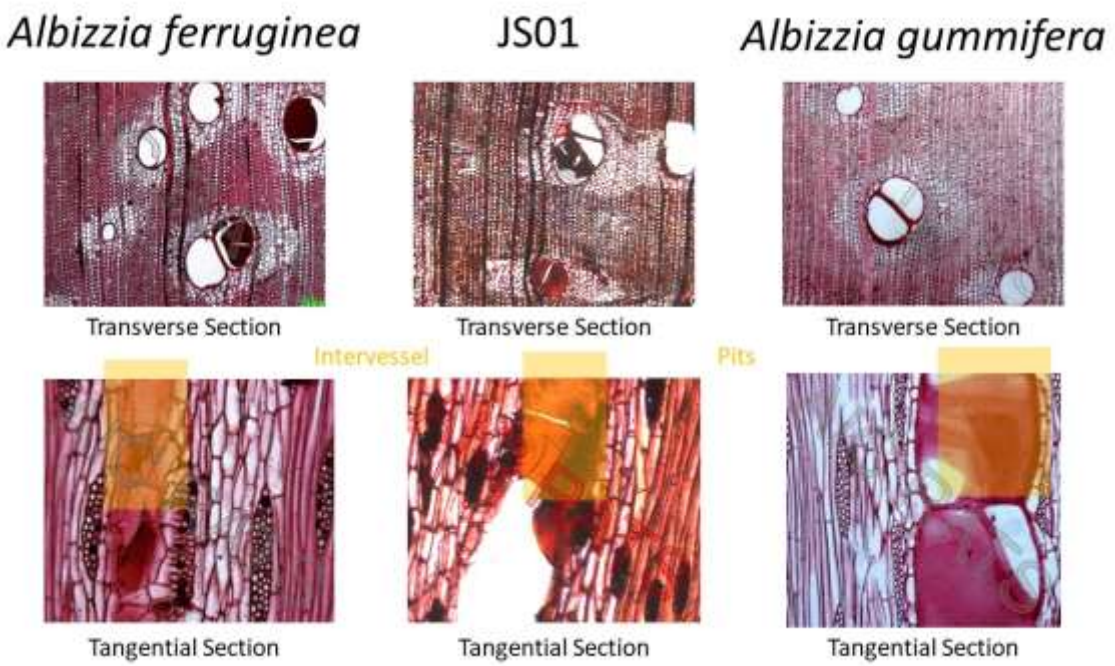
Samples in ForeST Database

In many cases, the labelled genus appeared in the NIST search stage of analysis but not in significant enough number to enable me to make a model. In 26 cases, the label genus appeared among the top ten matches in the NIST search, and in 22 cases the label genus appeared among the top three. The DART results contradicted the labelled genus only once, when I was able to identify a sample, JS27, labelled as Ongokea Gore, as chemotypically a member of the *Afzelia* genus.

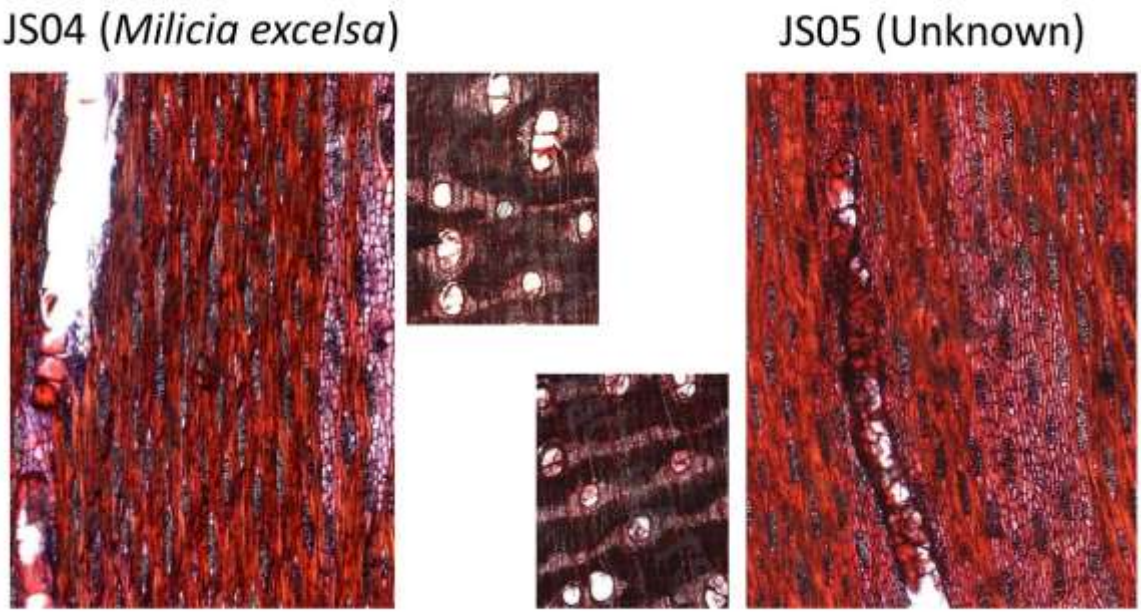


DART results were able to clarify discrepancies in the anatomy of some samples. These examples demonstrate the way in which DART can be a helpful compliment to anatomy.

For instance, JS01, which was labelled *Albizia ferruginea*, was identified by DART as *Albizia gummifera*.

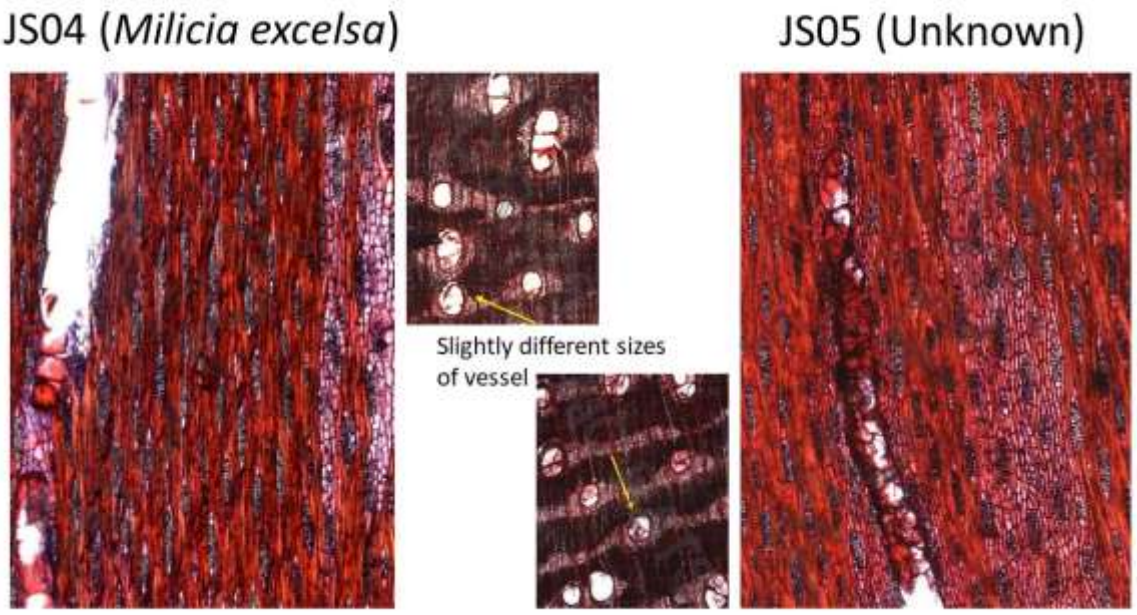


Albizia ferruginea and *Albizia gummifera* are anatomically very similar. Intervessel pits in *ferruginea* are medium in size, but those of *gummifera* tend to be smaller, almost minute. In my notes on the anatomy of my section of JS01, I had noted that the intervessel pits appeared smaller than those in my known, but this had not seemed significant enough for me to question my identification. DART analysis helped me to focus on a comparison of *ferruginea* and *gummifera*, and I was able to make this somewhat subtle distinction between the two and then confirm it by revisiting the anatomy.

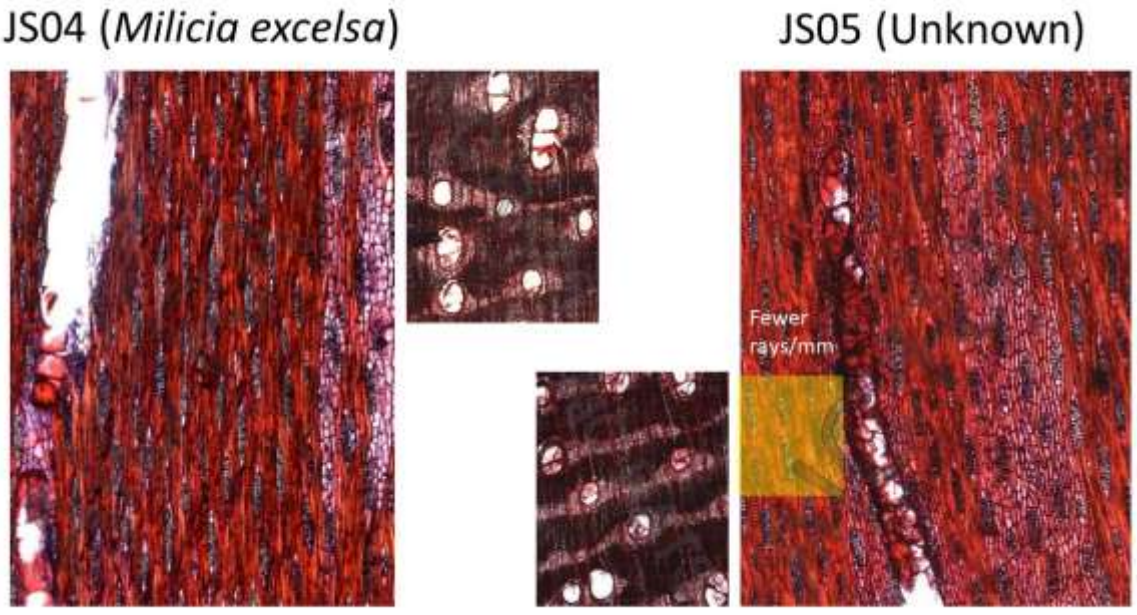


In most of the cases where I was able to arrive at an identification with DART-MS, this identification confirmed the label on the sample and the anatomy. This was the case with JS04, labelled *Milicia excelsa* (formerly known as *Chlorophora excelsa*), known locally as Iroko or, in Ghana, as Odum. Both anatomy and DART strongly confirm that JS04 is *Milicia excelsa*.

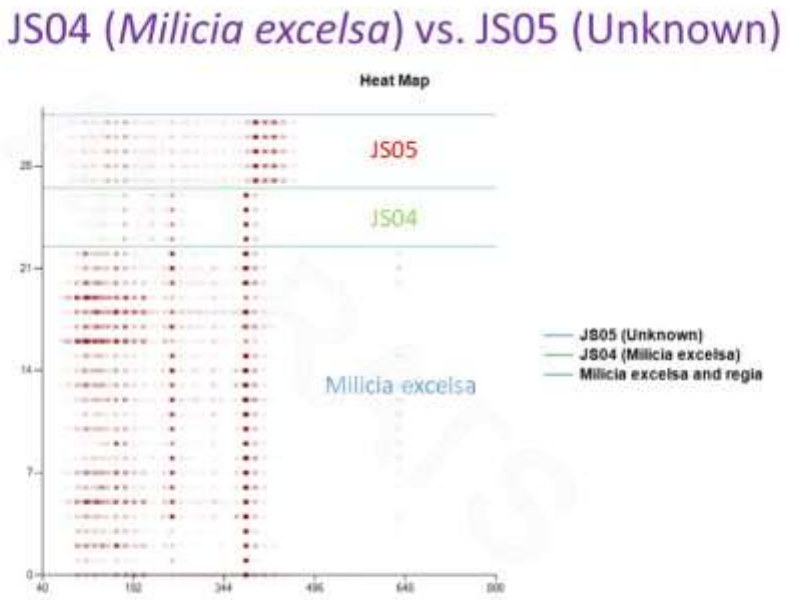
JS05, however, was also labelled *Milicia excelsa*. When I first examined it, I noticed it seemed more dense and oily than JS04. Indeed, the specific gravity of JS05 was higher than the specific gravity of JS04, although still within the range for *Milicia excelsa*. The cellular anatomy of JS05 was also basically consistent with *Milicia excelsa*,



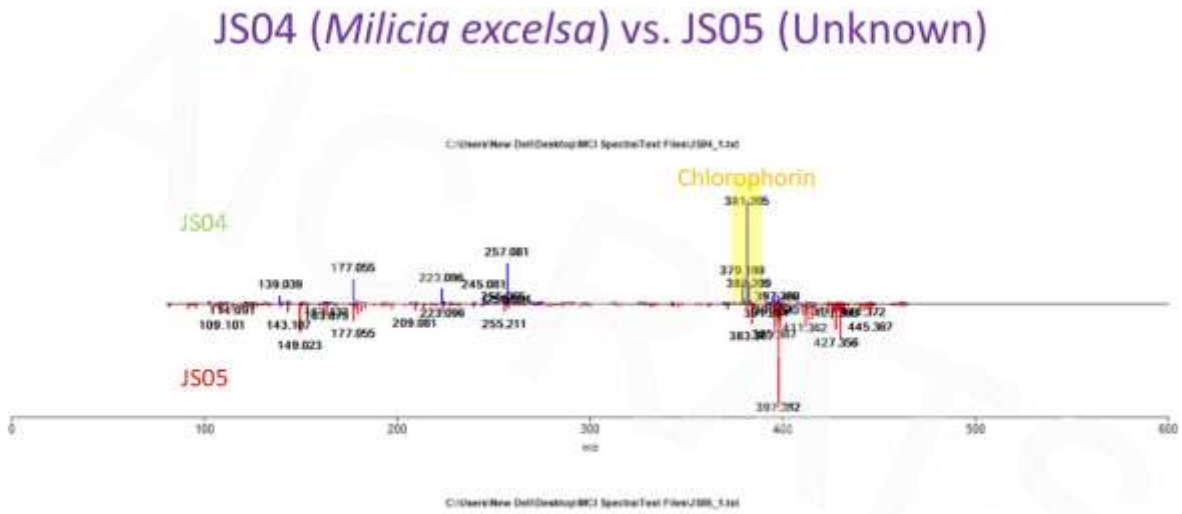
though the vessels were on the very small end for that species



and there were somewhat fewer rays per millimeter than would normally be expected for this species. Lactifers, which appear in *Milicia excelsa*, could not be found in my section, but, as with crystals, the absence of lactifers doesn't rule anything out. There was nothing in the anatomy to tell me this was not *Milicia excelsa*, but I had a feeling it was not because of discrepancies in the gross morphology.



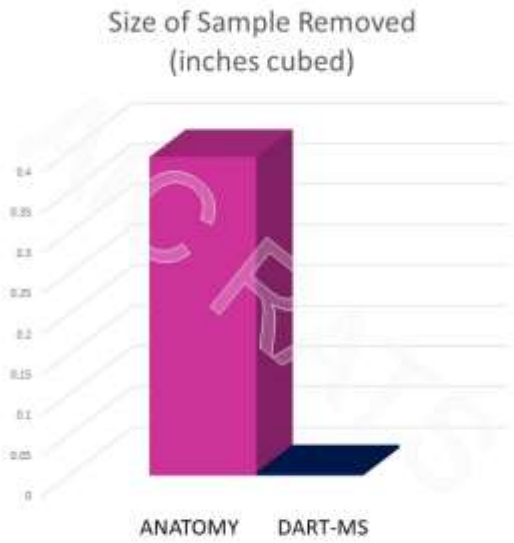
DART analysis confirmed my suspicion. While DART analysis could not identify JS05, it did reveal that JS04 and JS05 are likely not the same species. When compared, the spectra for JS04 and JS05 are quite different, and a heat map comparing the two of them to spectra of known samples of *Milicia excelsa* shows that JS04 is a much better match.



The compound chlorophorin ($C_{24}H_{28}O_4$), which is characteristic of *Milicia* and has a molecular weight of 380.2, can be found in its protonated form (+1) in high relative abundance in the spectra

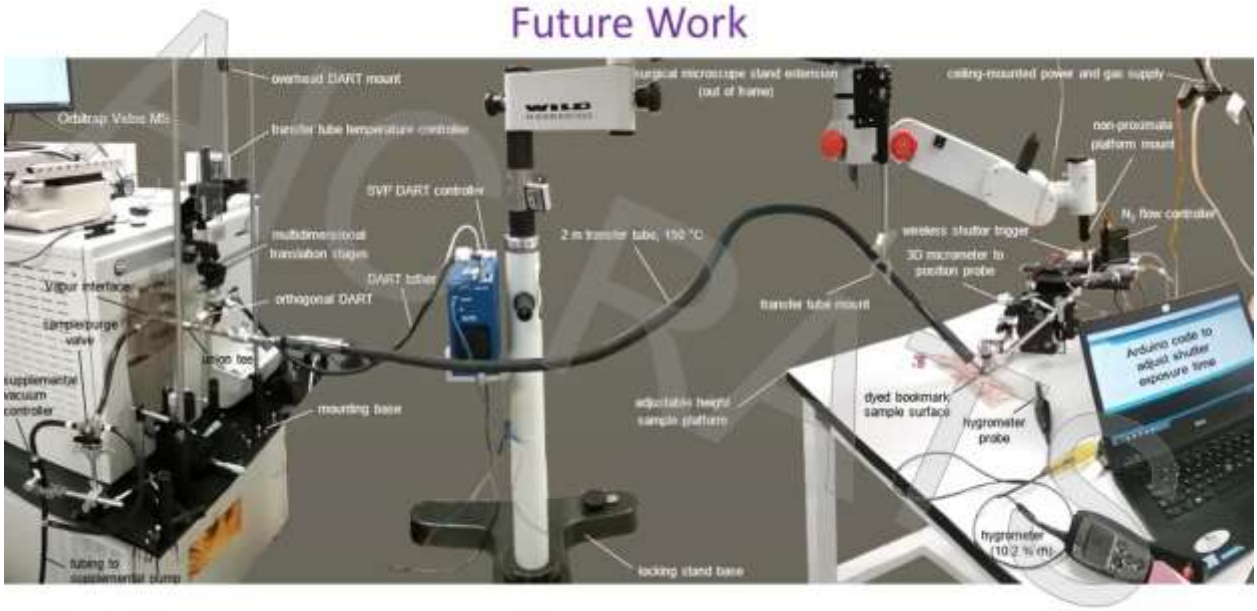
for JS04 but is not present at all in the spectra for JS05. JS04 and JS05 are anatomical lookalikes, but they are not chemical lookalikes. JS05 is not *Milicia excelsa*.

To sum up my findings so far: Reliable species identification of African woods using cellular anatomy requires a huge sample in Art Conservation terms, many hours of work, and significant expertise gained from years of practice and study. Even the world's foremost experts in wood anatomy will hesitate to make identifications down to species level and will likely only be able to identify to genus level. Even then, the most experienced wood anatomists will hesitate to confirm a species identification without any caveats.



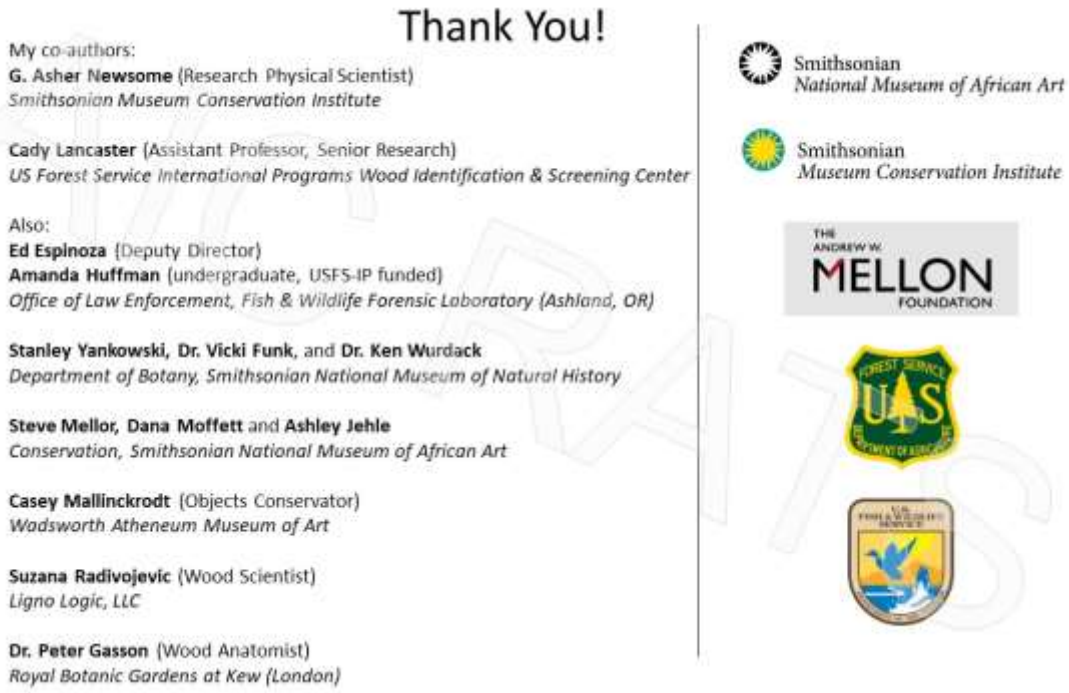
Reliable species identification of African woods using DART-Mass Spectrometry requires a much smaller sample and much less time, and it is a comparatively easier process to learn. While DART-Mass Spectrometry of these African Wood samples yielded a low number of positive identifications, the identifications it did provide may be more reliable and specific than those arrived at through examination of cellular anatomy. The most satisfying results, however, were achieved when the complementarity of these two approaches was exploited.

DART-MS has great potential to aid in the identification of African Woods, especially if the mass fingerprinting approach can be supplemented by the identification of specific ions represented in a spectra, and by matching those to what is known to be characteristic of particular species, as in the case of my *Milicia excelsa* sample.



Graphic: G. Asher Newsome

In our future work, we intend to more systematically compare results from the JEOL Time of Flight Spectrometer to the results we have obtained on the Orbitrap at MCI, to see if these systems can both use the ForeST database with equal success to identify West African woods. We are also planning to build on Asher Newsome's previous work with non-proximate sampling to see if we can use DART-MS to analyze the wood on complete objects, eliminating the need for samples altogether. Ultimately, the plan is to use these non-destructive methods on large African sculptures from the National Museum of African Art to see if we are able to identify the wood they are made from without taking any sample or leaving any mark at all.



Please feel free to contact me through the AIC directory, or at campbellsuch@gmail.com with any questions.

Evaluation of Angle-Resolved X-Ray Fluorescence for Stratigraphy Elucidation in Paintings

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Keywords: X-Ray Fluorescence, Paintings, Stratigraphy

Extended Abstract

X-Ray Fluorescence (XRF) is an established non-destructive technique utilized in the identification of pigments that contribute to conservation and technical art history research efforts. Most paintings and other polychrome works of art, exhibit a stratigraphic structure. For example, paintings typically consist of a support, a sizing layer, ground layer, the pigment layer, and the glaze of varnish layer. Consequently, the XRF spectrum of a specific area in a painting will include peaks associated with the elemental composition of all the constituent layers, as the primary x-rays will penetrate all of the layers, yielding the corresponding aggregate secondary radiation. Although information gathered by the superficial visual inspection may be helpful in the interpretation of the spectrum, in many cases additional information is required to positively elucidate the stratigraphic composition of the sampled area. We report here on the successful application of a simple variation in the acquisition of XRF data incorporating spectra acquired at different angles to tackle this problem. The intensity of the XRF signal for a constituent element displays different behavior depending on its stratigraphic position, i.e. whether it is in a superficial upper- or under- layer. This is an expected result due to the difference in the radiation absorption introduced by the layer geometry.[1] The XRF setup used in our study consisted of a *Mini-X-Ray* source with an Ag anode and an *AMPTEK* 1-2-3 Spectrometer outfitted with a Si-PIN detector with a 10 μm Be window. The thickness of the window limited the detectability to elements heavier than magnesium. These components were mounted on an *AMPTEK Experimenters Kit* plate. The x-ray tube power parameters used were I = 40 μA and V = 25 kV. The angle between the source and the detector was kept constant at 45° while the angle θ between the plane containing the source and the detector and the sample was varied. This setup is shown in the inset of Figure 1, and hereon will be referred to as Angle Resolved X-Ray Fluorescence (ARXRF).

Fourteen bi-layered paint standards (with individual layer approximate thicknesses of 0.14 mm) were prepared using eight different *Liquitex Professional Heavy Body* acrylic paints on foam board supports. The paint combination of the bi-layered samples studied is shown in Table 1; manufacturer's names and the corresponding color index name codes are shown. Spectra were acquired for angles in steps of 15° from θ = 30° to 90° for the cerulean blue ($CoCr_2O_4$) over cadmium orange ($CdS_{1-x}Se_x$) bilayer sample. The corresponding sulfur K_α peaks for these spectra are shown in Figure 1. As seen there, the intensity of the S peak decreases in intensity with decreasing angle θ. This result is consistent with the longer path (with the associated increase in absorption), that the primary and secondary radiation must travel to and from the fluorescent element. In addition, spectra were also obtained at angles θ = 90° and 30° for all fourteen bi-layered samples. In all the obtained spectra the peak associated with elements in the underlayer were weaker in the spectra obtained with θ = 30° as compared to the peak obtained with θ = 90°. Conversely, in the majority of the spectra, peaks associated with elements in the upper layer, were stronger for the shallow angle, θ = 30° with respect to the intensity of the peak in spectra acquired with θ = 90°. The departures from the expected results from the application of the simple absorption model assumed, are likely due to matrix-geometry factors not considered that may be important for the particular elemental composition of the pigments in these layered samples. We tested further the proposed ARXRF technique with its application to the elucidation of the strata elemental composition in a painting by the Puerto Rican painter Francisco Oller where elements associated with the preparatory layer were identified successfully. Of particular interest was, the ability to distinguish between the lead white in the preparation layer and the zinc white in light blue regions from the ARXRF data.

ACKNOWLEDGEMENTS

This work was supported through a grant from the Institutional Funds for Research (FIPI) of the University of Puerto Rico, Rio Piedras campus. We are grateful to the University of Puerto Rico's Museo de Historia, Arte y Antropologia, Instituto de Cultura Puertorriqueña and, to the Museo de Arte de Puerto Rico for facilitating access to Francisco Oller paintings.

REFERENCE

1. X-Ray Mass Attenuation Coefficients NIST Standard Reference Database 126

DOI: https://dx.doi.org/10.18434/T4D01F

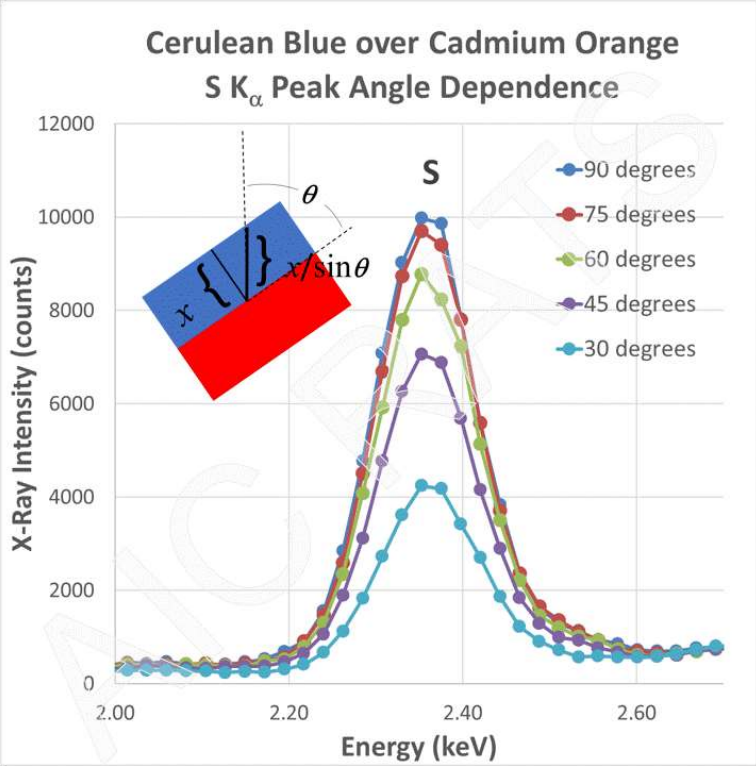

Figure 1. Angle dependence of the S K_α peak for the spectra obtained in a cerulean blue ($CoCr_2O_4$) over cadmium orange ($CdS_{1-x}Se_x$) bilayer sample

PAINT COMPOSITION	CHEMICAL COMPOSITION
cobalt blue (PB28)-cadmium red medium (PR108)	$CoAl_2O_4$- CdSe
cerulean blue (PB36)-cadmium orange (PO20)	$CoCr_2O_4$-$CdS_{1-x}Se_x$
chromium oxide green (PG17)-cerulean blue (PB36)	Cr_2O_3- $CoCr_2O_4$
titanium white (PW6)-red oxide (PR101)	TiO_2/Fe_2O_3
cadmium orange (PO20)-red oxide (PR101)	$CdS_{1-x}Se_x$- Fe_2O_3
titanium white (PW6)-cadmium yellow light (PY35)	TiO_2- $CdZn_{1-x}S_x$
cadmium yellow light (PY35)- chromium oxide green (PG17)	$CdZn_{1-x}S_x$-Cr_2O_3

Table 1. Detailed description of the composition of the bi-layered standards.

Digital Simulations: Terminology and Ethical Use

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Keywords: Digital Simulation, Simulation, Reconstruction, Photoshop

Submitted Abstract

Digital simulations are a useful and effective visual tool for conservators to share findings with scholars, researchers, and the general public. These simulations function as translations of the scientific and historical data we have collected; however, it is important for the audience, who may not be well-versed in reading technical images and spectra, to understand that such simulations are informed hypotheses—not fact. As Hyperspectral Imaging (HSI) and Macro X-Ray fluorescence (MA-XRF) scanning are becoming more accessible, conservators and allied professionals are generating more digital simulations, but we have not begun to talk about the ramifications of presenting and publishing potentially misleading images that depict visual interpretations of data, not physical artworks. In an era of the Internet and widespread misinformation, it is imperative that we develop appropriate terminology to describe these images. Thus, now is the time to be proactive and address the language and ethical use of digital simulations and their current and future place in the field of Conservation.

In this paper, I will propose a list of terminology, definitions, and disclaimers to initiate efforts to codify the language we use to describe digital simulations. As examples, I will provide three case studies of work resulting in digital simulations. The first two studies were produced in collaboration with imaging scientists, curators, and other conservators at the National Gallery of Art, Washington. Using information derived from traditional imaging methods (infrared reflectography, x-radiography, and transmitted light imaging), cross sections, HSI, and MA-XRF, I created simulations of Young Girl Reading by Jean Honoré Fragonard and Feast of the Gods by Giovanni Bellini and Titian to approximate each respective painting in an earlier state of its creation.

The last case study I will discuss includes several simulations that I made in collaboration with the Conservation Department for the Detroit Institute of Arts. These simulations address color changes that have occurred in The Wedding Dance by Pieter Bruegel the Elder. This series of digital simulations was informed by XRF spot analysis and fiber optics reflectance spectroscopy (FORS). Each case study will highlight different methods used to emphasize the hypothetical nature of digital simulations, and offer solutions to ensure that such simulations can be readily identified.

Finally, I will offer other ways that we can use Adobe Photoshop to suit our needs (for example, to better visualize underdrawings in infrared images and to quantify areas of loss in a paint layer)

and suggest free web-based alternatives that can perform most of the same functions. Adobe Photoshop and similar software are powerful tools, and I encourage conservators to approach and explore them with both creativity and mindfulness.

Polymeric Treasure: Evaluating the Composition of Civil War Era Rubber Objects from the USS *Monitor*

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Keywords: Natural Rubber, Oxidation, Vulcanized Rubber, Infrared Spectroscopy, Composition, Deterioration

Extended Abstract

Civil War era rubber objects were recovered from the USS *Monitor* marine wreck and have been treated by conservators at The Mariners' Museum and Park over the last two decades. These objects have been exposed to burial environments and differing treatment conditions which have altered their composition. Some objects have fared better than others due to their isolation from environmental conditions as components of larger machines. These rubber objects offer a unique analytical viewpoint on historical rubber objects and rubber manufacture in the mid-19th century, as the ship was built and sank in 1862. The marine burial environment, along with the placement of some of the artifacts (particularly the gaskets) produces a unique environment that limits the availability of oxygen and water, two key factors in the rate of oxidation of organics like rubber. The composition and stability of rubber gaskets were evaluated using Fourier Transform Infrared Spectroscopy. The results reveal a wide range of conditions and variations in compositions for the rubber gaskets from USS *Monitor*, providing us with a better understanding of rubber manufacture in the Union during the 19th century, and a baseline of how this rubber has oxidized.

The types of rubber objects recovered from USS *Monitor* range from hardened materials like buttons to softer materials like gaskets. Thirty nine rubber gaskets were evaluated for this study and at the time of testing were either in treatment or newly completing treatment. A Bruker Alpha attenuated total reflectance-Fourier transform infrared (ATR-FTIR) spectrometer was used to collect spectra from each object tested, when possible three locations per object at minimum. The spectral range was 4000-400 cm^{-1}, with 64 scans collected at a resolution of 4 cm^{-1}. A background spectrum was collected prior to measurement under the same conditions. The spectra were interpreted using Bruker's OPUS® software version 7.8 Build: 7,8,44.

Infrared spectroscopy was used to determine the isomer present in each of the tested rubber gaskets. Identification of the possible rubber source plants, via identification of 1,4-*cis*-polyisoprene vs 1,4-*trans*-polyisoprene with vibrational spectroscopy has been demonstrated by Haider 2012. A majority of the rubber gaskets tested, twenty-six, are comprised of 1,4-*cis*-

polyisoprene indicating that the rubber likely is sourced from Central or South America. Two rubber gaskets contain 1,4-*trans*-polyisoprene. Eleven gaskets contain a mix of isomers or their isomers could not be identified and require further testing.

Measurement of rubber oxidation with infrared spectroscopy was done using the ratio of methyl/methylene peaks (Salomon and Van Der Schee 1954). A lower ratio of these peaks indicates a lower oxidation level of the rubber. No rubber tested in this study was in the ratio range of 0.71-0.75 which correlates to "like new" rubber as shown in Figure 1 (left).

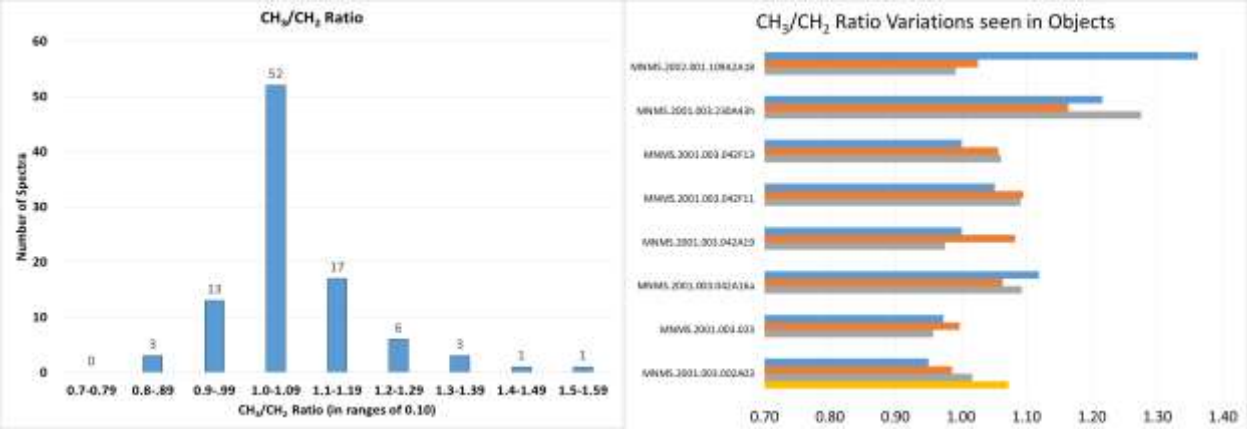

Figure 1 (left) Number of spectra that have CH_3/CH_2 ratios, broken up into 0.10 ranges (right) Oxidation ratio in rubber objects, each object numbered on the left axis having 3 to 4 measurements represented by different colored bars.

The majority of the tested rubber had a ratio of 1.0-1.9, with the most brittle rubber at the highest ratios 1.4-1.59. Objects sometimes had a wide variation in oxidation levels at different testing locations while others had more consistent oxidation levels as shown in Figure 1 (right).

The oxidation levels will be monitored with ATR-FTIR periodically and as further rubber objects are found from USS *Monitor* these will be tested and entered into the dataset. All USS *Monitor* rubber objects are stored under anoxic conditions and handling of these objects is limited to prevent further oxidation (King, Haines and McGath 2020).

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King, Laurie, Lesley Haines and Molly McGath. "A Sticky Situation: Conservation of Historical Waterlogged Rubber" Poster presented at the Annual Meeting for the American Institute of Conservation 2020, Virtual Meeting, July 21.

Salomon, G., and A. Chr. Van Der Schee. 1954. "Infrared Analysis of Isomerized, Vulcanized and Oxidized Natural Rubber." *Journal of Polymer Science*, 14 (74): 181–92. doi:10.1002/pol.1954.120147405First words

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Research and Technical Studies Specialty Group & Collections Care Network Joint Sessions

A Case Study in Establishing and Maintaining Elevated RH Levels in Microclimate Casework

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Keywords: Microclimates, Relative Humidity, Elevated Relative Humidity, Active Humidification, Loan Requirements

Extended Abstract

INTRODUCTION

The Cleveland Museum of Art's (CMA) 2019 exhibition "Shinto: Discovery of the Divine in Japanese Art" presented 125 works of art assembled from religious institutions and museums throughout Japan, as well as from collections in the United States. Loan negotiations for the objects from Japan required the museum to maintain an elevated level of humidity. CMA staff viewed this as an opportunity to improve preventive conservation standards in display case design, and to test and utilize active humidification units.

Requirements stipulated that objects must be displayed at 60% RH, significantly higher than most U.S. standards of 50%. Current understanding dictates that variation in humidity is less of a risk to many collections than previously thought[1]. We initially explored the merits of acclimatizing objects to 50% RH for the exhibition, but in the end, the museum was invested in the accommodation of the lender requests. Elevating the humidity of the gallery was not an option as it would stress our HVAC and raise the humidity in adjacent spaces, risking damage to our own collection. We needed to use microclimate casework for every Japanese loan object.

CASE TYPES AND MATERIALS

We chose five case styles to test, all produced in-house by our CMA cabinetmakers.

CMA cases are constructed primarily of obomodulan®, a cast polyurethane board that passes the Oddy test. Silicone gaskets are used where vitrines meet casework and around the edges of climate chamber doors. Vitrines are usually acrylic but occasionally glass. Gaps of a ¼" minimum

[1] Stefan Michalski, "The Ideal Climate, Risk Management, the ASHRAE Chapter, Proofed Fluctuations, and Toward a Full Risk Analysis Model." *Proceedings of Experts' Roundtable on Sustainable Climate Management Strategies, Tenerife*, The Getty Conservation Institute, 2007.

around deck edges are standard to allow for air flow between the below-deck climate chamber and the display.

TESTS

Two sets of tests were performed: a leakage test, and a performance test using high RH gel. We also assessed two active humidification units from Glasbau Hahn GmbH- the RK-2/5 and the RK-2-Xa/5, to investigate their installation and performance.

LEAK TESTING

Leak testing was performed on four case types. Leak testing measures the rate that carbon dioxide leaks out of a case, giving a measureable number for the airtightness of a case.

After filling cases with CO2 and tracking their CO2 levels over a period of time, the following formula was used to determine air exchange rates:

$$k = \frac{\ln(C_{start\ enclosure} - C_{room}) - \ln(C_{end\ enclosure} - C_{room})}{t_{start} - t_{end}}$$

where:

- t is in units of days.
- C_{room}= the baseline concentration of CO_2 in the room.
- $C_{start\ \text{enclosure}}$ = the concentration of CO_2 in the case at the start of the test.
- $C_{end\ \text{enclosure}}$ = the concentration of CO_2 in the case at end of the test.

[2,3]

GEL PERFORMANCE TESTING

Cases were tested for performance using a 60% RH gel. RHapid gel was sourced from Art Preservation Services due to its quick production and delivery time. For the exhibition, Artsorb was the preferred gel to use, due to its buffering capacity at and above 60% RH. RHapid gel performs best in a range of 45-55%.[4]

ACTIVE HUMIDIFICATION UNITS

Two units sourced from Glasbau Hahn GmbH were tested, the RK-2/5 and the RK-2-Xa/5. The units were installed in our casework and run for 21 days. We used dataloggers to assess efficiency and to determine best practices for installation. We also investigated maintenance and water supply requirements.

TEST CONCLUSIONS

We came to several conclusions. First, several cases failed to reach 60% RH despite having the required amount of gel and favorable air exchange rates. Second, all cases were observed to have

[2] Peter Brimblecombe and Brian Ramer, "Museum Display Cases and the Exchange of Water Vapour." *Studies in Conservation*, vol. 28, no. 4, 1983, pp. 179–188.
[3] Steven Weintraub, email to the author, Tuesday, September 15, 2020.
[4] Steven Weintraub, "Demystifying silica gel." *Objects Specialty Group Postprints*, vol. 9, The American Institute for Conservation of Historic & Artistic Works, 2002.

discrepancies between the humidity of the environmental chamber and of the deck. Improved air flow was required. Cases employing gel as the primary means of climate control required new perforated aluminum decks. Some case styles required active humidification in order to be used effectively. The RK-2-/5 and the RK-2-Xa/5 were highly efficient and are particularly useful for humidifying oversize casework.

CONSTRUCTING THE EXHIBITION

We produced new casework for the exhibition, utilizing perforated aluminum decks, wider airflow gaps, and tubing for active units. We worked with Glasbau Hahn GmbH to install seven RK units, providing 60% RH to 34 cases. Channels to hide tubing were placed behind molding in walls and beneath false floorboards. Closets and compartments were built to hide the RK units.

Artsorb at 60% RH was installed in cases using the RK units, to improve efficiency and to provide a failsafe in case of mechanical failure. For cases using gel alone, I prepared Artsorb to reach a relative humidity of 70%. This allowed cases to settle at 60% after acclimatizing the 50% air in the casework.

On April 7, 2019, "Shinto: Discovery of the Divine in Japanese Art" opened to the public. The active humidification units ran well, and the Artsorb-only cases were successfully buffered to 60% RH. A true test of our setup came when our power company experienced an outage, leaving generators to run environmental functions for almost 24 hours. During installation we had placed all humidification units on emergency power rather than standard electrical, as a failsafe for a worst case scenario. To our surprise, this scenario occurred, but none of the cases dropped beneath their 60% RH threshold.

CONCLUSION

This project was an opportunity to work within the guidelines of Japanese preventive conservation standards in presenting an extraordinary loan exhibition in the United States. The loan requirements led us to an increased understanding of available resources for preparing and maintaining microclimates. It was an opportunity for us to assess our casework and to raise our preservation standards. It was also an illustration of the successes that occur when multiple stakeholders work together to create a preservation management plan. When a power outage occurred, we avoided stressing the objects or negating our loan agreements. It is our hope that the testing and implementation of new microclimate standards at the CMA will prove useful for other institutions facing similar challenges.

REFERENCES

Brimblecombe, Peter and Brian Ramer. "Museum Display Cases and the Exchange of Water Vapour." *Studies in Conservation*, vol. 28, no. 4, 1983, pp. 179–188.

Michalski, Stefan. "The Ideal Climate, Risk Management, the ASHRAE Chapter, Proofed Fluctuations, and Toward a Full Risk Analysis Model." *Proceedings of Experts' Roundtable on Sustainable Climate Management Strategies, Tenerife*, The Getty Conservation Institute, 2007.

Weintraub, Steven. "Demystifying silica gel." *Objects Specialty Group Postprints*, vol. 9, The American Institute for Conservation of Historic & Artistic Works, 2002.

Weintraub, Steven. Email to the author, Tuesday, September 15, 2020.

Accessible and State of the Art Pollution Monitoring Systems for Enclosures

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Keywords: Showcases, Pollution, Ventilation, Measurement, Sorbents

Annotated Powerpoint

ABSTRACT

Enclosures are a very valuable approach to individually controlling environments and offer very significant improvements in sustainability. Their major drawback is the concentration of pollution from materials and objects. In both the British Museum and English Heritage all instances of observed corrosion were investigated. Corrosion products were identified, environmental conditions and pollution levels were measured and any materials not previously Oddy tested were tested if possible. In over 1000 instances no gas phase corrosion was observed where materials passed Oddy tests. Several instances of direct contact corrosion and object-sourced corrosion were recorded. The Oddy test has been modified to also include direct contact. A test has been published using paper instead of metals, and evaluating with viscometry. This has now been modified to use the more accessible ATR-FTIR. Additional tests to evaluate materials including silk and archaeological bone have been developed. English Heritage has showcases that date from as early as 1840.

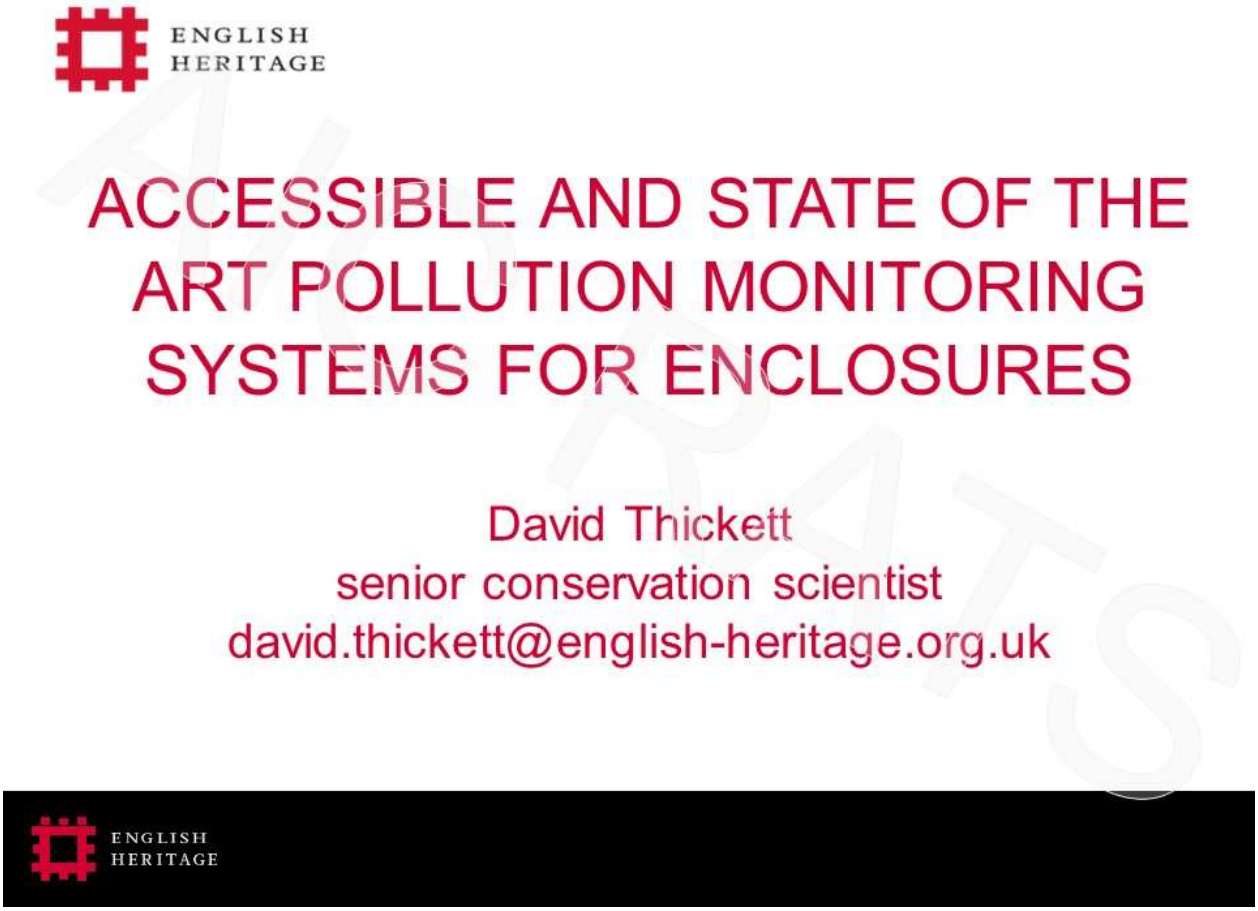
Although testing is essential for new cases, measuring pollution levels or corrosion rates is also critical for existing enclosures. Several instances of objects causing corrosion of other objects or components within themselves are documented, meaning even comprehensive materials testing will not eliminate the problem. Research over the past three decades has developed several continuous monitors and dosimeters.

Whilst there is no doubt continuous measurement is desirable, such systems are expensive and dosimeters tend to cost less, but give more limited information. The function and utility of coated piezo electric quartz crystals, resistance based metal sensors, tVOC and single gas sensors, glass slide dosimeters and early warning organic dosimeters will be reviewed. Costs are often a critical restriction for many smaller institutions, simple, more accessible methods have been developed. Exposure and colorimetry of Acid/detection (A/D) strips can measure equivalent acetic acid levels. Visual examination of exposed lead and silver coupons should also be used.

This combination of rapid and long or very long term monitoring provides tools covering the whole gamut of common needs. Colorimetry can be used with silver coupons to provide quantitative results, if available. This approach deals with the most commonly reported damaging pollutants. The weaknesses of each method will be discussed.

The response of A/D strips to formic acid at a range of RH values, and to light has been assessed, as well as response times. A guide chart has been developed to assess A/D strips semi-quantitatively, without a colorimeter. A survey of heritage institutions found a lack of knowledge was another major barrier to pollution monitoring. The EU funded MEMORI project developed a decision support model to guide non-expert users through the measurement, assessment and mitigation process.

The basic data has now been expanded to include sulfur gases and silver and the impact of RH on metal corrosion rates, allowing the incorporation of archaeological iron and copper alloys. Improved use of enclosures has dramatically reduced English Heritages carbon footprint. Pollution issues can derail such improvements without adequate measurements and suitable mitigation.



English Heritage has lots of challenging, high RH, low RH, or fluctuating RH environments. Use enclosures when appropriate to protect collections, they need to work hard. Also polluted sites such as Apsley, with lots NO2, H2S and fine particulate. There is now approximately 20% more traffic than prior to lockdown in London. But main reported issue internal enclosure pollutants.

Large number of historic showcases and frames, need to work with them to improve internal pollution problems for some objects

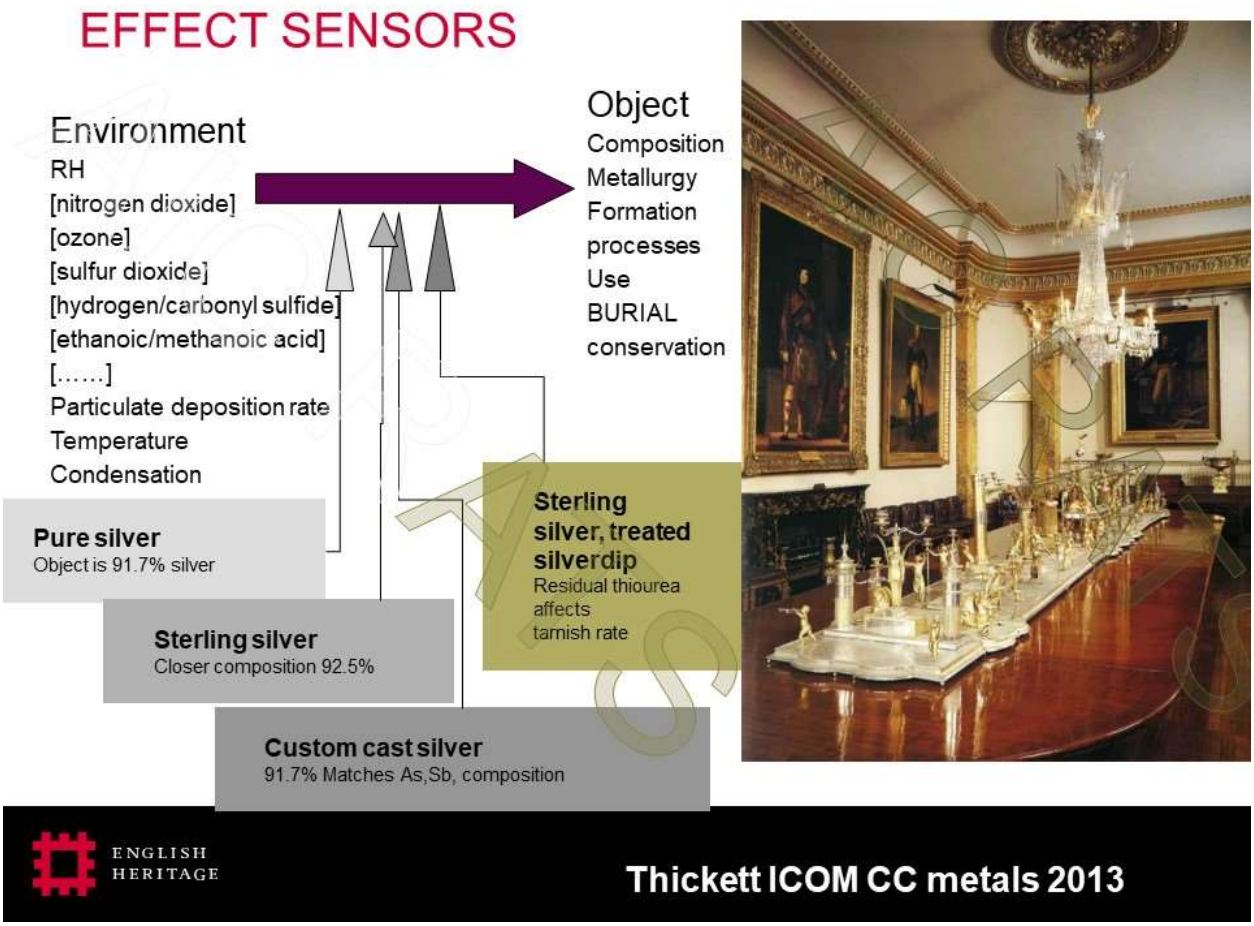
Even for new showcases, if fully test all materials and all inert some objects cause problems to other objects or even themselves, Topkali figure wood and lead, lead corrodes in enclosure due to acetic acid from the wood. Other examples reported, planned presentation at IAQ virtual meeting in October

SITUATIONS FOR MONITORING

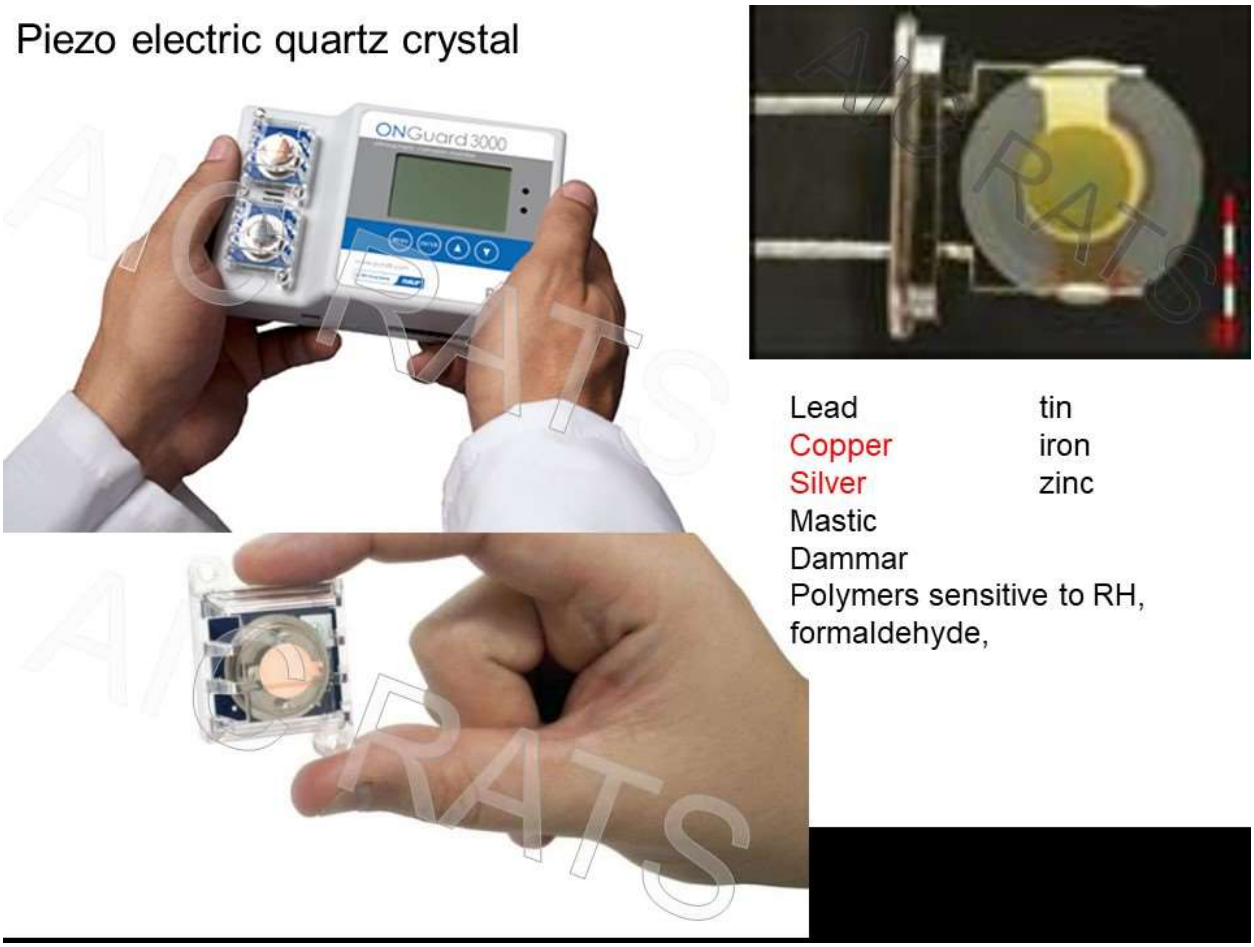
- Fast initial check if its safe – exhibitions, collections moves - need measurement results before objects start to be effected
- Investigation of damage observed
- Risk assessment
- Checking mitigation has worked
- Long term monitoring

Spot versus continuous readings

Size is an issue in many settings, packed showcases, print, painting and daguerreotype frame rebates

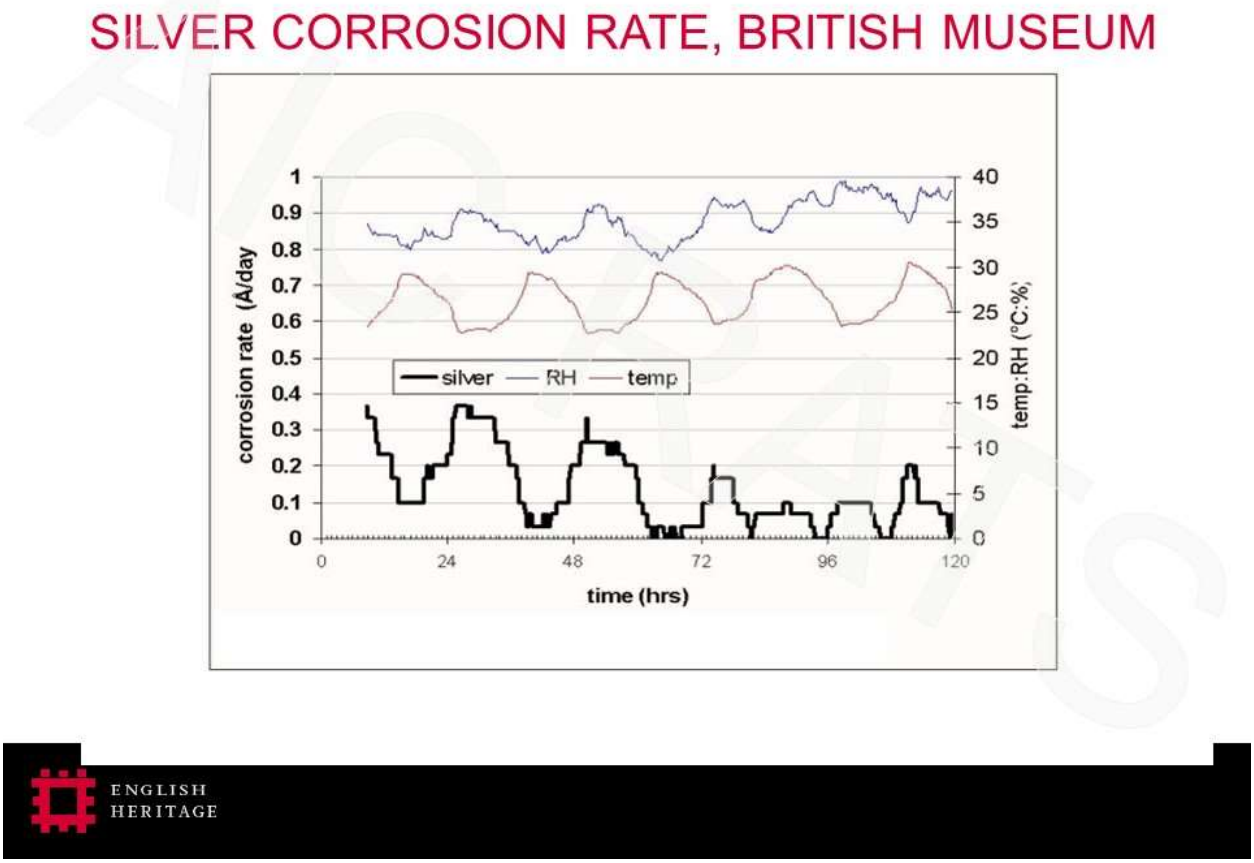


Effect sensors better term than dosimeters. Complex environment, complex objects, difficult to assess likely change given environmental data. Place pure silver coupon, increasingly representative, never will probably get perfect match, but gives indication to risk of class of objects and allows to compare environments. Integrates effects onto sensor which then measure.

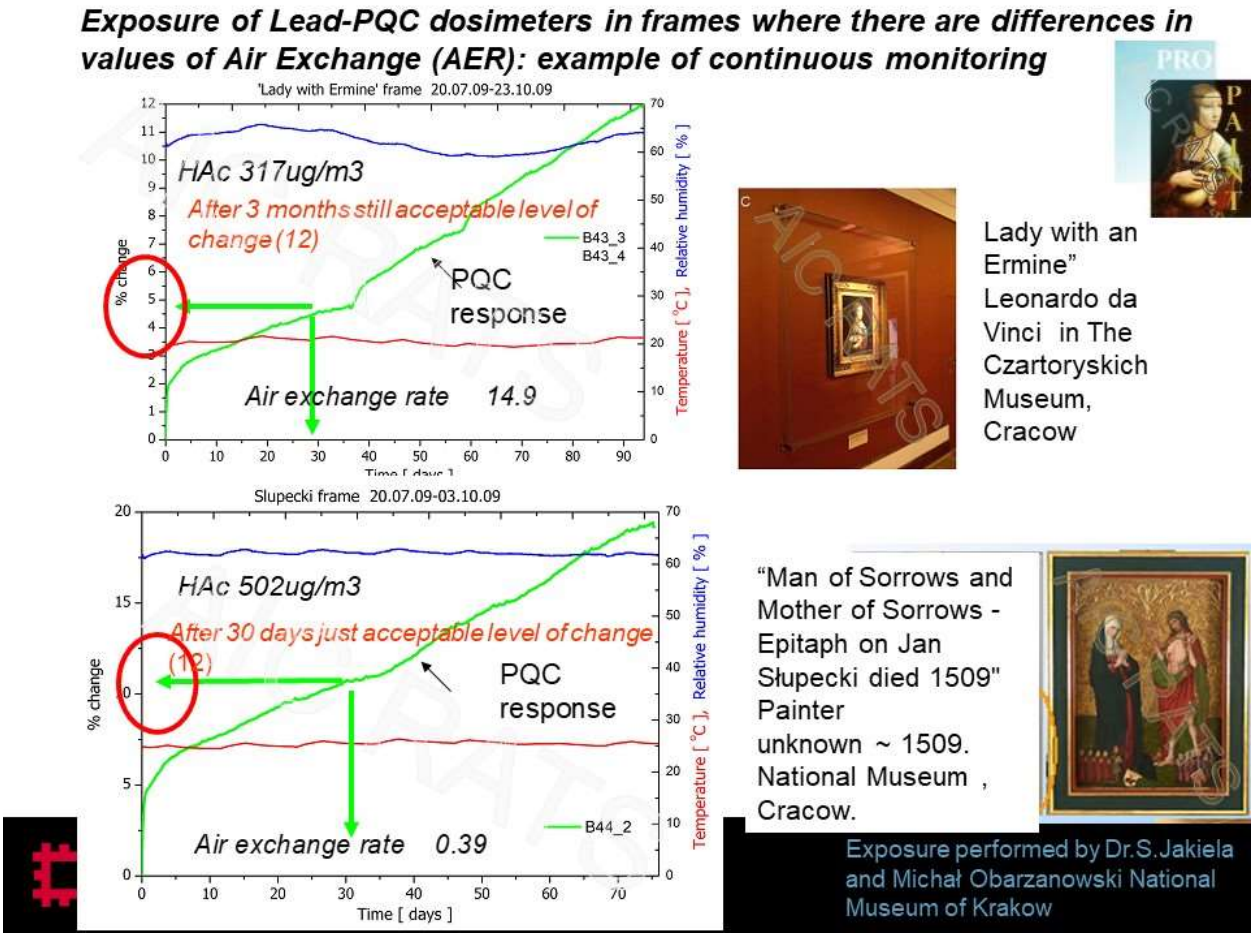


Starting with high tech; Piezo electric quartz crystal with coating, essentially immensely sensitive balance, anything that changes weight or stiffness can be monitored commercially. Commercial air quality Onguard system only silver and copper, lots of other coatings developed for conservation

Image credits: purafil.com, the 3000 is no longer available, it is now the 4000



Typical data, Continuous, trace shows measurement in British museum, for first two days tarnish rate corresponds with increasing RH, day 5 different behaviour. Need investigate further differences (actually more sunlight on carpets releasing sulfide gases).



Data from two exposures with lead coated PQCs from Propaint project, courtesy Marianne Odlyha, Man with sorrows frame much tigher and high acetic acid concentration, hence higher lead corrosion rate. Marianne is integrating the results into MEMORI system, see later

PQC ISSUES

Temperature effect

Onguard compensation circuit, not fully effective, but can correct

Other researchers 'control crystal'

Measures mass, dust issue

6MHz crystals Onguard

Can't settle on 10MHz crystals

Interpretation

Onguard uses 'average' tarnish composition to convert mass to thickness

Other researchers use F_{crys}/F_{cont}

Some calibration to standards/acetic acid levels

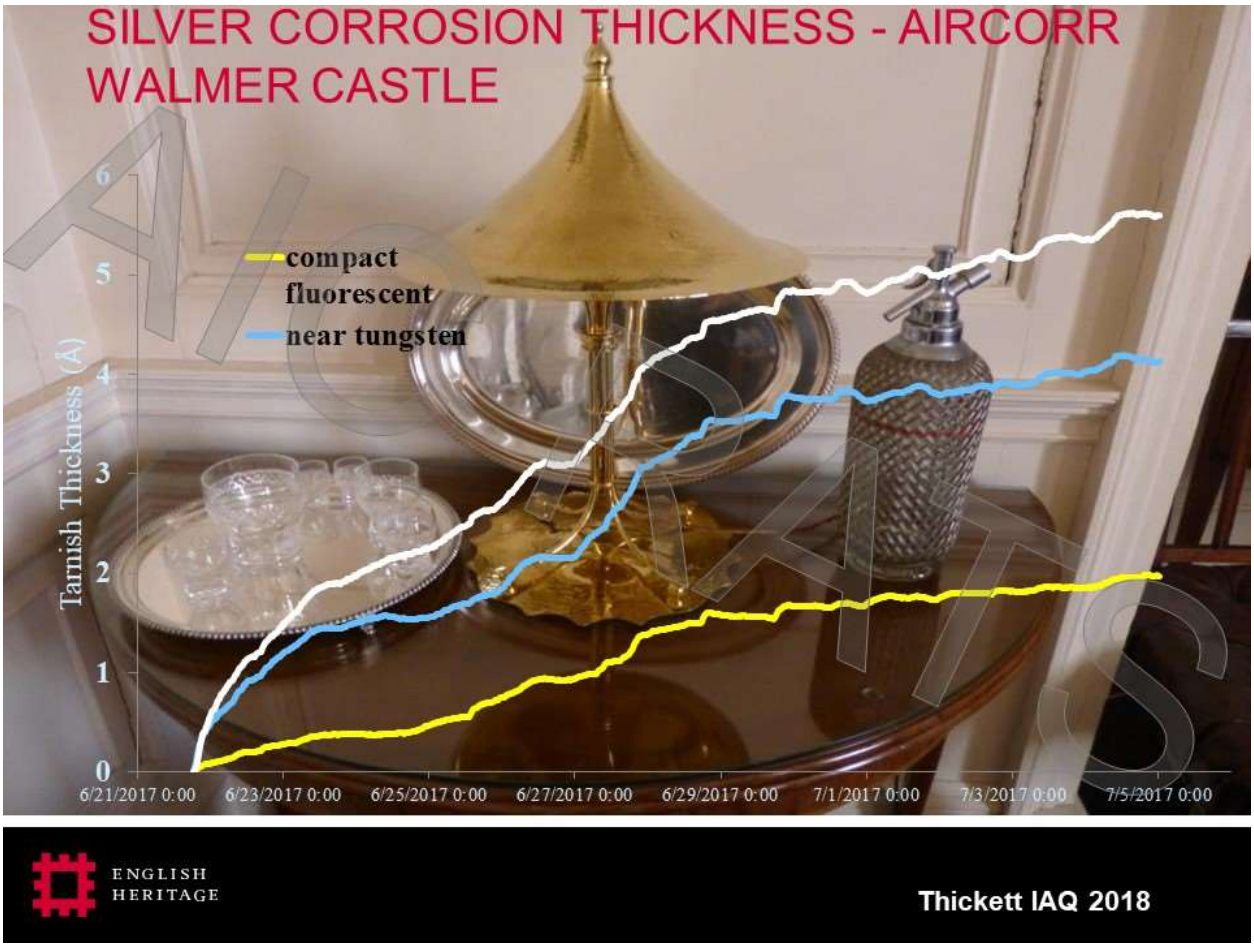
Cost

Onguard 4000 circa $2400, crystals $300

Scientific $800, uncoated crystals $10 (silver coated possible)

AirCorrr development of industrial resistance based sensors for museums, more sensitive, different materials, now commercially available

Work to develop patinated tracks (patinated bronzes can corrode much faster or slower than bronze of same bulk composition) and work in currect project to reduce size and cost significantly



Typical data, used to show difference in silver tarnish near cold compact fluorescent lamp and very hot tungsten, white is under lamp, blue to side near tray.

IR reader, can read through showcase glass

AIRCORR LIMITATIONS

Condensation/deposition of salts can effect

(otherwise can look at effect of dust on surface)

'Light' can effect silver and copper readings by

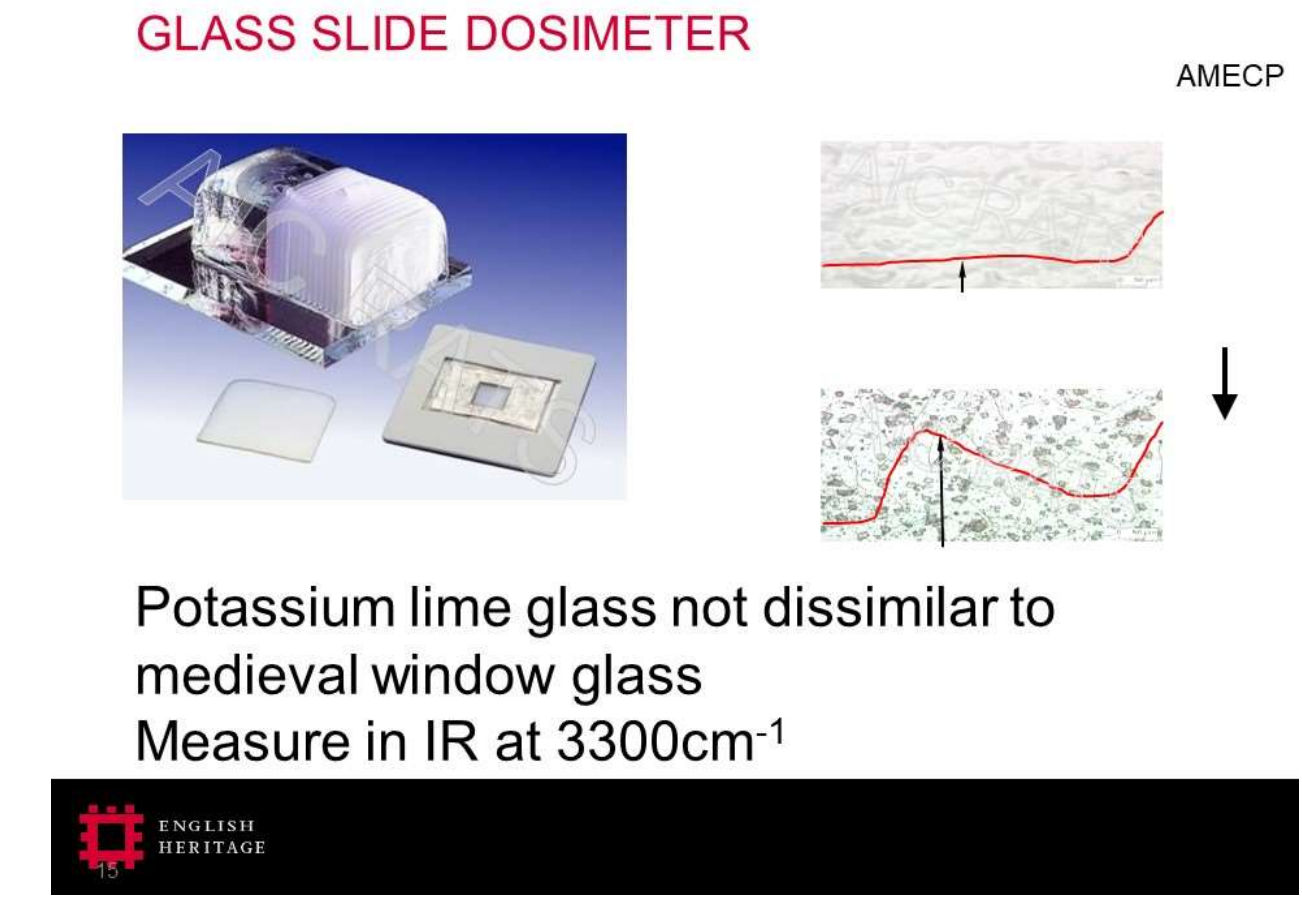
heating darkening surface of measurement track more than control track

and silver also by reducing resistance of silver sulfide - semiconductor

COST

Single unit $1200, sensor $40-400

Double unit $2400



GSD, sliver of reactive glass, returned to lab after exposure, analysed with FTIR

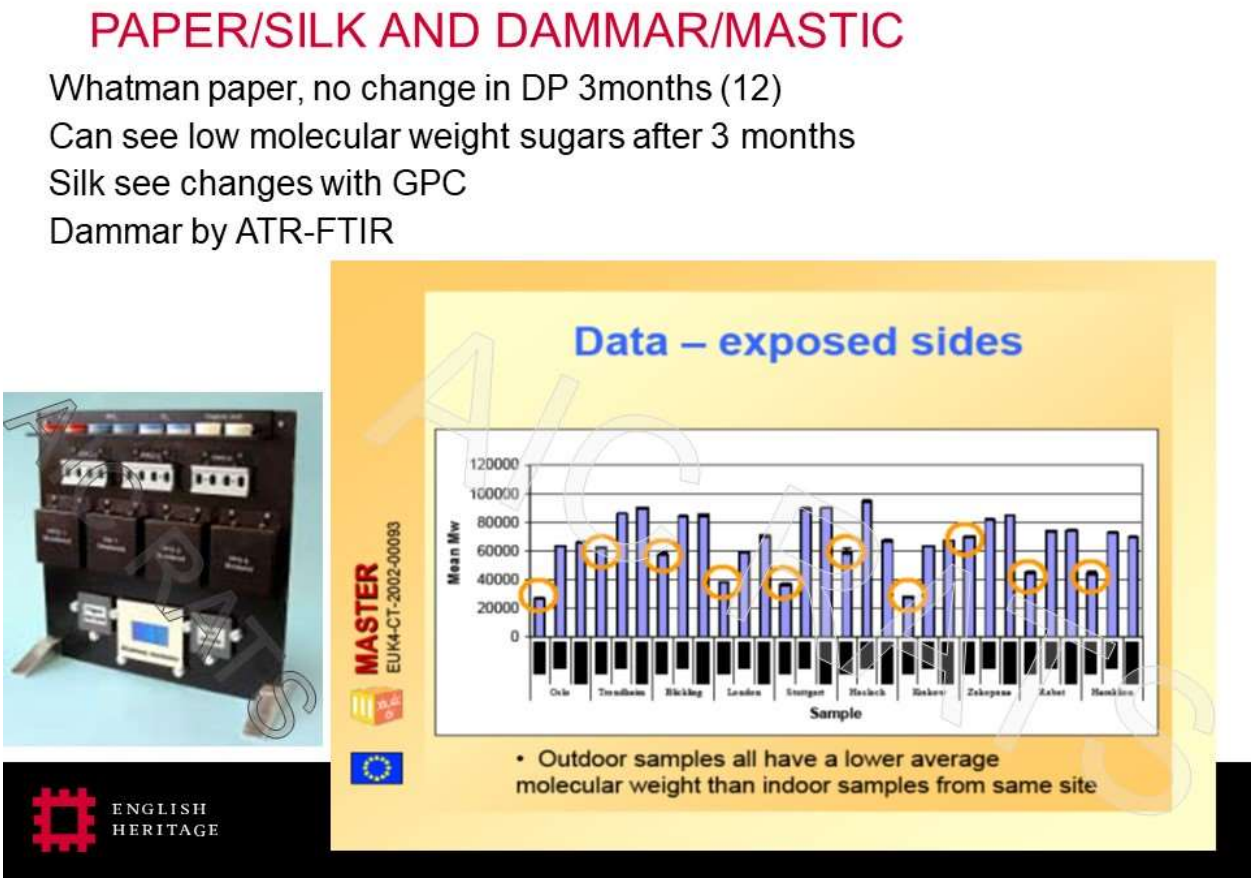
GSD LIMITATIONS

Affected by RH aswell as acetic acid

Probably stronger Formic acid effect

Damp (>50%) environments can affect results

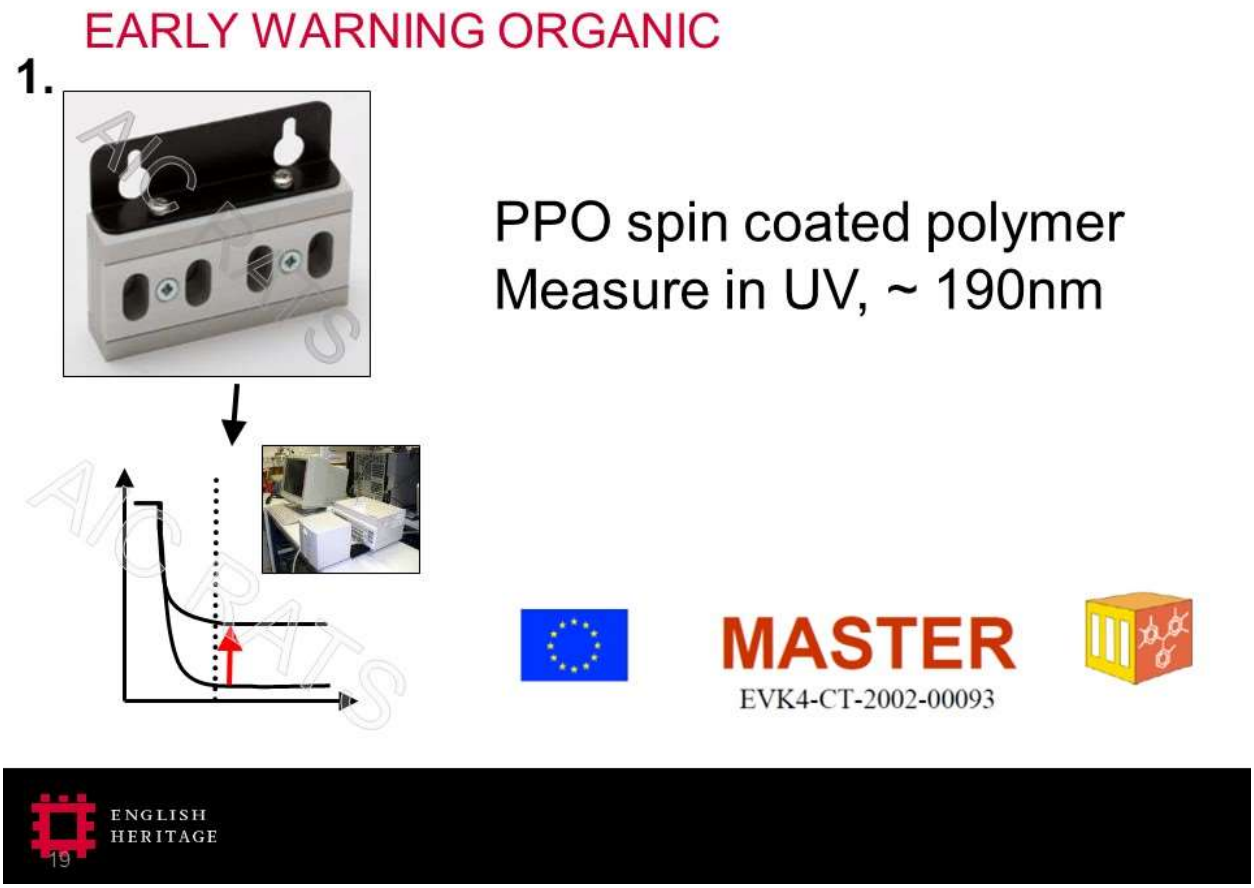
COST circa $400, almost only used in research projects in conservation



Several organic materials used as affect sensors, paper and silk in MASTER project, DP is insensitive unless very long exposure, over 12 months, can see changes earlier with Gel permeation chromatography for silk (and probably paper) or see low molecular weight sugars from paper in 3months with ion chromatography with pulsed ampometric detection. Damar and Mastic recently developed new method with ATR-FTIR more sensitive, can see changes earlier than previous FTIR method.

SILK/PAPER/MASTIC/DAMMAR LIMITATIONS

- ❑ Relatively slow response (accelerated for Mastic/Dammar)
- ❑ Analysis can be expensive/difficult especially for silk and paper
- ❑ Mastic/Dammar ATR/FTIR



EWO developed in MASTER project for NO2 and O3, measured in lab after exposure with UV spectrometer.

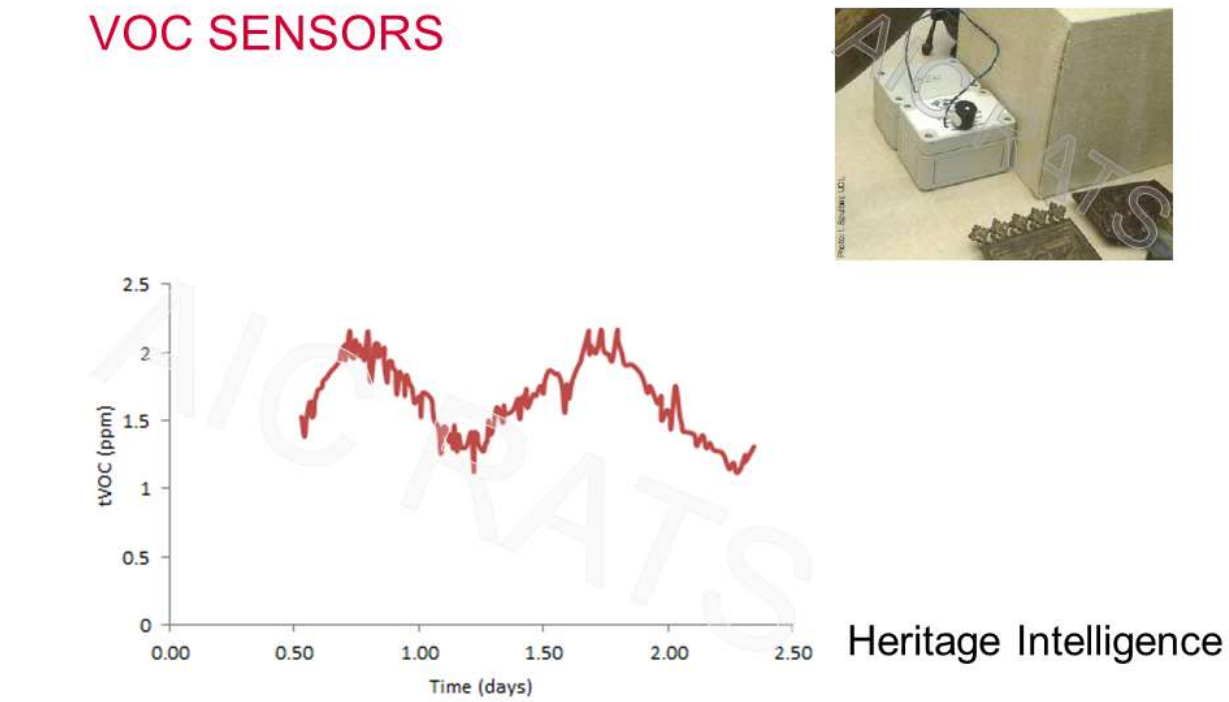
EWO LIMITATIONS

- Joint measurement nitrogen dioxide and ozone (and RH and UV)
- Comparable in cost to diffusion tubes, which are more specific and precise
- Can be small

For external pollution, several groups used Teledyne continuous sensors for past two decades, but large and need power and use a pump, which can be an issue inside showcases, Lots of smaller sensors developed but 10ppb resolution not sufficient unless major pollution issue, Eltek accuracy 0.1ppb, just appeared on market

Image credits: Teledyn - www.teledyne.com, Egg - https://airqualityegg.wickeddevice.com/portal,

Flow - https://plumelabs.com/en/, Greywolf - https://graywolfsensing.com/iaq/, Eltek - http://eltekdataloggers.co.uk/

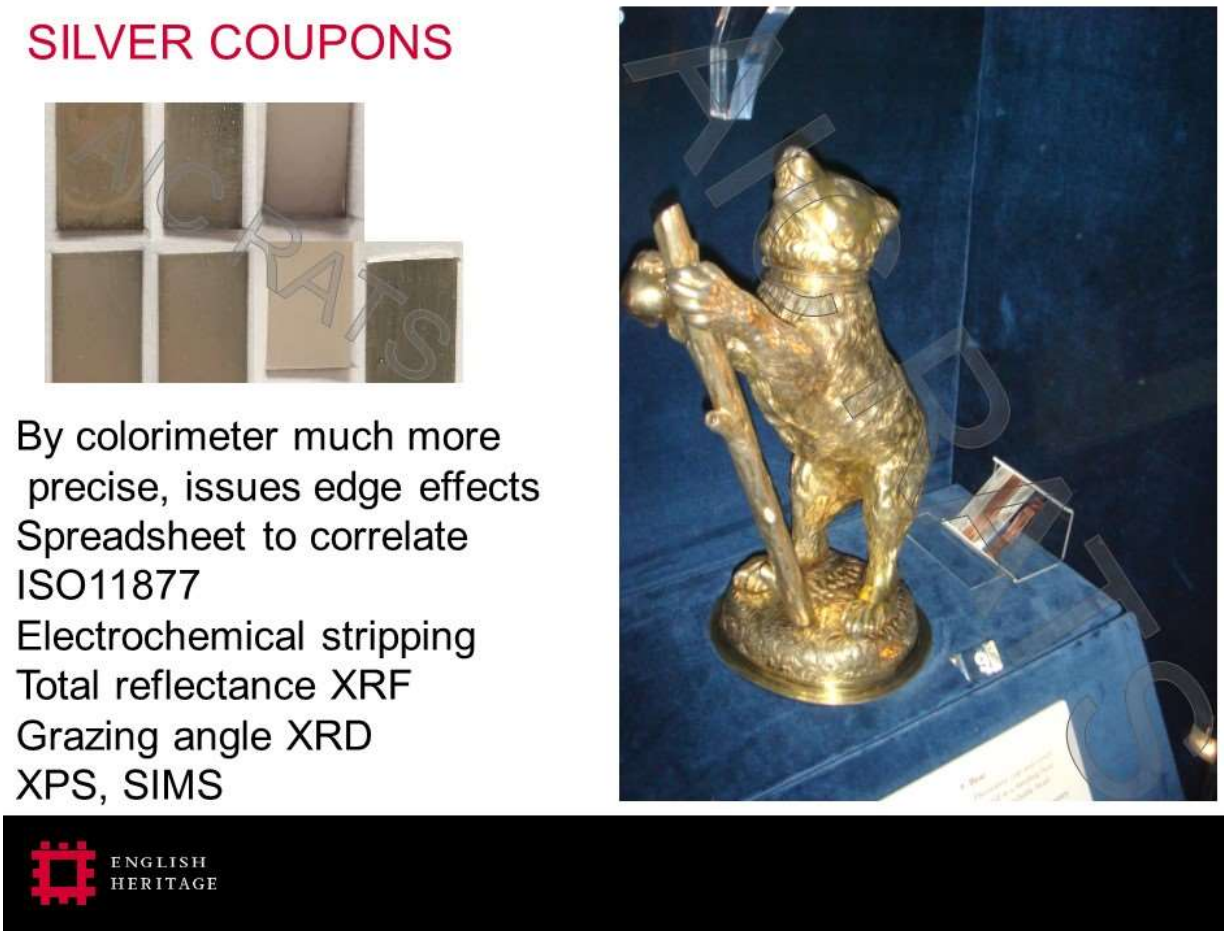


tVOC sensor deployed in Heritage Intelligence project, see results from British Museum showcase, development of better VOC sensors in two ongoing EU projects, but issues with tVOC, see next slide

GAS SENSOR LIMITATIONS

- Species choice very limited
- High cost for sufficient accuracy
- tVOC non specific, looking for 34 species in amongst 200-400 in average showcase from set of 2000-4000
- Low reading can be very corrosive, high reading can be non corrosive
- Many won't detect certain important compounds such as acetic acid

ENGLISH HERITAGE

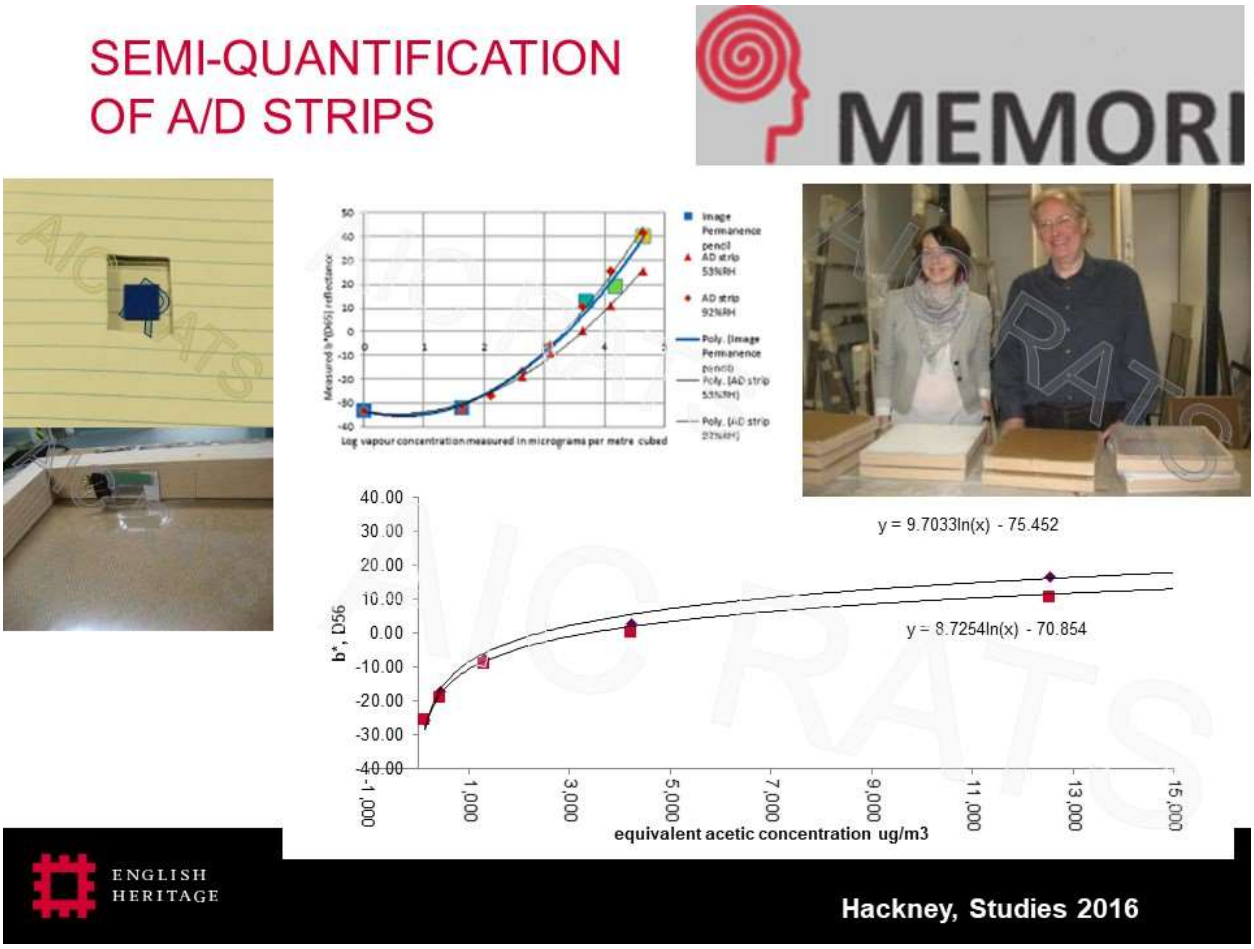


Silver coupons can expose, assess by eye after a period, 12 months ideally, can see differences between showcases in a month is some instances. Use colorimeter for faster (shorter exposure time), more precise result. Variety of other analytical techniques have been used on exposed coupons, increasing sensitivity

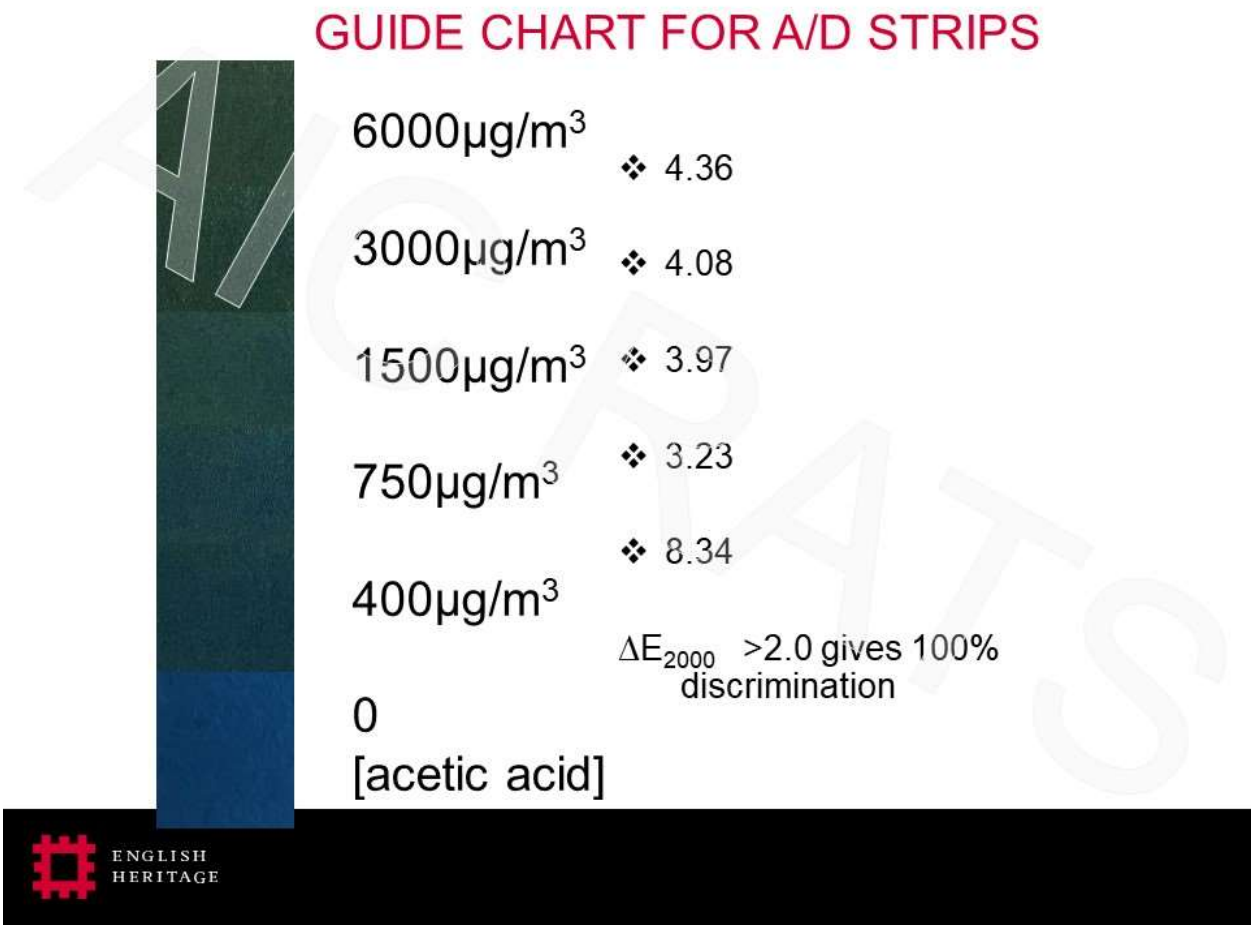
Similarly lead, can also analyse for more quantitative results. Issue won't corrode at even very high acetic acid levels at 30% RH, okay for lead objects as they won't corrode (provided RH doesn't rise), but other object types less RH sensitive

ISSUES

- By eye, subjective (can be improved)
- Relatively slow
- Silver by colorimetry, much more precise, can't do for lead
- Orientation can affect
- Some showcase materials can cause corrosion by direct contact and not in air
- Silver reaction can be very position sensitive in some showcases
- Lead will not react at low RHs



A/D strips form of rough quantification with colorimeter developed by Stephen Hackney.



Also now developed a visual comparison chart, should work for most assessors, only tested 4 people due to pandemic, only good enough for the rough divisions shown

A/D ISSUES

- ❑ Respond to last 3 days
- ❑ Need to read within 5 minutes
- ❑ Light sensitive, okay 200 lux 60days

1000 microgram/m^3 ACETIC, 200 FORMIC ACID

	Period (max)	Detects	Accuracy	Cost
A/D strips, fuji dots	1-3 days (2 months at 200lux)	combined	Low	Low
Lead coupon	30days by eye (25 years) 1day SIMS/AFM	combined	Low High	Low
GSD	30 days (12months)	combined	Med	Med
Radiello diffusion tubes	1 day (28 days)	Both	High	Med
Palmes diffusion tubes	2 days (45 days)	Both	High	Med
Active sampling *	30mins (2 days)	Both	Very High	High
Automated IC	30mins	Both	Very High	U high
Aircorr (lead)	15mins (10 years plus***)	combined	Ultra High	V high
Onguard (copper)	14 days (10 years plus**)	combined	High	V high
PQC (lead)	15mins (5 years***)	combined	Ultra High	High

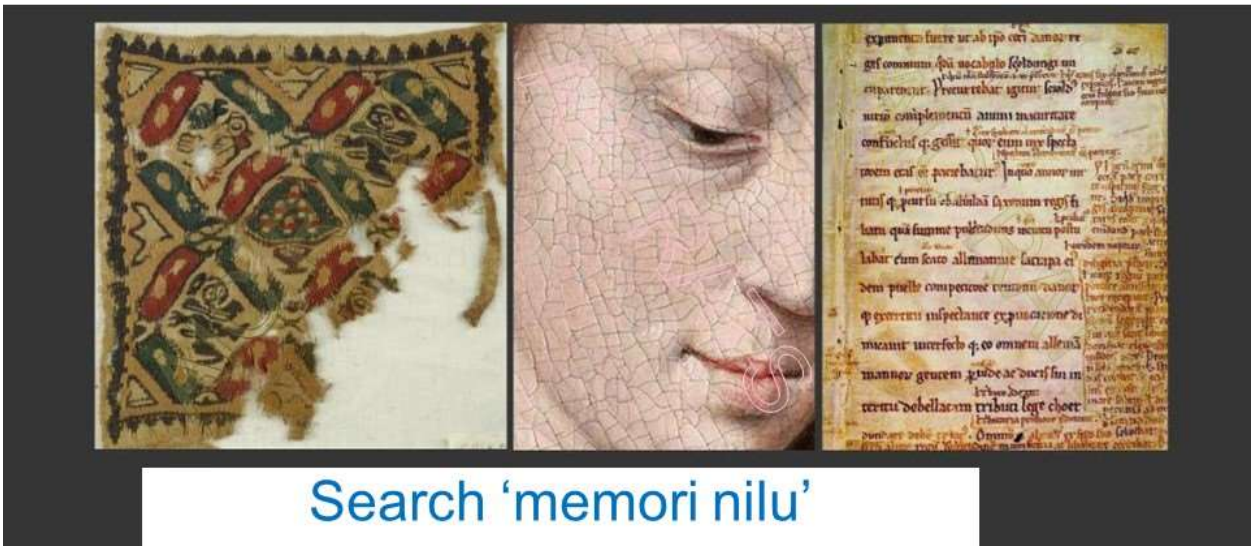
ENGLISH HERITAGE

* Can disturb atmosphere when used in enclosures
** Need to changes sensors every 24 months (RH)
*** Need to changes sensors every 6 months (RH)

Look at time taken to detect 1000ug/m3 and how long can leave out for continuous monitoring, * sensor can be totally corroded and need replacing earlier

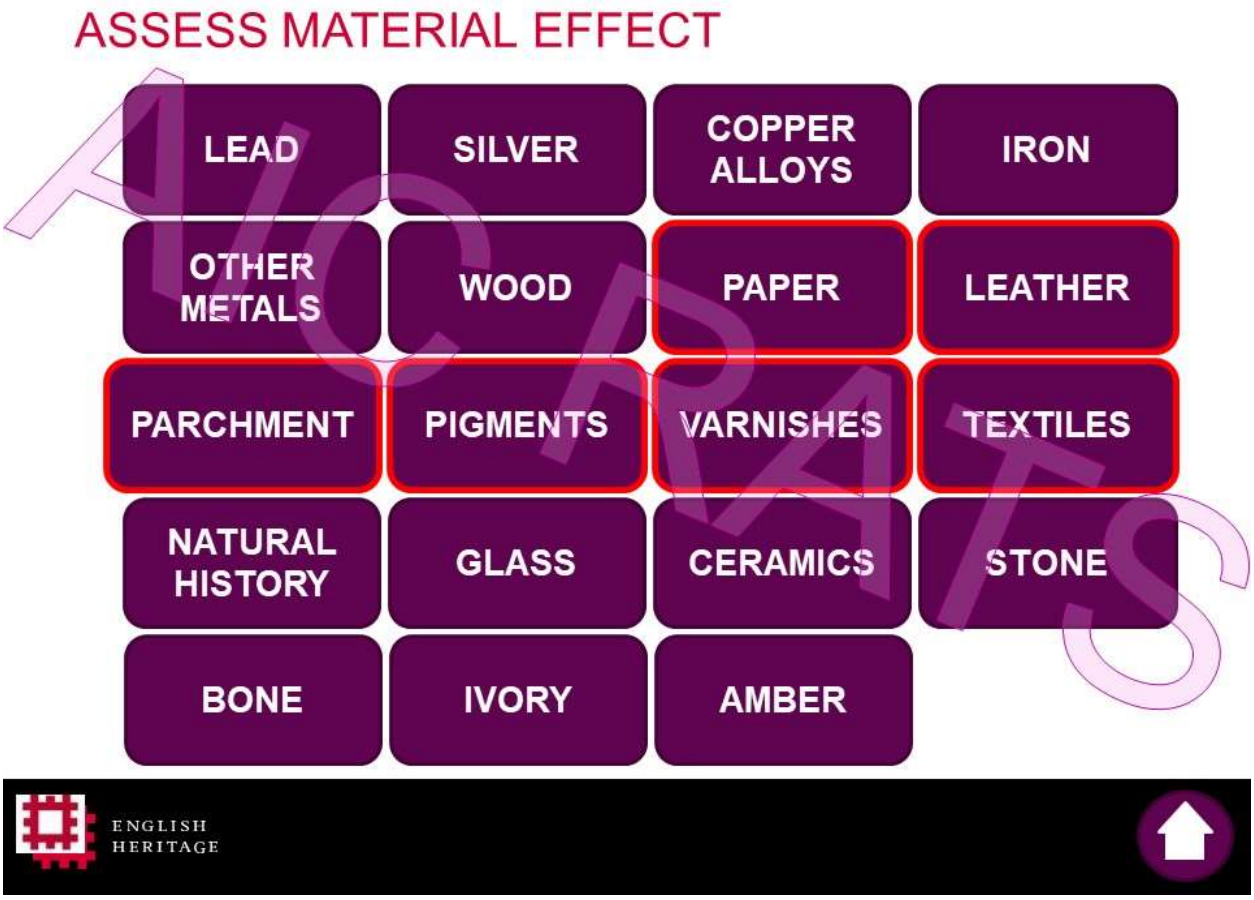
Rangs of techniques for metal coupons, by eye least sensitive>SEM-EDX/electrochemistry>grazing angle XRD Ultra sensitive static SIMS and AFM (probably faster than a day, but haven't tried)

Mitigation - if levels are too high, need practical solutions. Air conditioning for rooms is well understood, but can still be poorly implemented. In showcases, mitigation and passive application of sorbents raises many questions and the details seem to have a big influence on whether it works or not. Applying sorbents in pumps can give more control, but requires maintenance and in the absence of continuous monitoring means replacement is difficult to optimise.



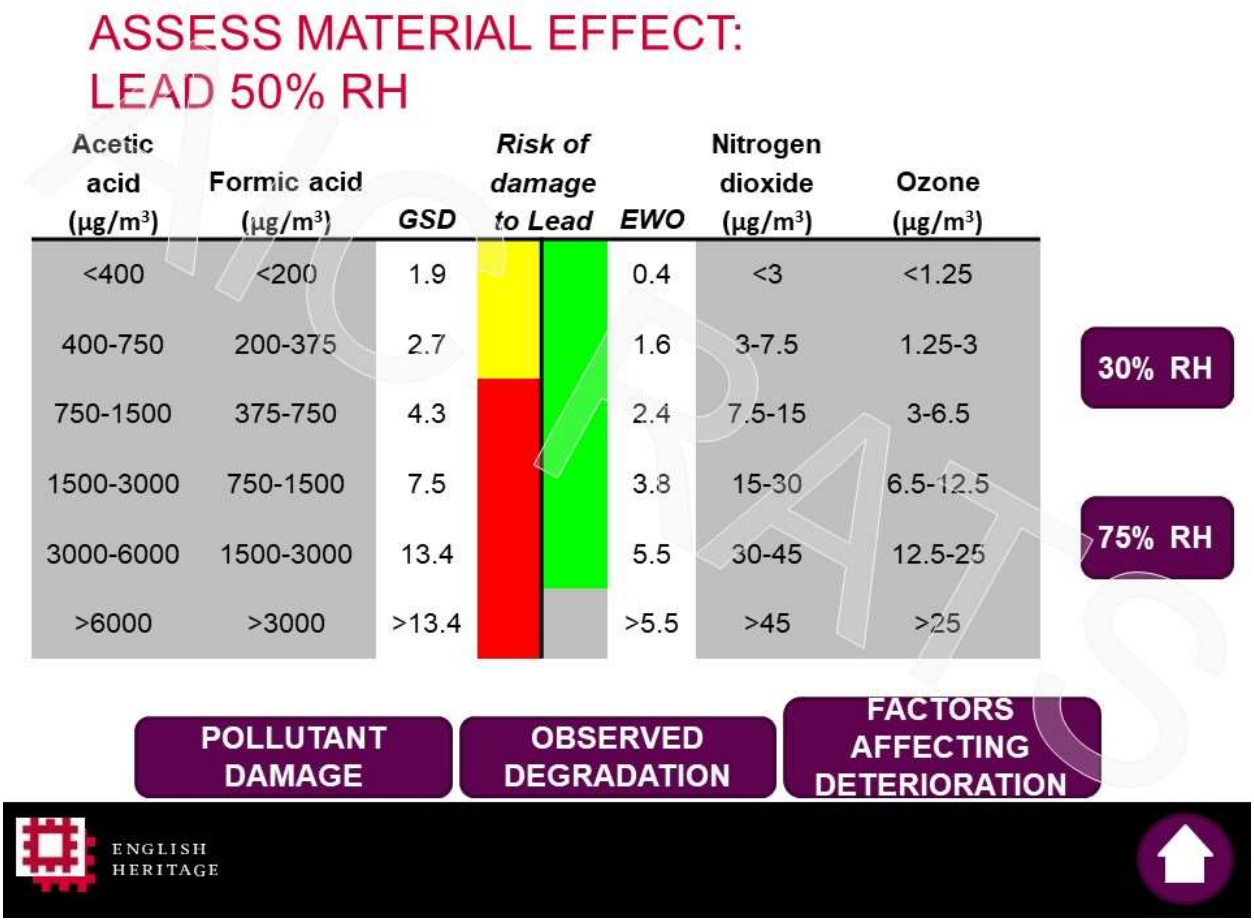
Finally talk about mitigation if levels too high, need practical solutions and details seem to have big influence on whether they will work or not.

Tried to pull info on acetic/formic acid and NO2 and O3 (6000 references in total) together in MEMORI website and downloadable decision support model



Substantial information on 19 material types, data for those outlined in red developed in project research (mainly not yet published), each has several pages of information

Exists in powerpoint with active links

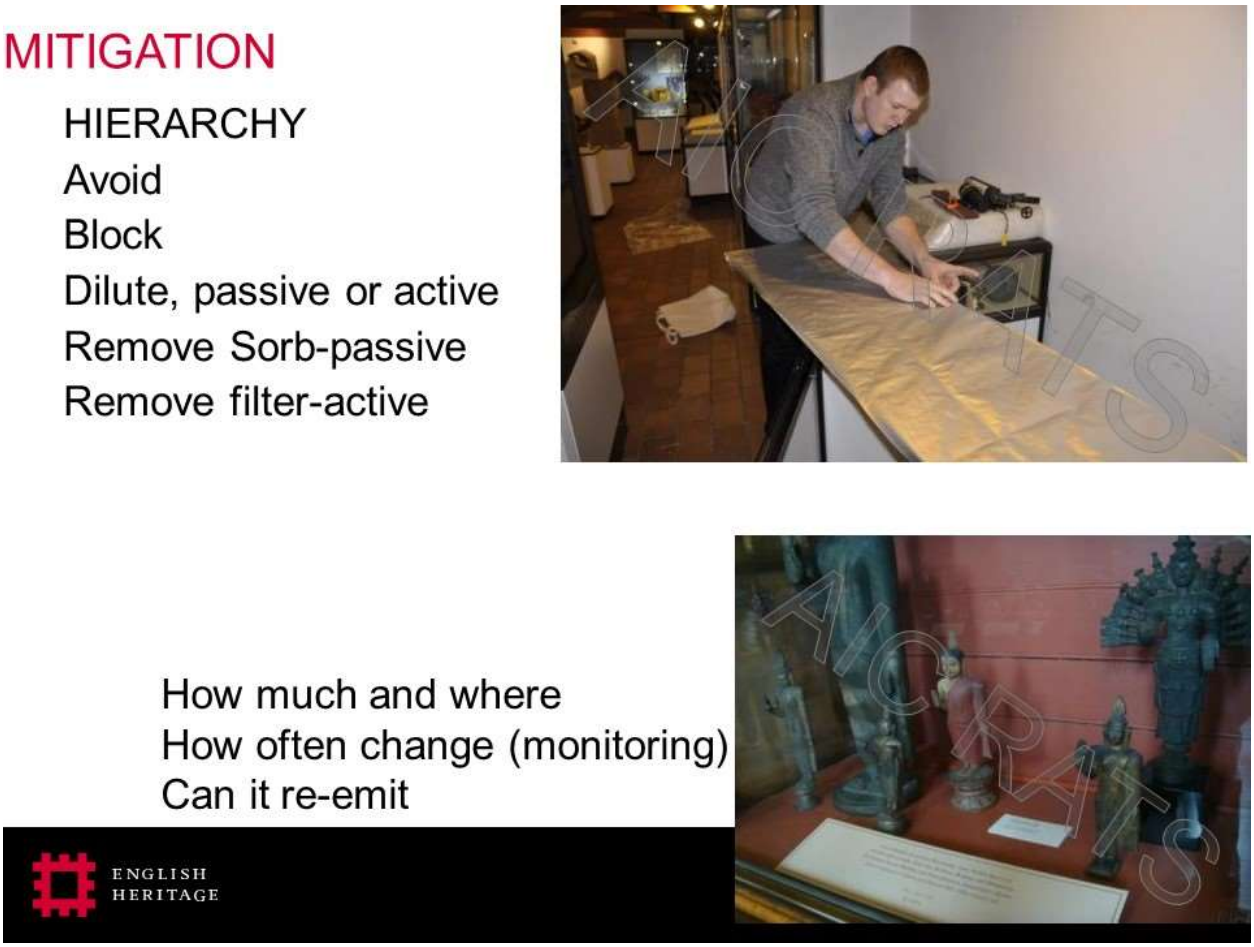


Their sensitivity to the two groups of gases (acetic/formic – internal, nitrogen dioxide/ozone external)

Here red means damage (a very simplified definition, avoiding all context of values, now being developed) likely within 2 years

Green no damage within 20 years, max threshold thought we could draw form present research data, amber in between, grey just don't know, no data

Response if for two sensors amalgamated in project, but as now not available. Added equivalent for acetic and formic acid for GSD and NO2 and O3 for EWO and response at different RH values, very strong effect in most metals, glass



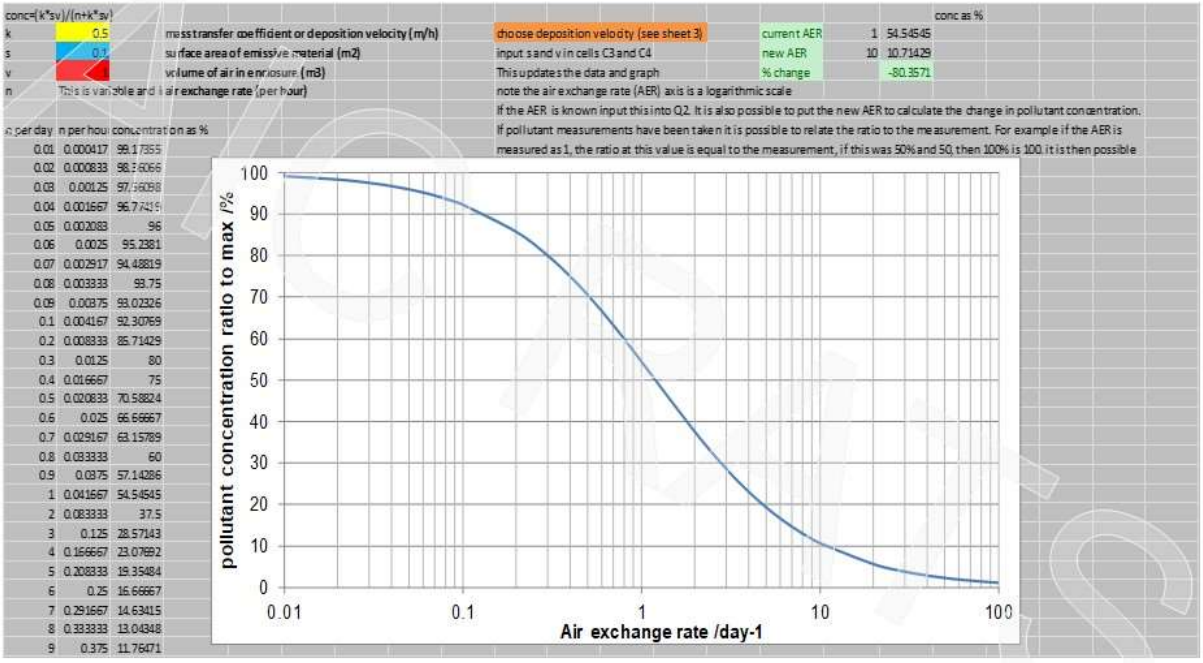
And what to do if need to reduce levels. Followed Michalski scheme, modified by Jean Teterault, best to avoid with materials testing,

If can't then block, fitting aluminium foils to an MDF panel for existing showcase.

When using sorbents (passive better as no need to know a pump is running properly), usually have same questions

How much do I need, where can I put it to work, when will I need to change (monitoring is required) and some reports of sorbents re-emitting large amounts of pollution under certain circumstances (always in pumps so far), only very small scale re-emission from passive activated charcoal

AIR EXCHANGE RATE MODELLING TOOL – ONE OF SEVERAL



Measuring air exchange rates and pollution levels we can make a lot of predictions, well enough, about how mitigation will probably work. Still several key areas we don't fully understand. How high does air mix in different showcases, what size holes work for sorbent enclosures, what is lifetime for different sorbents?

Model for effectiveness of ventillation, passive or active, if have pollutant measurement and air exchange rate, sets point on curve, can see whats needed to reduce to certain level, website has several other excel based tools

USER HAS TO FILL IN DEPOSITION VELOCITIES FROM SHEET BEHIND

CONCLUSIONS

- Quite a lot of tools available
- Cost will limit use of several to better financed institutions/research projects
- However, their use in research can guide the whole profession if directed towards practical issues
- Some more accessible, low cost options available, give an indication, guide further studies

ENGLISH HERITAGE

ACKNOWLEDGEMENTS

- MEMORI partners
- Marianne Odlyha, Birkbeck College
- Stephen Hackney, Tate
- Kathryn Hallet, Royal Historic Palaces
- Matija Strlic, UCL
- Eltek
- RKE
- Purafil
- 7th framework program EU, grant 265132

Effect of Long-Term Impact of Climate Change and Urban Pollutants on Cultural Heritage Sites and Collections

Peter Brimblecombe[1]

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Submitted Abstract

A changing climate is now widely observed. Within the field of heritage protection, it is seen as important factor, even though it is not always clear how its impact will be revealed. Coastal flooding and increased tropical storms are key cause of concern. Gradual change to climate can also have effects, although a few degree increase in temperature or 10% change in rainfall amount might seem of little relevance to monumental structures. However, small changes can be amplified: ice melts at 0°C, so a very small increase in temperature can cause the loss of an archeological site in permafrost. Small changes in humidity can cycle salts between crystals and brines, so induce salt weathering in porous stone.

Biology can also amplify small changes. Insect infestations may be catastrophic after only a slight change in temperature or a new species may suddenly become a threat, while microbial growth on surfaces can be affected by subtle shifts in relative humidity. Air pollution though decreasing in many cities is changing in character resulting in altered pressures on heritage. As historic houses often lack climate control, the changed climate can propagate indoors. Landscape, the context to heritage sites is affected by climate change altering the picture they offer visitors. This presentation will explore with a range of examples of changes under way, the effect on heritage and attempt to project these through the current century.

Examining Commercially Available Sorbents to Understand and Maximize the Mitigation of Volatile Organic Compounds

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Keywords: Pollutants, Sorbents, Storage, Exhibit cases

Submitted Abstract

For decades, sorbents in a variety of forms and compositions, such as silica gel, zeolites, or activated carbon, have been sold and used in the conservation world. These materials are placed in exhibition cases and storage spaces to stabilize environments be it by controlling the humidity or removing compounds that can tarnish or degrade collection objects. Each of the different materials work to mitigate volatile organic compounds (VOCs) through different mechanisms and not much is known about the capacity, selectivity, or potential for off-gassing for these sorbents. As such, it can be challenging to know how much of a sorbent is needed for an exhibit case or how long before the sorbent needs to be replaced. Sometimes the silica gel used for humidity control can absorb volatiles, the challenge with this not being the ab/adsorption, but the potential future re-release of these compounds that could lead to degradation of collection materials.

Through the use of headspace sampling and thermal desorption gas chromatography mass spectrometry thirteen different sorbents and two silica gels were characterized. This work will detail how each sorbent and silica gel was tested to determine their selectivity for adsorbing a series of VOCs commonly found to be off-gassed by paper collections and then tested to determine how readily they off-gas the compounds that were originally collected. These tests were conducted with the goal of being able to assist in determining when sorbents need to be replaced and selecting the best type of sorbent for mitigating degradation products of different types of collection items and the residual VOCs from building, construction, and housing materials. Examples of sorbents used with collections items will be discussed.

New Guidelines for the Desiccated Storage of Archaeological Metal Artefacts

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Submitted Abstract

Corrosion of archaeological metals, particularly iron and copper alloy artefacts, is an ongoing problem for conservation and collections care. If not managed, corrosion can lead to reduction in value or complete loss of artefacts and collections. This paper presents the results of a long-term research programme at Cardiff University which investigated corrosion rates linked to humidity levels and best practice in creation of desiccated microclimates for corrosion prevention. Surveying sector practices in the post-excavation storage of archaeological metals has revealed the complexity of the decision-making process and a distinct lack of evidence-based guidance to direct protocols. Immediately post-excavation, free water in corrosion product layers can create high humidities and drive destructive electrochemical corrosion.

Advice on drying techniques is limited and conflicting, leading to ad hoc practices and consequent danger to objects. Once dry, chloride-bearing compounds mean archaeological and marine iron artefacts can remain unstable down to 15% relative humidity (RH). Therefore, for most museums and archaeological units, long-term corrosion control is by desiccated storage reliant on creating and maintaining low RH microclimates in plastic boxes. Success of these microclimates is driven by air exchange rates of boxes which are in turn dictated by box design and size. Along with the mass of silica gel included, these variables determine the lowest RH achievable and its longevity. Without evidence of the influence of these variables, effective management of storage procedures is impossible.

This paper delivers new data on the influence of post-excavation drying, storage box variables, mass of silica gel and gel regeneration cycles in successful creation of desiccated microclimates for medium and high RH external store environments. Combining this with corrosion rate data for iron and copper alloy objects between 20-80% RH allows predictions to be made about the risk to artefacts of following a range of common protocols. Guidance on best-practice drying and storage procedures to minimize corrosion and enhance object longevity are now offered to the heritage sector. The research updates previous, generic guidance on storage box selection and silica gel use. Results of surveying practice indicate that the go-to guidance remains First Aid for Finds, the most recent edition of which was published in 1998. Advice on silica gel per volume of box in that publication was based on contemporary practice rather than evidence-based data and no guidance on box selection was offered beyond the ubiquitous Stewart Sealfresh.

The synergy of conservation science and practice reported here combines laboratory experimentation using climatic chambers, oxygen consumption corrosion rate testing and air exchange measurements with an extensive survey of sector practice and close liaison with end users to produce pragmatic guidelines for practitioners and managers. Supporting cost benefit

decision-making in storage box selection and silica gel regeneration cycles, these guidelines will allow managers of archaeological metalwork collections to design bespoke storage protocols which have the potential to extend lifetimes of collections. Assessment of risk to objects can be weighed against hardware and human resource costs and variables manipulated to design workable, case-specific solutions to a widespread problem.

Research and Technical Studies Specialty Group & Contemporary Art Network Joint Session

Addressing a Growing Concern: Preliminary Research Towards an Understanding of Mold on Modern Paints

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Keywords: microbial activity, mold, biodeterioration, acrylic emulsion paints, synthetic polymers, relative humidity, water activity

Extended Abstract

The biodeterioration of cultural heritage is a considerable concern for cultural institutions as the material variety within heritage objects provides diverse ecological niches for microorganisms to colonize. The majority of research concerning microbial activity within cultural heritage focuses on naturally derived materials as these provide a suitable and readily available nutrient source for most microorganisms. Furthermore, naturally derived materials make up a large percentage of cultural heritage collections, meaning more objects are at risk of biodeterioration. However, from the 19th-century onwards, many collections gained a large quantity of artworks made from synthetically derived materials, such as plastics, as their frequency in modern life was increasing. While these materials have their own conservation issues, their risk to biodeterioration has been largely overlooked as synthetic materials have been incorrectly assumed to be resistant to biological attack. As a result, the risk colonization by mold and other microorganisms poses to synthetic materials is severely underestimated. Molds require certain environmental parameters to support growth. The amount of "free water" available within a substrate (i.e. water activity (aw)) as well as an available nutrient source are the two most influential factors in a mold's capacity for growth. Additionally, factors such as temperature, light, pH, and oxygen levels can also affect mold growth. The susceptibility of a substrate to mold colonization is largely dependent on these factors. This study presents preliminary research into the susceptibility of synthetic polymers to biodeterioration, specifically on the risk mold poses to modern paints, by addressing their susceptibility to mold growth when certain environmental parameters are in place.

Two dominant mold species were isolated, and identified through DNA analysis, from an infested 20th-century oil painting donated to the Queen's University Art Conservation program. They were identified to be Aspergillus sydowii and Trichoderma viridescens. Six types of Golden Artist Colors® Heavy Body Acrylic Emulsion Paints, titanium white (PW 6), mars black (PBk 11), ultramarine blue (PB 29), phthalocyanine green blue shade (PG 7), quinacridone red (PV 19), and cadmium yellow (PY 74/PY 175/PY 83), were inoculated with the individual mold species and incubated for thirty-one days in closed-system humidity chambers at 76% and 86% relative

humidity, respectively, achieved using saturated salt solutions. Clean and artificially soiled paint films were inoculated with mold. After the incubation period, the paint films were removed from the chambers, water activity measurements of each film were taken, and mold growth assessments of each film were done through microscopic observation.

Table 1 and Table 2 show the results of the mold growth assessments and water activity measurements of the mold-treated clean and artificially soiled paint films after incubation at 76% and 86% relative humidity, respectively.

Table 1 *Mold growth assessments and water activity (a_w) measurements of clean and artificially soiled paint films inoculated with A. sydowii and T. viridescens after incubation at 76% relative humidity*

Clean acrylic paint films				
Paint color	**Mold treatment**	**Samples (#) with mold growth***	**Mean mold coverage****	**Mean paint film water activity (a_w)**
PW 6	*A. sydowii*	0	None	0.668
PBk 11	*A. sydowii*	0	None	0.681
PB 29	*A. sydowii*	0	None	0.637
PG 7	*A. sydowii*	0	None	0.602
PV 19	*A. sydowii*	0	None	0.670
PY 74/PY 175/ PY 83	*A. sydowii*	0	None	0.646
PW 6	*T. viridescens*	0	None	0.694
PBk 11	*T. viridescens*	0	None	0.715
PB 29	*T. viridescens*	0	None	0.677
PG 7	*T. viridescens*	0	None	0.623
PV 19	*T. viridescens*	1	Low	0.697
PY 74/PY 175/ PY 83	*T. viridescens*	0	None	0.673
Artificially soiled acrylic paint films				
Paint color	**Mold treatment**	**Samples (#) with mold growth***	**Mean mold coverage****	**Mean paint film water activity (a_w)**
PW 6	*A. sydowii*	2	Low	0.615
PBk 11	*A. sydowii*	1	Low	0.631
PB 29	*A. sydowii*	4	Moderate	0.615
PG 7	*A. sydowii*	1	Low	0.617
PV 19	*A. sydowii*	2	High	0.602
PY 74/PY 175/ PY 83	*A. sydowii*	2	Low	0.648
PW 6	*T. viridescens*	0	None	0.666
PBk 11	*T. viridescens*	0	None	0.661
PB 29	*T. viridescens*	0	None	0.649
PG 7	*T. viridescens*	0	None	0.655
PV 19	*T. viridescens*	0	None	0.643
PY 74/PY 175/ PY 83	*T. viridescens*	0	None	0.671

* Sample size (N) for each color is 4.

** The mold coverage of each sample was determined based on the following criteria: None = 0% coverage, Low = < 20% coverage, Moderate = 20-50% coverage, High = > 50% coverage. The amount of mold coverage was averaged between the 4 samples for each color.

Table 2 *Mold growth assessments and water activity (a_w) measurements of clean and artificially soiled paint films inoculated with A. sydowii and T. viridescens after incubation at 86% relative humidity*

Clean acrylic paint films				
Paint color	**Mold treatment**	**Samples (#) with mold growth***	**Mean mold coverage****	**Mean paint film water activity (a_w)**
PW 6	*A. sydowii*	0	None	0.857
PBk 11	*A. sydowii*	0	None	0.859
PB 29	*A. sydowii*	0	None	0.852
PG 7	*A. sydowii*	0	None	0.786
PV 19	*A. sydowii*	1	Low	0.846
PY 74/PY 175/ PY 83	*A. sydowii*	0	None	0.848
PW 6	*T. viridescens*	0	None	0.853
PBk 11	*T. viridescens*	0	None	0.853
PB 29	*T. viridescens*	0	None	0.849
PG 7	*T. viridescens*	4	Low	0.794
PV 19	*T. viridescens*	4	Moderate	0.843
PY 74/PY 175/ PY 83	*T. viridescens*	0	None	0.848
Artificially soiled acrylic paint films				
Paint color	**Mold treatment**	**Samples (#) with mold growth***	**Mean mold coverage****	**Mean paint film water activity (a_w)**
PW 6	*A. sydowii*	1	Low	0.826
PBk 11	*A. sydowii*	1	Low	0.826
PB 29	*A. sydowii*	3	Moderate	0.826
PG 7	*A. sydowii*	4	Low	0.796
PV 19	*A. sydowii*	3	Low	0.790
PY 74/PY 175/ PY 83	*A. sydowii*	2	Low	0.835
PW 6	*T. viridescens*	0	None	0.821
PBk 11	*T. viridescens*	0	None	0.814
PB 29	*T. viridescens*	1	Low	0.845
PG 7	*T. viridescens*	3	Moderate	0.790
PV 19	*T. viridescens*	4	High	0.801
PY 74/PY 175/ PY 83	*T. viridescens*	0	None	0.830

* Sample size (N) for each color is 4.

** The mold coverage of each sample was determined based on the following criteria: None = 0% coverage, Low = < 20% coverage, Moderate = 20-50% coverage, High = > 50% coverage. The amount of mold coverage was averaged between the 4 samples for each color.

Both clean and artificially soiled paint films that were incubated at 86% relative humidity were more susceptible to mold growth of both species after the thirty-one day incubation period. These paint films were also recorded as having higher water activity levels than those that were incubated at 76% relative humidity. The susceptibility of most acrylic paint films increased, at both 76% and 86% relative humidity levels, when an easily accessible nutrient source, the artificial soil formulation, was available on the surface of the substrate. Substrate water activity and the availability of an accessible nutrient source were observed to have the most significant impact on the paint films' susceptibility to mold growth. As acrylic paint films easily attract and imbibe dirt and can be subjected to high relative humidity environments, whether due to disaster situations or inadequate museum environmental controls, these results indicate that under certain environmental conditions modern paints are at risk to microbial colonization and subsequent biodeterioration.

Some pigments demonstrated more susceptibility to mold growth as both clean and artificially soiled films, namely the organic pigments PV 19 and PG 7. Figure 1 shows the growth of T. viridescens on an artificially soiled paint film of PG 7 after incubation at 86% relative humidity. Despite being synthetically derived, organic pigments are more susceptible to mold growth compared to inorganic pigments. Furthermore, due to their unique physical and chemical properties, pigments such as PV 19 and PG 7 often require the inclusion of additional additives and fillers in their formulations to produce a stable paint film, which may be providing an additional nutrient source for many molds, thus increasing the film's susceptibility to mold colonization.

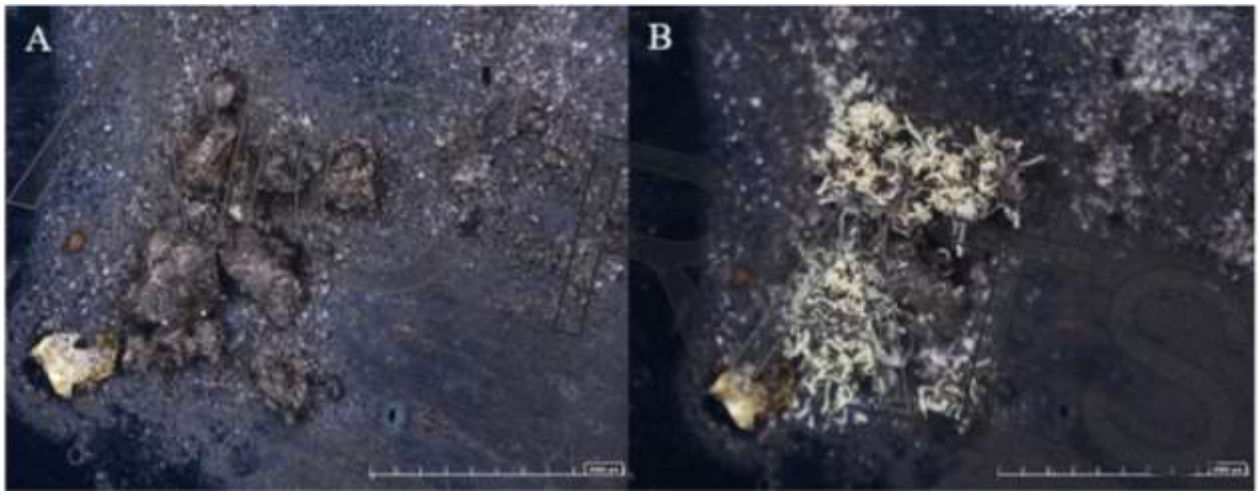

Figure 1 Digital micrograph comparing growth of T. viridescens on an artificially soiled PG 7 paint film before and after incubation at 86% relative humidity for thirty-one days. **A)** PG 7 paint film before incubation period. **B)** PG 7 paint film after incubation period .

This preliminary research has brought to light the need for a larger, in-depth investigation of the effects of mold growth on modern paint substrates, a much larger body of research that will work to further inform conservation efforts and potentially lead to the development of new treatments. Future research should prioritize the chemical analysis of modern paint films to

investigate how the presence of certain additives and their quantities may affect a film's susceptibility to mold, as well as investigating the susceptibility of degraded paint films when additive leaching has occurred, and studying the long-term effects of biodeterioration of modern paint films and appropriate conservation treatments.

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Scratch That: Conservation Treatment of Abraded Plastic, a Technical Study

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Keywords: Plastics, Polishing, Profilometry

Extended Abstract

Aging plastics create challenges for conservators attempting treatment, with scratches, abrasion, discoloration and other condition issues often arising. While cleaning and/or polishing these surfaces may improve the appearance, questions remain regarding which protocol to follow. This on-going technical study of aged Cellulose Acetate Butyrate (CAB) evaluates a commercial product marketed for plastic/acrylic objects, the NOVUS 7100 Plastic Polish system, which includes three compounds (1, 2, and 3) meant to be applied in sequence. Between 2013 and 2018 SBE Conservation LLC, a Brooklyn-based private objects conservation firm, conserved three vacuum-formed reverse painted UVEX (a commercial name for CAB) sculptures by Tom Wesselmann, created in the mid-1960s. These complex, large-scale objects presented a range of condition issues, including those related to fabrication stress, expected plastics degradation, and past restorations. The conservation treatments focused on overall stabilization of the fragile objects, visual reintegration of areas of plastic loss, surface cleaning and polishing, and replacement of the deteriorated backing. This comprehensive project served as the impetus for the study, which utilized samples of both discarded, aged CAB and recently manufactured "fresh" CAB. Samples of both plastics were abraded with 800 and 1500 grit Micro Mesh, in a uni-directional pattern, and then polished with the NOVUS system. Reflectance Transformation Imaging (RTI) was used to document the qualitative results of polishing. Optical profilometry was used to characterize the surface morphology and quantify the surface roughness; specifically, height profiles were obtained using a Nanovea ST400 optical profilometer, which uses chromatic confocal microscopy to determine pixel heights. Results showed that treatment with Novus 1 alone was not very effective as the difference in surface roughness between scratched and treated samples was minimal. Polishing with the addition of Novus 2 and 3 was much more effective as the roughness decreased significantly in these cases. Preliminary contact angle measurement

results were presented demonstrating significant differences between fresh and aged CAB in surface chemistry, but further investigation of changes in surface chemistry is planned to complement the analyses already performed. To this end, future research with accelerated aging is planned to allow assessment of long-term effects of different polishing techniques and materials, including questions of residues left on sensitive plastic surfaces.

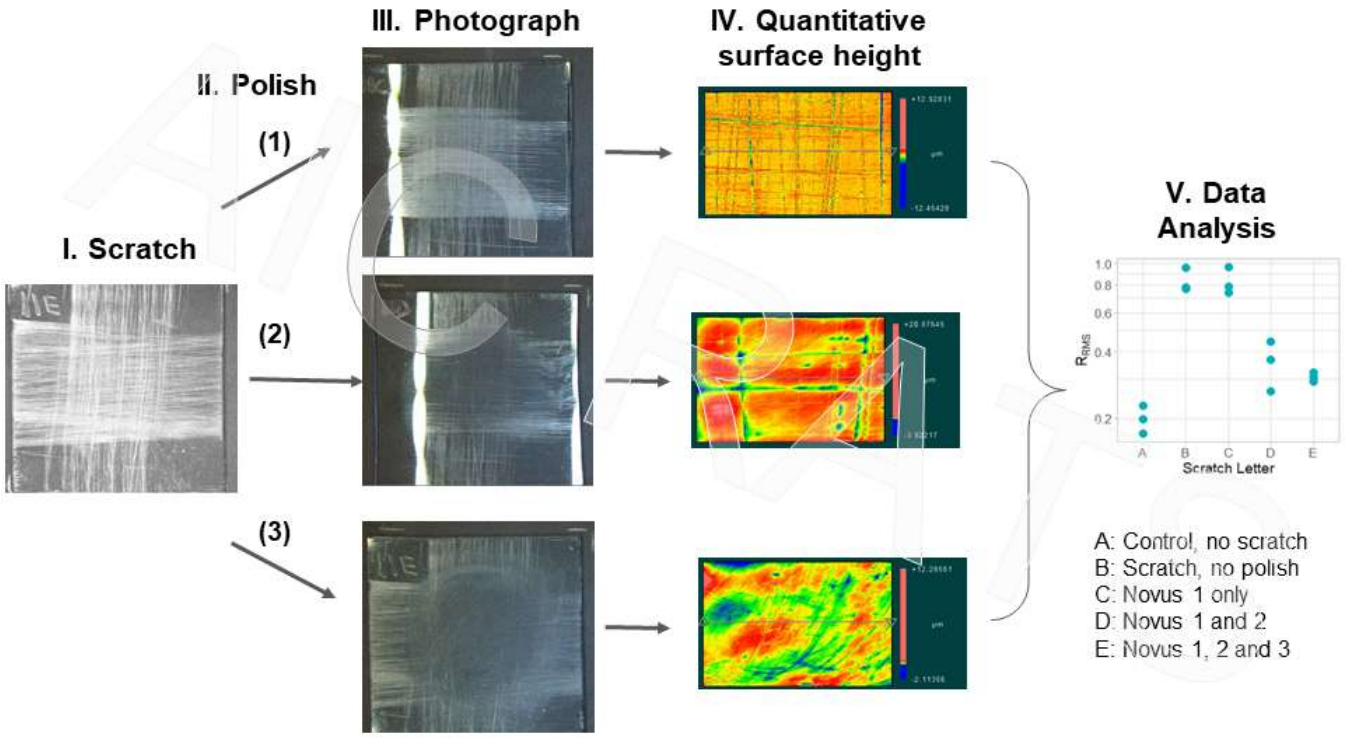

Figure 1. Overview of process flow in this study. (I) A subset of samples were scratched in a controlled manner, (II) A subset of samples were polished using three steps of the Novus®□ system, (III) Samples were photographed before and after scratches. (IV) Samples were measured via optical profilometry, and (V) OP data were analyzed using *R Analytics* to quantify the effect of scratching and the different polishing methods.