

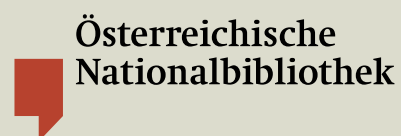
# Paper Conservation: Decisions & Compromises

ICOM-CC Graphic Document  
Working Group – Interim Meeting

Austrian National Library, Vienna  
17 – 19 April 2013



International  
Committee for  
Conservation



**Paper Conservation: Decisions & Compromises**

Extended Abstracts presented at the  
ICOM-CC Graphic Document Working Group  
Interim Meeting Vienna,  
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17-19 April 2013

Edited by LIEVE WATTEEUW and CHRISTA HOFMANN

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## Paper Conservation: Decisions & Compromises

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### Introduction

After a very successful 16<sup>th</sup> Triennial Meeting in Lisbon in 2011, our ICOM-CC Working Group of Graphic Documents continues to develop the themes of research and conservation practice for library and archival documents. The aim of the ICOM-CC Graphic Documents Working Group is unchanging: to gather and disseminate information from around the world on the conservation of all forms of documents, including, but not limited to, those on paper, parchment and papyrus.

The working program of the graphic document group 2011-2014 reflects the fast evolution in the professional field. The program has seven main targets focusing on research and practice, at object and at collection level, from diagnosis to imaging and digitalization. The objectives are situated in the following areas:

- Multidisciplinary projects dealing with the treatment of artifacts on paper, parchment and papyrus (such as manuscripts, printed books, albums, atlases, prints, drawings, architectural drawings, cartoons, scrolls, herbaria, collages, three dimensional objects in papier maché, etc).
- Imaging as support to the diagnosis and treatment of conservation issues with paper objects.
- The challenges of digitalization in the archive-, museum- and library- world (at collection level).
- The extent to which decision processes in the conservation of paper-based collections are influenced by changing views of the ethics of conservation.

- The mix of Western and Eastern traditions in paper conservation.
- Models for surveys and risk assessment of graphic documents collections.
- Growing competences in the field of paper-, library-, archive- and print- conservation.

The Interim Meeting of the Working Group Graphic Documents in Vienna (17 - 19 April 2013) on the theme Paper Conservation: Decisions & Compromise, provides a forum for the broad spectrum of activities our professional community is developing. Ever increasing competences are demanded of paper-, library-, archive- and print conservators by, on the one hand, the challenges of digitalization in the archive-, museum- and library- world, the global impact of changing cultural policies and economic constraints and, on the other hand, new research, new materials and new techniques. We realize that decision processes in conservation are influenced by changes in ethics, politics and science. In the light of this, conservators need to shape their professional profiles to these processes and to play their part as valuable partners in negotiations over the future of documentary heritage.

The publication of the extended abstracts of the 43 contributions to this Vienna Interim Meeting presents a fascinating overview of the current state of research, practice and progress in the field of paper, book and document conservation and preservation. We thank the Vienna organization team, coordinated by Christa Hofmann and the authors for sharing their skills, experience and knowledge.

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# New Trends in Preservation in the Digital Age: New Roles for Conservators

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## Introduction

The role of conservators has broadened during the last several decades. This is driven in part by changes in cultural institutions, such as the Austrian National Library, the Library of Congress and others, because they are now stewards of an ever-increasing variety of documents, written, imaged, or otherwise captured in multiple media and formats. As this interim ICOM-CC conference shows, these formats range from atlases and albums to architectural drawings; broadsides to books of hours and herbaria; codices to cartoons; iron gall ink manuscripts to medieval illuminations; parchments to prints and photographs; and wall paintings to wall paper. Add to this legacy motion picture films and recorded sound cylinders, cassettes, compact discs, and other electronic analog and digital media, and the scope of formats and resultant issues facing today's libraries, archives and museums (LAMs) can be daunting.

But there are several emerging trends that expand a conservator's capabilities in our digital age. This paper is intended to challenge conservators and other cultural stewards with a premise, a problem, and some solutions, based on those trends.

## Premise

There are billions of cultural heritage items requiring preventive and interventive conservation actions. This fact was documented in the US by the 2004 Heritage Health Index Survey of the nation's collections<sup>1</sup>, which showed that institutions holding primary source materials face the following specific challenges:

- Collections, which are in fact a cultural institution's business assets, are extraordinarily and increasingly, vast and complex, with a large percentage requiring preventive and/or interventive care. Consequently, more surveys of collection needs and demography are required to help cultural stewards prioritize the allocation of dwindling resources, based on value, use and risk criteria relevant to respective collections.<sup>2</sup>

- Institutional staffs often lack sufficient resources and, in some cases, training. Therefore, more educational opportunities such as the ICOM-CC conferences, and more innovations such as automation, are needed to maximize efficiency in the face of all too frequent staff reductions, especially as institutional responsibilities multiply.<sup>3</sup>
- Contemporary collections can be as vulnerable as any. It is imperative that more research into the needs of modern media is designed, funded, conducted and disseminated, before the records of our current-day accomplishments vanish without a trace.<sup>4</sup>

## Problem

Despite the desire for digitization to solve the problems of collection preservation, the fact is that collection complexity, exacerbated by inclusion of digital material, is growing, not slowing, while resources are reduced or reallocated to scanning projects. What can conservators do to stem the tide of loss of collections?

## Solutions

Conservators are among the most effective advocates for cultural stewardship. We can stem the tide of loss by harnessing digital technology to advance emerging trends in libraries, archives and museums. By harnessing these technologies, we can develop solutions for the preservation of original primary source materials to strengthen and advance the following:

- Science-based research for preservation, to support the needs of collections and conservators, and other scholars, through research and development (R&D).
- Cost-effective preventive preservation for improved access, to support efforts of cultural stewards through automated storage and display systems and environmental monitoring.
- Preservation partnerships and conservation collaborations with funders and allied associations, to support students and professionals through hybrid educational endeavors, such as webinars, online courses, and other exercises

including computer-simulated and decision-making modeling.

## Trends

The solutions above are reflected in three emerging trends that expand preservation capabilities of LAMs in our digital age, and are the focus of this paper:

- 1 Technological science-based research and development derived from collaborations among conservators and other experts in library, computer and materials science to extract evidential information from primary source material and to expand the useful life of collections.
- 2 Preservation and access developments for at-risk items of high value and use through cost-effective innovative storage and display systems, as well as environmental monitoring and control.
- 3 Methods to maximize minimum resources through national and international partnerships, including ICOM, IFLA, ICCROM, AIC, Heritage Preservation, and others.

These three trends are discussed more fully below.

### 1 Technological Research and Development

Collaborations among conservators and other experts trained in library science, computer science and materials science expand options for using and preserving the most seminal, vulnerable, and at-risk examples of our collective cultural heritage. These collaborations are increasing the amount of valuable information extracted from primary source materials for use by scholars, utilizing diverse forensic techniques.<sup>5</sup> Such collaborations not only preserve evidence inherent to primary source materials, but also extend the useful life of these materials, through development of decision-making tools for new treatments (as exemplified by Library of Congress work presented on iron gall manuscripts or other treasures such as Ptolemy atlases).

Other advances in forensic analysis, derived from CSI-like strategies and innovations, include hyperspectral imaging (HSI). HSI employs high resolution and false-color component analysis to characterize treasured items (such as Waldseemüller's 1507 *Universalis Cosmographia*, the map that "named" America). HSI can document changes in condition over time caused by natu-

ral aging. HSI can also reveal evidential content, such as text or unique identifiers, hidden or obscured by time (as exemplified in examinations of Jefferson's Rough Draft of the Declaration of Independence,<sup>6</sup> Lincoln's Gettysburg Address, or L'Enfant's Plan for the City of Washington).<sup>7</sup> Other advances have occurred in environmental scanning electron microscopy (ESEM), which can produce elemental "dot maps" using false color to identify chemical compositions, as well as reveal activation sites for deterioration in traditional and audiovisual materials. An ESEM chamber can simulate environments to mimic adverse conditions of temperature and relative humidity to image in real time their effects on collections, as a form of artificial accelerated aging. ESEM, along with HSI, can aid in prediction of useful life by tracking changes induced by simulating the effect of exposure to adverse environments of high temperature and relative humidity levels that lead to polymer chain scission from chemical breakdowns caused by thermal-oxidation or acid hydrolysis.<sup>8</sup>

The information derived from these and other techniques can be combined to produce a composite digital image of a document, in effect a virtual "digital object" enhanced by "scripto-spatial" analysis, akin to GIS mapping. This aids authentication through detection, revelation and mapping of unique identifiers or other special features. To house the resultant vast complex of data, the Library of Congress developed a state-of-the-art Center for the Library's Analytical Scientific Samples (CLASS). CLASS houses physical collections (such as TAPPI Fibers, Forbes Pigments, and many others), and provides a database framework for accessing scientific information derived from sample and historic collections. It is intended to foster international scholarly studies of the Library's unique reference sample and other data to advance science and scholarship.<sup>9</sup>

The Library of Congress has invested in other R&D projects to advance preservation and access, included in the discussion below.

### 2 Preservation and Access Developments

Recognition of the importance of environment on reducing change in, and risk to, primary source material has spurred investments in R&D to improve preventive preservation. Integrated automation systems have streamlined detection



and monitoring against adverse environmental changes, as exemplified by the various climate monitoring systems developed by the Image Permanence Institute (IPI).<sup>10</sup> IPI research supports the principle of reducing thermal- and photo-oxidation through cold, dark storage systems. A salient example of cold storage, maximized by high-bay shelving, is the Library of Congress new storage complex at Fort Meade.<sup>11</sup> Other examples incorporate sustainability through naturally cool environments, such as underground or mountain storage, as in the National Library of Norway facility in Mo-I-Rana.<sup>12</sup>

Cold, dark storage can reduce the effects of thermal- and photo-oxidation. But these effects can also be moderated by reducing the levels of oxygen, through low-oxygen or anoxic storage. An example of the principle of low-oxygen storage is the British Library's Boston Spa storage facility, planned to combine cold storage with robotic retrieval in an atmosphere of low oxygen levels.<sup>13</sup> These environments are intended as fire prevention systems, but they also may have some effect in controlling object aging and pest infestation, especially in anoxic environments.<sup>14</sup>

For exhibition, anoxic, hermetically-sealed "visual storage" cases for treasured collections on display, such as the Library's Waldseemüller Map, have been developed in partnership with the National Institute of Standards and Technology (NIST).<sup>15</sup> The notion of "visual storage" has been maximized by several Smithsonian Institution museums through the use of diverse compact storage techniques. The Smithsonian American Art Museum has entire galleries with public displays on movable racks.<sup>16</sup> The Smithsonian's Museum Support Center has further examples of innovative adjustable and compact systems, employing cabinets and shelves that move in innovative lateral-track directions, as well as in the perpendicular-track direction found in many library compact shelves. These compact shelving systems can be hand-driven or automated.

Automation has also enabled more cost-effective mass preventive care through computerized box-making and mat-cutting systems, which help containerize items on display or in storage. Such containerization at the item- and collection-level is important, as well, for emergency preparedness, and is maximized when supplemented by

further containerization in furniture and room design, especially when reinforced by innovated fire prevention, detection and suppression systems.<sup>17</sup>

A salient example of the principle of cold storage, containerization and tailored fire suppression systems is the National Audiovisual Conservation Center on the Packard Campus of the Library of Congress in Culpepper, VA, which among other innovations including underground cold storage vaults, has cubby niches and innovative sprinkler designs for safe storage of highly flammable and self-combustible early nitrate film.<sup>18</sup>

Recognition of the importance and extreme vulnerability of analog and digital audiovisual collections, which are most reflective of our current cultural creations, has led to substantial investments in R&D at the Library. Enhancements in digital imaging technologies, developed with the Lawrence Berkley National Laboratory (LBNL), have resulted in the "IRENE" machine and newer confocal imaging devices for sound reproduction from unplayable audio recordings, including cylinders of indigenous languages (such as the now extinct Yahi tribe). This technology is so sensitive it can even capture sound from soot on paper (in the earliest phonautogram) or from emulsion on glass (part of Alexander Graham Bell's work) and other experimental recordings of human voices. Current efforts seek to make the "IRENE" technology portable enough to serve collections worldwide.<sup>19</sup>

Developments such as this enable conservators and other cultural stewards to directly assess and prioritize needs for at-risk collections. Similar efforts focus on developing other portable instruments with innovative, and integrated, analytical programs, such as a portable Fourier Transform Infrared Spectrometer (FTIR) programmed to detect chemical markers of degradation in audiotapes with "sticky shed" syndrome, which renders tapes unplayable.<sup>20</sup>

Other trends further access to the intrinsic and associative value of collections by producing "digital objects" while also promoting initiatives in preservation of digital assets. Studies in natural and accelerated aging of digital collections have characterized the vulnerability of



current electronic physical formats such of CDs and DVDs.<sup>21</sup> More reliable media are needed. One candidate is DNA, which has myriad advantages as an encoding system, from a preservation and information management perspective.<sup>22</sup>

### 3 Maximization of Minimal Resources through Partnerships

Partnerships, like the aforementioned examples with IPI, NIST and LBNL, promote preservation possibilities, especially when supported by public and private funders and associations such as AIC, ICON, ICOM, ICCROM and IFLA. Examples of powerful partnerships that will advance preservation of collections include the following:

- Digital Preservation Groups, such as that at the Library of Congress, which promotes preservation of digital formats most at risk, by developing guidelines based on best practices of life cycle management.
- National Endowment for the Humanities/ National Digital Newspaper Program, which provides a model for preservation of at-risk collections by its initiative to preserve newspapers through digitization from microfilm.<sup>23</sup>
- Council on Library and Information Resources' Digital Humanities Fellowship, which advances scientific studies of primary source materials.<sup>24</sup>
- Andrew W. Mellon Foundation's Grant for Library and Archives Conservation Training, which aims to advance graduate training through partnerships among institutions such as the Library of Congress.<sup>25</sup>
- Heritage Science Programs, such as that at the University College of London (UCL), to advance the new discipline of heritage science within university STEM (science, technology, engineering and math) curricula, as supported by national science agencies.<sup>26</sup>

#### New roles for conservators

Conservators have long recognized the importance of materials science in assuring the long-term efficacy of our efforts. We now have new opportunities to exploit advances in computer science, particularly in the fields of imaging and data analysis, facilitating the emerging discipline of digital humanities. Partnerships with our computer savvy counterparts can ultimately lead to innovations that, for instance, enhance conservation treatment training through computer simulation incorporating haptic biofeed-

back technology, similar to that used to train medical surgeons.<sup>27</sup> This, particularly if coupled with the development of expert systems for decision-making, can extend our skills and judgement.

We need to continue to promote surveys to document and prioritize collection needs, incorporating new endeavors that leverage economies of scale, such as UCL's collection demography survey, or, in the US, the upcoming second Heritage Health Index Survey planned by Heritage Preservation to capture changes in stewardship, awareness and needs during the last decade.

Finally, we must educate ourselves to recognize the pressing needs not only of our traditional collections, but also of the most vulnerable media in our audiovisual and digital collections, which are the legacy of our own era.

#### Conclusion

The trends described in this paper, which are becoming more prevalent in major institutions tasked to preserve our collective cultural heritage, aim to maximize today's minimal resources through expanding preservation capabilities and partnerships. Despite economic limitations, we are all compelled to recognize our responsibilities to sustain and conserve our cultural resources, just as we do our natural resources, though development of information and educational outreach initiatives.<sup>28</sup>

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### Notes

- 1 For more on the Heritage Health Index, see: <http://www.heritagepreservation.org/hhi/>
- 2 The topic of survey techniques is not covered in this paper, but for information on preservation priority surveys to compare and group collection needs for conservation treatment and general care, and random sampling surveys to determine resource allocations for vast and diverse collections, as well as item level surveys, see: Van der Reyden, D., H. Tennison, F. W. Tsai, and M. Parish. "An 'Angel Project' of Dinosaur Proportions." *Book and Paper Group Annual 15* (1996): 145–160. <http://cool.conservation-us.org/coolaic/sg/bpg/annual/v15/bp15-18.html>
- 3 To address educational challenges, a symposium funded by the Getty and organized by the Library of Congress on Preservation Education in the 21st Century, published a report available at: <http://www.loc.gov/preservation/outreach/symposia/preseduc.html>
- 4 For an example of a national scientific research agenda addressing the needs of collections, see: <http://www.loc.gov/preservation/scientists/>
- 5 For more on return-on-investment science-based resources for preservation, see: Van der Reyden, D. "The Science-Based Fight Against 'Inherent Vice.'" *International Preservation News*, 50 (2010): 5-10. [PDF: 2.2 MB / 44 p. (entire issue)] <http://www.ifla.org/files/pac/ipn/50-may-2010.pdf>
- 6 See article by the Washington Post's Marc Kaufman on "Jefferson changed 'subjects' to 'citizens' in Declaration of Independence", on July 3, 2010 at <http://www.washingtonpost.com/wp-dyn/content/article/2010/07/02/AR2010070205525.html>
- 7 See France, F. "Best Practice and Standards in Environmental Preservation for Cultural Heritage Institutions: Goals, Knowledge, Gaps", British Library Conference: Advances in Paper Conservation Research, 23-24th March 2009, at <http://www.bl.uk/aboutus/stratpolprog/ccare/events/France.pdf>.
- 8 For more on the chemistry of degradation, see: Van der Reyden, D. "Recent Scientific Research in Paper Conservation." *Journal of the American Institute for Conservation* 31, no. 1 (1992): 117–139. [http://cool.conservation-us.org/jaic/articles/jaic31-01-014\\_idx.html](http://cool.conservation-us.org/jaic/articles/jaic31-01-014_idx.html)
- 9 For more information on CLASS, see <http://www.loc.gov/preservation/scientists/projects/class.html>
- 10 For this and other innovations from IPI, see <https://www.imagepermanenceinstitute.org/>
- 11 For more on Fort Meade, see <http://www.loc.gov/preservation/resources/misc/fortmeade.pdf>
- 12 or more on Mo-I-Rana, see Myrbakk, G. "Mountain Vaults: a thousand years perspective" at <http://www.ifla.queenslibrary.org/iv/ifla71/papers/153e-Myrbakk.pdf>
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## The Albums of Duke Charles de Croÿ: Consolidation and Modified Re-housing of Double-sided Miniatures on Parchment in Bound Volumes

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The ongoing conservation project of the so-called Croÿ-albums, Codices Miniati 49 and 50, part of the collection of Manuscripts and Rare Books at the Austrian National Library, involved an unusually wide range of possibilities and several levels of decisions. The large number and the size of the objects to be treated multiply the consequences of choices.

The albums make up a total of 15 Baroque red leather bindings which contain a total of 423 parchments measuring from 51,0 to 54,0 cm by 38,0 to 40,5 cm. The skins were painted on both sides, thus acting as supports for 846 gouache paintings. These pieces are a portion of an original collection of reportedly about 2500 objects assembled in 23 volumes. They were commissioned by Duke Charles de Croÿ d'Arshot (1560 – 1612) during the Spanish regency of the Southern Netherlands and depict views of those territories which enclose areas of today's Belgium, Northern France and the Netherlands. They were executed between 1590 and 1611 by the artist Adrien de Montigny (d.1615) and his workshop after detailed land registers.

The large collection was sold and thus dispersed after Duke Charles de Croÿ's death. Today paintings are in the collections of various European institutions and private owners. The pieces from the Viennese Croÿ-Albums were acquired by Duke Charles of Lothringen (1712 – 1780); it is assumed that he bought the paintings at three auctions. They were incorporated into the imperial collections and the royal geographer, Abbé Palquois de Reigniere, arranged the order of the parchments after 1753. The sheets were adhered to paper mats with animal glue. These were bound into albums with alternating supporting pages of rag paper. Today we consider these Baroque volumes containing the parchments as historic, but not original since they are not the first presentation of the pieces.

The albums reveal some conservation history: in the mid-1970s the parchments were removed



Fig. 1: parchment sliding out of polyester pocket, adhesive tape lost in the tail area

from the books because of severe cockling and heavily-flaking pigments due to material tensions and friction. The paper frames were cut off leaving a fold about 4 cm wide in the book. After removing the parchments from the paper frames, conservation treatment consisted of consolidating the paint layer. Parchment glue was sprayed over the surface several times after pre-treating the sheets with ethanol. The skins were flattened after humidifying and stretching. Eventually the individual sheets were placed into transparent polyester pockets which were attached onto the remaining folds with synthetic adhesive. The pockets, open at the top and bottom, were partially secured with transparent pressure sensitive tape, allowing some air circulation. Additional slits were cut into the fore-edge of the pockets to allow further air exchange.





Fig. 2: detail with losses and loose pigment flakes (raking light)



Fig. 3: feathered hinges attached along the edge on the verso of a painting

Besides the visually disturbing “plastic feeling” within the shiny polyester pockets, the current problems of the paintings include their sliding within the partially creased pockets when turning pages (Fig. 1). Abrasion occurs as well as static charges which endanger loose pigments (Fig. 2). Some of the tapes’ adhesive has migrated into the supporting paper, some of the carriers have fallen off.

The range of possible conservation interventions to secure the condition of the Croÿ-Albums included doing nothing (leading to denying access to the objects for readers), minimal intervention (replacing the pressure sensitive tapes), as well as an overall treatment (remounting the parchments within the Baroque bindings). The extreme intervention considered was to remove the paintings from the books and to re-house them in individual double-sided matboards stored in acid-free boxes.

Creating a decision-making tree helped to visualize the complexity of the issues involved and to better understand common points and differences between the various options. The treat-

ments’ impacts were discussed considering the factors of safety for the objects, practical feasibility, time (labour costs, balancing priority with other projects), material costs (custom-made rag paper for frames, Japanese paper for protective sheets, archival quality matboards) as well as a possible increased need of storage space. The common requirements for the time-consuming invasive interventions (remounting or removing from the bindings) were the consolidation of the flaking paint layers, and to ensure safe handling of the objects in order to allow a careful although restricted use of the valuable paintings. Some of the theoretical treatment options, like remounting each parchment in a paper frame reflecting the Baroque mounting, were ruled out after evaluating the results of practical tests and mock-ups.

Considering the importance of the Croÿ-albums, a cost- and time-intensive overall treatment seemed justified. Finally, the choice was made to remove the polyester pockets from the books and to attach the consolidated parchments with adapted T-hinges to the supporting paper pages.

A few paintings with very fragile paint layers and heavy pigment losses will not be remounted into the books but kept separately in double-sided matboards.

The estimated timeframe per treated volume is roughly 300 working hours.

A positive side-effect of this long-term project, during which each of the parchments needs to be handled, is the chance to digitize the paintings after consolidation before remounting. The availability of high quality digital images facilitates access to the content of the valuable miniatures. At the same time it permits to strictly limit the physical use of the fragile originals.

For areas with poor adhesion, consolidation is realised with gelatine 1% w/v in water (Gelita Novotec GP Type 73 189 technical grade, type B) using an ultrasonic mister (AGS 2000, ZFB). For flaking areas the gelatine is applied 2% w/v with a thin, long-hair brush (5/0 da Vinci, Nova Synthetics). Hinges of Japanese paper (Paper Nao RK-38, 16g/m<sup>2</sup>, 3 x 2 cm) are attached along the left edge on the back of the treated parchment using a mixture of wheat starch paste and Methocel A4M 2.5% w/v (spacing 0.7 cm) (Fig. 3). A sheet of strong, yet smooth and slightly translucent Japanese paper (Paper Nao RK-19, 32g/m<sup>2</sup>, 59 x 46.5



Fig. 4: turning the supporting paper between the verso of the left painting and the protective sheet of Japanese paper over the recto of the right painting

cm) is placed over the recto of each gouache and pasted over the hinges onto the supporting paper with Methocel A4M 2.5% w/v. This construction protects the painting's surface while reinforcing the row of hinges. Careful handling allows turning the pages without the risk of sliding and friction (Fig. 4). An illustrated instruction sheet has been designed for curators showing the handling of the parchments in the books step by step.

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# A 1763 Illuminated Haggadah Manuscript: How Ineffective Past Treatments Resulted in an Antioxidant Research Project, Impacting Current Treatment Decisions

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This 1763 Altona Haggadah (Fig. 1 ) is a mid-eighteenth-century illuminated manuscript from the Lowy Collection of Library and Archives Canada (LAC). The manuscript is particularly important as it does not represent high book art, but gives testimony to the way a middle class Ashkenazi family of the 18th century would have celebrated Passover. The text is accompanied by 97 illuminated miniatures and a fully illuminated frontispiece. Analysis of paper, ink, pigments and coatings from the manuscript was undertaken using Fourier transform infrared spectroscopy (FTIR), energy dispersive x-ray spectroscopy (EDS), scanning electron microscopy (SEM), x-ray diffraction (XRD) and/or polarized light microscopy (PLM) at Canadian Conservation Institute (CCI) (Helwig, Corbeil: 2009).

The text is written in iron gall ink and the pigments used in illuminations are predominantly red, blue and green. They were identified as dry process vermilion or cinnabar, Prussian blue, and atacamite/paratacamite (copper chloride hydroxides). Unidentified yellow, glaze-like paint is very thinly applied. Gold toned colours were found to be composed of brass flakes. The colours are transparent and the pigment vehicle is hard and glossy. Lighter colours are also present although these are less concentrated dispersions of the same red, blue and green pigments. Gum was identified as the only binding media present.

The paper support is in fragile condition due to iron gall ink and copper containing atacamite corrosion. On several pages, ink had penetrated to the verso of the page, making the text difficult or impossible to read. It is unevenly discoloured and stained throughout. Handling and use is the cause of much of the grime around the edges of the folios. There are large brown liquid stains on several pages caused by splashed red wine, most probably during the ceremonial Passover meal.



Fig. 1: Frontispiece of the 1763 Altona Haggadah, from the Jacob M. Lowy Judaica Collection, Library and Archives Canada, (BM674.6 A3 1763 xxfol. LOWY)

## Past Conservation Treatment Highlights

1987 examination revealed that deterioration of the paper was further advanced in areas of densely applied iron gall ink (Fig. 2) The green copper pigment had also caused similar deterioration of the paper. Treatment in 1987 included dismantling the manuscript and deacidifying the pages with solvent based Wei T'o #2 solution (methyl/ethyl magnesium carbonates in 1,1 Dichloro-1-Fluoroethane (HCFC-141B) and methanol). This was followed by tissue repairs using carboxy-methyl-cellulose as an adhesive.

Examination In 2007 revealed many new cracks and losses throughout the manuscript. It



Fig. 2: Close-up of some of the losses found in heavily inked areas of the manuscript.



Fig. 3: Pigment samples being pre-aged in LAC's humidification chamber

was evident that the deacidification treatment of 1987, had been unable to completely protect the paper from continued deterioration caused by the iron gall ink and atacamite pigment. The poor 2007 condition of the Haggadah prompted discussions about the need for further conservation treatment, required to effectively delay damage caused by oxidation, catalyzed by copper and iron in the inks and pigments.

Due to the water sensitivity of many elements in the manuscript, only non-aqueous methods could be considered for future treatment. Solvent based antioxidant treatments were still at the experimental stage at that time and required further research before they could be applied to originals.

Until an appropriate treatment could be found, it was necessary to mechanically stabilize the damaged and fragile areas of the manuscript. Berlin tissue, one of the lightest tissues presently available, was coated with gelatin and used as a remoistenable tissue. Recent studies have shown that type B gelatin with a high or medium Bloom, is effective in preventing migration of free iron (II) ions (Kolbe 2004). The coated tissue was reactivated in situ on the suction table, using an ethanol/water solution (Pataki, 2009).

At this point, a joint research project was developed between Library and Archives Canada and the Canadian Conservation Institute, to investigate treatment options for the Haggadah.

### Joint CCI / LAC Research Project Highlights

The paper, inks, pigments and experimental conditions were selected based on a review of recent studies and literature. We chose verdigris and atacamite as the pigments, Iron gall ink and iron gall ink with copper as the two types of ink. The European co-founded InkCor project, identified a number of antioxidants that can be used in solvent based solutions. Halides were among the most effective for treatment of both iron and copper inks and pigments (Malesic et al. 2005 and 2006; Kolar et al. 2008). We chose Tetrabutyl ammonium bromide (TBAB) and 1-ethyl-3-methylimidazolium bromide (EMIMBr) as the two antioxidants for the project. For deacidification, we chose WeiT'o, to simulate the past treatment of the Haggadah and Bookkeeper spray, as it is widely used in conservation.

Sample preparation (Fig. 3), treatment methods and detailed results of this project are available in the 2012 AIC Book and Paper Group annual (Tse et al. 2012).

### Brief Summary of Results

#### Ink Samples:

Both WeiT'o and Bookkeeper improved the paper strength with both types of ink samples. They also increased the pH of the two inks, though not all of the acids were neutralized, as the inks remained acidic. This acidic pH means that deterioration of paper will continue, but it will be slower than without treatment. In the ink



Fig. 4: The Rebound manuscript with the antioxidant impregnated interleaving

samples, the addition of antioxidants showed no improvement in paper strength over deacidification alone. The addition of antioxidants did not influence the pH before or after aging.

#### Verdigris Samples:

Deacidification alone resulted in a slight improvement of paper strength and the addition of an antioxidant did not affect the pH of the samples. WT deacidification, followed by an antioxidant, did not improve paper strength substantially, though the antioxidant and Bookkeeper treated samples showed some improvements, especially with EMIMBr.

#### Atacamite Samples:

The antioxidant treated samples showed a marked improvement over just deacidification alone. Though both antioxidants were effective, the antioxidant/Bookkeeper combinations gave the best results for this sample group.

#### Research Project Conclusions:

This study indicates that the benefits of the two antioxidants are not evident when the inks are still acidic. Deacidification treatments do not automatically ensure neutralization of all the acids, so it is important to verify the pH of the ink lines on the manuscript, not just of the surrounding paper (Tse et al 2012).

Past WeiT<sup>o</sup> treatment of the Haggadah improved the pH of the paper and though the ink is still acidic, we believe that the WeiT<sup>o</sup> treatment has delayed corrosion. Deacidification was necessary but not sufficient by itself.

Though this study has added to the body of knowledge available on antioxidant treatments, we hope to gain confirmation of our results

through current and future studies, including similar work being done at the Austrian National Library, for example, before committing to a specific antioxidant treatment for the Haggadah.

### Re-binding the Haggadah

As the Haggadah at this point remained disbound and antioxidant treatment possibilities required further confirmation before being considered, discussions took place regarding the re-binding of the manuscript. In the end, it was decided to rebind the manuscript and that the contemporary cover boards would not be re-used for two reasons. First, the valuable evidence of past bindings and repairs would need to be removed, in order to improve flexibility and allow reattachment of the cover. Second, reusing the covers would limit the board re-attachment methods to those using sewn supports, either laced or cased. These traditional structures can cause compression of the spine during opening, resulting in arching of the pages, which places the manuscript support and media at serious risk.

The condition of the Haggadah, combined with other important factors, defined the requirements for a new binding structure. Also, to prevent the spread of copper and iron II ions further into the paper, only non-aqueous adhesives could be used for spine linings and other binding procedures. A second requirement was the inclusion of interleaving. The type of paper, method of attachment and whether to add an alkaline reserve to the interleaving, with or without an anti-oxidant buffer, were all taken into consideration.

To prevent physical damage to the fragile



manuscript paper, the binding would need to lay completely flat when open, avoiding stress on the paper folios and arching of the pages. The options for binding structures would need to consider the sewing method, spine shape, spine lining and board attachment method. Reversibility was also essential for the binding. Planning ahead for possible antioxidant treatments which would require dis-binding, meant that the sewing, linings and covers had to be removable without causing damage to the manuscript. To provide for long-term preservation of the manuscript, the use of recognized techniques and archival quality materials was essential.

Research and sample mock-ups resulted in a suitable binding option. The sewing method selected required minimal manipulation of the text block. The binding would have a flat opening, supple boards, little or no change in dimensions and would require very little use of adhesive and to improve the ageing properties of the manuscript indirectly, interleaving papers were impregnated with an alkaline buffer and antioxidant (Hansen, 2005).

The stabilized Haggadah has been digitized due to its restricted access and is stored in the dark, in a controlled environment of 18 degrees Celsius and 40% RH, awaiting possible antioxidant treatment in the future (Fig. 4).

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# The Conservation of the Hussite Codex (Mus.Hs.15492) Considerations on Minimal Intervention

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Fig. 1: before conservation

This paper discusses considerations on minimal conservation intervention, using the example of the Hussite Codex, which is in the collection of the Department of Music at the Austrian National Library in Vienna.

## History<sup>1</sup>

The Hussite Codex is one of the most famous graduals (books containing antiphons and choral music) of Kutna Hora (Czech Republic). Known as Hussite Codex or Smisek Gradual, this gradual is called the Hussite Codex because it contains illuminations showing scenes of the life of the reformer John Hus<sup>2</sup>, while its other name, the Smisek Gradual, reflects its original ownership by Michal Smisek of Vrchoviste, who commissioned it from Matthew's workshop in Prague. A note on the last page of the manuscript records 1491 as the year of completion.

## Miniature painting

The gradual is extensively illuminated. A large part of the first page is gilded. Beneath a picture of the Madonna, the Smisek family is portrayed. All initials are decorated, either with ornamental patterns or in figurative paintings.

The first page of each choral is lavishly illu-

minated as well, for example with scenes of the life of Jesus Christ or motives including vines, angels, birds or fruits.

## Technical description

The object is very large and heavy, measuring 63 cm in height, 42 cm in width and 21cm thick. All together it comprises 491 parchment leaves. Because of its size and the substantial metal fittings the Hussite Codex weighs 42 kg (Fig. 1).

The textblock is sewn on 6 double cords made of leather plus two cords for the endbands. The leather of the cover is blind-tooled. The arms of the commissioning client is situated in the middle of the board. There are two huge clasps at the front, one of which is engraved with the year '1562'.

Another important detail: the headbands were plaited, which means that the strips of leather are sewn around the primary headbands as well as through the leather of the cover. As the primary headbands are part of the sewing, the cover of the spine is fixed to the textblock on head and tail.

This detail will play a significant role in our considerations on conservation treatments.

## Damage

The parchment of the textblock was in good condition, though there were minor losses or abrasions on the illuminations.

The greatest damage and at the same time the greatest challenge was the fragile connection between textblock and the upper board.

The upper board was connected with the textblock by just two strips of parchment backing and two weak and deteriorated double-cords as the leather of the cover, most of the backing and the flyleaves were broken in the upper joint. Due to this damage in combination with the weight of the front board every opening of the manuscript could have led to a total separation of board and textblock.

The leather of the spine is very brittle and was also already broken at the joint to the lower



Figure 2 partial sewing: the blue dental floss in the injection needle

board over the length of some centimetres. In the event that the manuscript is often used, the damage is likely to become more extensive and the leather could break further.

### Considerations for a conservation concept

The aim of the conservation treatment was to strengthen the connection between textblock and upper board in order to relieve the two weak double cords of their great burden and prevent them from breaking.

Conventionally, the broken cords could have been reconnected and the torn leather would have been glued with a new strip of leather. However, it would have necessitated the removal of the metal fittings so that the leather on the upper board could have been lifted up. Solid leather conservation at the spine would also have required undoing the plaited headbands, because of which the leather of the spine could not be lifted up. Thus the opening between leather and textblock only extended to a width from about 1 to 4 cm. This implicates that there was not much space left to work and it would not have been possible to provide steady counter-pressure for glueing the leather together, because the spine is hollow as it was not rubbed in between the raised double cords.

Each of those considerations would have meant a great intervention into the original structure.

Leather conservation alone would not have affected the stability needed to support the cords. Nevertheless it was necessary to do something about the broken leather, as it stuck out

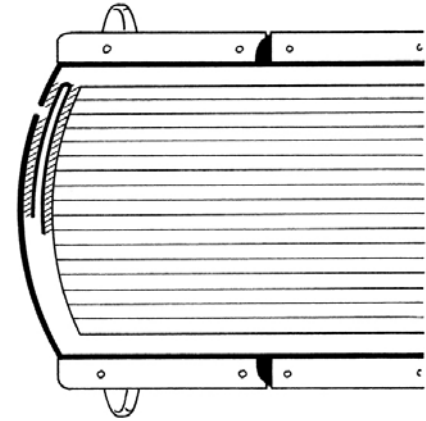


Figure 3 “half” paper tube glued to the spine of the textblock and the reverse side of the leather

and therefore was in danger of being damaged through handling.

As the abovementioned possibilities were excluded, we decided to apply an additional backing as well as a fold around the first section. Both the backing and the fold should extend onto the upper board thus stabilizing the connection to the board to some extent.

The second question was what to do about the broken leather, as we decided it was necessary to at least do something about it. Due to the technical details described earlier, it would not have been possible to close the tear with one piece of new leather as there was not enough space nor the possibility to press it.

### Conservation report

First, all illuminations were consolidated with the ultrasonic nebulizer with a 0.5 % gelatine solution.

The pastedown of the upper board was lifted up with a metal spatula. A fold made of linen was put around the first section. It was cut around the cords, so that it could be put around the section without cutting the sewing thread. The linen was glued to the verso of the first section with starch paste.

The next step was an additional spine lining. New strips of linen were glued onto the original lining. The spine was brushed with glue while the linen was brushed with wheat starch paste. As the gap between the spine of the textblock and the leather only had a maximum of 4 cm, it was not possible to glue it across the whole



width of the spine. We thought this to be acceptable as the original vellum lining was still intact and was very stable in those areas.

For further stabilization the first section as well as the spine lining was partially sewn to the first sections. There was insufficient space to do the sewing in the usual manner.

#### Workflow of partial sewing (Fig. 2):

Due to the strength of the parchment the holes had to be pre-stitched with a pricking awl. To pull the thread through the section a threading aid (dental floss) was used. As the floss was too flexible despite the pre-stitching, in most cases it still could not be pulled through the hole in the section fold. Therefore a thick injection needle was used as a temporary inflexible lead to pull the thread through. The injection needle was manoeuvred through the section and while the floss was held in place, the needle was removed. Now the thread could be threaded into the floss and be pulled through the leaves.

After partial sewing the loose linen folds were attached with animal glue to the inner side of the upper board. The paste-down was glued with rice starch paste into its original position.

The next step was to stabilize and consolidate the broken leather at the spine. It would not have been possible to close the tear along the whole length, and as there was no way to press it, the old and new leather could not have been glued together firmly. Therefore the tear was just closed in between each cord under the original leather.

The material used was linen lined with Japanese paper. It was sprayed with Aero Color<sup>3</sup> dye and was cut into strips which match the distance of the cords. It was worked similarly as a “half” paper tube (Fig. 3), as it was open on one side covering only the half width of the spine.

First of all one side of the linen fold was glued to the spine of the textblock with animal glue and wheat starch.

The other half of the linen fold was glued to the spine leather. For drying it was supported by two boards of Vivak<sup>4</sup>. These had been cut to two different templates to allow each to be pulled beneath the leather of the spine; the smaller one could even be pulled through the narrow slit above a double cord. The templates overlapped slightly to provide the necessary counter-pres-



Fig. 4: Vivak templates for supporting the spine leather and linen glued together to press it while drying

sure (Fig. 4). From the outside it was pressed with a screw clamp put on a sheet of polyester felt and a board of wood.

#### Conclusion

The conservation treatment presented effected the stabilisation of the connection between textblock and upper board. Due to its great weight the upper board should still be supported carefully when moved.

The torn leather was consolidated with the strips of linen to prevent its edges from tearing.

Nevertheless it is recommended that access to the Hussite Codex should be largely restricted. The leather of the spine is very brittle, so it is probable that at some time it will also break in the lower joint.

Therefore, the manuscript should not be opened further than to an angle of 90° and only while being supported carefully.

#### Endnotes

- 1 Fritzschn, K.E., „Die Kuttenerberger Bergbauminaturen des Illuminators Mathaeus“, *Deutsches Jahrbuch für Volkskunde*, 1960 (Bd. VI), pp. 213-228
- 2 Jan Hus, Theologist and Reformer, born 1369, died 1415 as martyr
- 3 Aero Color is a fine spray colour on acrylic basis.
- 4 Vivak is a transparent copolyester board, thickness 1,5 mm.

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## Books in Exhibitions: History and Adventures in Display

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### Introduction

The history of display of manuscripts and early printed books is shifting from the age when they were in use, to an epoch wherein their physical presence became a tangible mirror of a far and distant past. Our contemporary understanding of an 'exhibition', from the latin *exhibere* (to hold out, display) stems from the 19<sup>th</sup> century on the concept of a 'large-scale public showing'<sup>1</sup>. However, the display of books and documents on shelves and lecterns is starting from the early Middle Ages on. We find evidence of this in medieval paintings and illuminations, illustrating scriptoria, writing desks, *armaria* and *studiolos*. The display of books didn't refer to aesthetics, but to wealth, devotion and erudition. Overall, books and documents were displayed in public places like churches, to strengthen their legal

and devotional importance or to commemorate. In this perspective, these early displays are antecedents of the modern concept of an exhibition. Complementary to iconographical sources, archival and literary texts are revealing the close attention for security and physical integrity which the owners and custodians of books had in the dawn of book display. From the end of the 18<sup>th</sup> century on, but prominently from the middle of the 19<sup>th</sup> century, medieval and early printed books left the closure of their repositories and through the modern exhibition, became part of a new form of visual culture. As a result of this approach, custodians and librarians were increasingly pressured to permit books out of their secure storage, and sources reveal occasionally a severe resistance to this trend of public displays. Restorers -as craftsmen- were in service of this changing vision and function of the early book heritage. This essay will shed light upon these early tensions between conservation and exhibition by presenting and discussing the documented evidence we have of medieval and modern displays.



Fig. 1

### On book niches, grills, curtains, glass and chains: Examples of display of books in the Middle Ages

Security was certainly the main issue during the public display in the Middle Ages, as medieval churches functioned not only as places of prayer, but as trade, market and negotiation centres. A number of entries in the Antwerp chapter's accounts of the Church of Our Lady around 1500-1503 mention 'metal windows' to protect books. Donors specified in their wills that books must be kept in a safe place. Johan von Heinsberg (1419-1455), Prince-Bishop of Liège, was aware of the potential risks and in 1424 issued a decree that taking, copying or damaging the all-important deed known as the *Paix des Douze* which was kept behind bars in a recess in one of the columns of St Lambert's Cathedral, would be punishable by the loss of a hand<sup>2</sup>. In 1449 the



Fig. 2

chaplain of St Brice's Church in Tournai gave a breviary to the church on strict condition that it would be kept safely behind iron bars in a niche in the wall next to his tomb<sup>3</sup>. In the painting of the Seven sacraments by Roger Van der Weyden, dated ca. 1445, a wooden book niche with grills is painted in detail (Figure 1). In January 1519 the will of Lodewijk Witkin of the Church of Our Lady in Bruges specifically required his books to be chained, so that they could be looked at, read or studied by all who wished to do so, but could not be stolen or lost<sup>4</sup>. Accounts for 1456 to 1475 from the Church of St Michael in Cornhill (Aberdeenshire) confirm that the price of a book chain was not an expensive method of 'prevention' against theft<sup>5</sup>. In the sixteenth century chained libraries became more common, especially in the Reformed parts of Europe, where the growth of semi-public libraries led to an increase in the chaining of manuscripts and printed books.

Moreover, display in private contexts would be surrounded with special care in the more physical sense. In the chambers of eminent individuals special measures were taken to protect books. This appears, for instance, in the description of the effects of Corneille Haveloes -the auditor of the Chamber of Accounts in Brussels in 1520- who had a red curtain complete with iron rod and rings, to hang in front of his books<sup>6</sup>. The library of Duke Anne de Montmorency (1492-1567) had bookcases protected by glass and completed with strong red wool curtains to save the volumes from the damaging effects of light<sup>7</sup>. Individual miniatures and small painted pictures hung on the walls, were sometimes covered with



Fig. 3

a plate of glass or crystal. That was the case for a small picture depicting the *Sweet Name of Jesus* behind glass, given by a nun – who was also an illuminator – to the Carmelites of Sion in Bruges in 1508<sup>8</sup>. In the same period, sisters in Malines were protecting small miniatures and devotional prints in their *retables* incorporating relics and ex-votos known as “Closed Gardens” or “Besloten Hofjes” with polished crystals (Figure 2). In manuscripts small veils of silk were sometimes added, chiefly to protect the raised gilding from abrasion<sup>9</sup> (Figure 3).

### On art exhibitions, disbanding, rebinding and reproductions: Display in the 19<sup>th</sup> century

After the *Ancien Regime*, more particular in the second part of the 19<sup>th</sup> century, medieval and early modern books were displayed in museums, often in efforts to legitimate and aggrandize the national past and its cultural heritage. Exhibitions or the more or less permanent display of old books and manuscripts in showcases became fashionable in several European cities and main libraries. Furthermore, the presentation of archival and library material was connected with the growing concept of leisure time and tourism. World exhibitions and exhibitions of medieval art, as a new urban phenomenon, were popular platforms for display of documents in a historical context. They generated a transnational mobility of people and artworks. One of the highlights in the middle of the 19<sup>th</sup> century was certainly the collection in the Victoria & Albert





Fig. 4

Museum in London and the prestigious exhibition of fine medieval art in Brussels in 1880<sup>10</sup>. This major exhibition included a large number of medieval manuscripts and incunabula from all over Europe and proved to have considerable public appeal. Already in 1860 there was a growing interest, especially in England, in travelling to the Continent to see actual medieval relics, a trend that the development of the railways had made possible.

On the other hand, the growing interest and public display of century old books encouraged the unbinding from their original bindings. For the 1880 Brussels exhibition a splendid illuminated book of Hours (the Hennessy Hours) was unbound and the folio's presented in movable wooden frames<sup>11</sup>. The same approach could be seen in the Bargello Museum in Florence where the collection of manuscript leaves of the French antiquarian *Francetti Carrand* (1821-1899) were put in 1894 on permanent display in vertical wooden showcases<sup>12</sup>.

The press took the communication for the exhibitions in their hands and Travel Guide Books like the little red *Baedeker*, *Handbook for Travellers* are revealing with great precision which precious books or documents the new traveller could see "on show" in the main European libraries, museums or archives. These institutions were open to the public, although limited hours a day or week. A closer look to the continuing new editions of the *Baedeker* show how long the same manuscripts and early printed books stayed on display, this could be without doubt between twenty and thirty years, with the opening on the same page. The example of the Antwerp Museum Plantin-Moretus is clear, the 1891 edition

of *Baedeker* is mentioning: *Room III. in the center, miniatures from the tenth to the sixteenth century*<sup>13</sup>. On the first floor of the Museum there were autographs, incunabula and documents on view in glass showcases, close to the windows. The showcases were covered with leather covers to protect against light (Figure 4). Not all repositories took these preventives measurements.

For public collections, there was another challenge. After the Sankt-Gallen (1898) and the Liège conference (1905) attended by a large group of European librarians, one of the solutions proposed to protect original book material was the making of reproductions<sup>14</sup>. The starting point was the idea that the original would be handled less and thus would be better conserved. Photographic reproduction, it was argued, allowed the user to view and study a manuscript as much and for as long as he pleased, without any risk to the original. In this scope, only facsimiles of European manuscripts were sent to the St. Louis World's Fair in 1904. The travel risks and the long display period were esteemed to riskfull.

## Conclusion

The context and evolution of display of historical documents in public and private places reveals a fundamental interest of the custodians for the protection and the prevention of the artefacts. In the modern period, the value of *libri antiqua* shifted to items with an historical, didactical financial and artistic value. In this context, books were from the 19<sup>th</sup> century on -without scrutiny- dismantled, mounted, restored and rebound to function in the shifting exhibition contexts. The 'progress' in display entailed occasionally a dramatic paradox for the physical integrity of the old document. The history of the display of an artefact is an important mark in the material pedigree of a book. In this regard, conservators -with their trained eyes and minds- can frequently reveal detailed material marks of those distant and mostly undocumented displays. In this way they are privileged observers and keepers of the unwritten history of a book or document<sup>15</sup>.

## Notes

- 1 The Old French the word exhibition from the latin exhibere (to hold out, display) is already mentioned in the 14th century.
- 2 The Paix de Douze is a the peace agreement that finally brought to an end a bitter vendetta between two noble houses that had devastated the principality of Liège. See : Stanislas Bormans, *Recueil des Ordonnances de l principauté de Liège*, 1st series 974-1506, Brussels, 1878: 556.
- 3 A. De La Grange, *Choix de testaments tournaisiens*, Tournai, 1897: 257, no. 908. n 24.
- 4 Luc Indestege, *Verslagen en Mededelingen van de Koninklijke Academie voor Taal en Letterkunde*, 1961: 77.
- 5 William Blades, *On Chained Libraries*, Read at the Annual Meeting of the Library Association, London, October, 1889, *The Library* (1889): 412.
- 6 Brussels, State Archives, CC, 28584, fol. 54r.
- 7 L. Mirot, *L'Hotel et les collections du Connétable de Montmorency*, Paris, 1920: 57-58, 70-73, 103-105 and 161-162
- 8 James Weale, 'Le couvent de soeurs de notre Dame de Sion, à Bruges', in *Le Beffroi*, vol. III, (1866-1870: 85 and 92
- 9 Christine Sciacca, 'Raising the Curtain on the Use of Textiles in Manuscripts', in *Weaving, Veiling and Dressing. Textiles and their Metaphors in the Late Middle Ages*, *Medieval Church Studies* 12, Kathryn M. Rudy and Barbara Baert (eds.), Turnhout, 2008: 168-171
- 10 Charles Ruelens, 'Les Manuscrits', in M. Camille de Roddaz, *l'Art Ancien à l'Exposition Nationale Belge*, 1880: 289
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- 12 Rosalia Bonito Fanelli, *Tessuti italiani del Rinascimento: collezioni Francetti Carrand*, Museo nazionale del Bargello, Prato, Florence, 1981
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- 14 Jozeph Van den Gheyn, *Les manuscrits des bibliothèques de Belgique à reproduire, Rapport présenté au Congrès international pour la reproduction des manuscrits, des monnaies et des sceaux*, Actes du Congrès international tenu à Liège, les 21, 22 et 23 août 1905, Brussel, 1905: 46-47
- 15 Further reference: Lieve Watteeuw, *The History of Conservation and Restoration of Illuminated Manuscripts in the Low Countries*, *Corpus of Illuminated Manuscripts*, Vol. 19, Low Countries Series, Peeters, London-Leuven-Walpole, 2013 (Forthcoming)

## Figures

Fig. 1: Book niche with grids in a 15th century church. Rogier Van der Weyden's Seven Sacraments Altarpiece (1445-1450), Antwerp, Koninklijk Museum voor Schone Kunsten, Inv. 394, detail of the central panel.(© Griet Steyaert)

Fig. 2: Miniature on parchment depicting the virgin and child, mounted behind a polished mountain crystal. Illumination damage by darkening of the lead white. Early 16th century, City Museum of Mechelen, "Closed Garden of the Unicorn" (© Lieve Watteeuw)

Fig. 3: 13th century red silk veil protecting an initial. Museum Plantin-Moretus, Antwerp, M. 16.3, Petrus Lombardus, *Sententiarum libri IV*, France or England, first quarter of the 13th century, (© Bruno Vandermeulen - KU Leuven)

Fig. 4: Exhibition room with showcases for manuscript display in the Museum Plantin-Moretus, Room III, Antwerp. Postcard - early 20th century ? (© Museum Plantin-Moretus)

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# Risk and Safety of Illuminated Manuscripts with Brittle Paint Layers: Can the Digital Scan Substitute Old Manuscripts? Are Old Choices of Conservation Reversible?

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Fig.1: Prudentius 9. Jh., Burgerbibliothek Bern, Cod. 264, 2, p.18 detail: a drop of petrolatum lays on the surface.

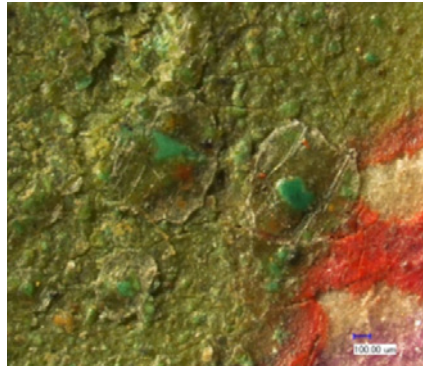


Fig.2: Prudentius 9. Jh., Burgerbibliothek Bern, Cod. 264, 2, p.21 detail: the petrolatum drops are so soft, so that scratches by touching can be seen.

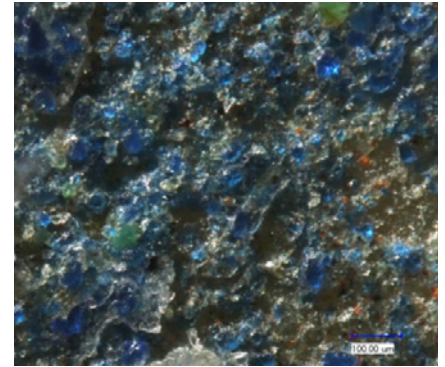


Fig.3: Prudentius 9. Jh., Burgerbibliothek Bern, Cod. 264, 2, p.33 detail: the blue pigments are embedded in the waxy mass.

Paintings on paper or in manuscripts were normally made in the watercolor technique. Pigments and dyes were mixed with a water soluble media and painted with a brush. Even the ground of gold or silver leaves and the gold and silver inks were bound with water-soluble glue.

Therefore one thought as a first idea for the consolidation of brittle paint layer to use a non-water soluble fixing agent. The idea was the reversibility of polymer agents with non-water solvents. But unfortunately it is not seldom that dyestuffs of the illuminations bled with the solvents. This made the restorer helpless and therefore it was decided to start researching the technique of mediaeval book paintings with a research institute at Göttingen University. This paper is based on research experience of more than 25 years.

Even up to now older consolidation techniques can present difficult problems for conservation. The digitization project of the Bern library made

it necessary to investigate some precious illuminations because the paint layer seemed too brittle for digitalization. We could prove that in the restoration of 1937 the restorer used petrolatum (Vaseline) to fix supposed brittle paint layers in many manuscripts. This soft waxy substance is still soft and glossy and has changed the appearance of the paintings.

This paper will compare different consolidation techniques and discuss the reversibility. Finally the question if the digital scan can substitute the old manuscripts will also be discussed.

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# Integrating Analytical Tools in Treatment Decision-making for a 1513 Hand-colored Ptolemy Geographia Atlas

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Fig. 1

## Introduction

In 2009, conservators from the Library of Congress (LC) undertook the technical examination of Claudius Ptolemy's *Geographia*, an atlas printed by Johannes Schott in Strasbourg in 1513 and now part of the Lessing J. Rosenwald Collection in the Rare Book and Special Collections Division. Bound in stiff-board vellum, the Atlas contains the text and mathematical coordinates from Ptolemy's second century A.C.E. work on world geography, a sixteenth century supplemental text, and forty-seven hand colored woodblock and letterpress printed maps. All but one of the maps in the Atlas are hand-colored in six hues, including a problematic green used for mountain features throughout the maps. The final map in the volume illustrates the territory of the book's patron, the Duke of Lorraine, and is an early example of multiple color woodblock printing.

The Rosenwald 1513 Ptolemy Atlas has been unavailable for study or display for some time due to its fragile condition. Initial examination of the Atlas by LC paper and book conservators confirmed that the vellum binding was extremely tight, preventing the book from opening com-

pletely and contributing to breaks in the gutter of the pages. In addition, conservators noted that approximately forty of the maps appear in relatively good condition, while seven of the maps (Fig. 1), are in extremely poor condition, with all colors dull or darkened, the green pigment sometimes powdery, and the paper generally soft and discolored. The green on these maps has sunk to the back of the support and caused offset onto the opposite pages.

In order to best approach the complex preservation of this important volume, a research team composed of conservators, scientists, and curators joined forces, resulting in an investigation into how the Atlas was produced, how it developed its current condition issues, and how to formulate a treatment strategy. Many of the specific research questions posed by the group have been systematically answered over the past two years through scholarly research and technical analysis, leading to informed conservation treatment planning and decision-making. The initial discoveries of the research team have been detailed elsewhere [1, 2, 3, 4], but are summarized here.

History records that the production of the 1513 Ptolemy Atlas began in the early 16th century in St. Dié, France, where a small group of humanist scholars known as the *Gymnasium Vosagense*, including Matthias Ringmann, Martin Waldseemüller, and their patron the Duke of Lorraine, combined efforts to produce a volume with newly corrected Ptolemy information, along with updated maps based on European discoveries of the late 1400's. This project appears to have been interrupted by the untimely deaths of the Duke and Ringmann and the volume was left unfinished until 1513, when it was published in Strasbourg by another consortium that included Waldseemüller.

Examination reveals that the Atlas is constructed from three different types of laid papers: twenty maps contain a slightly variant Crown watermark; four maps and seventeen text papers have a Lily watermark; and the remaining papers contain no watermark. Throughout the

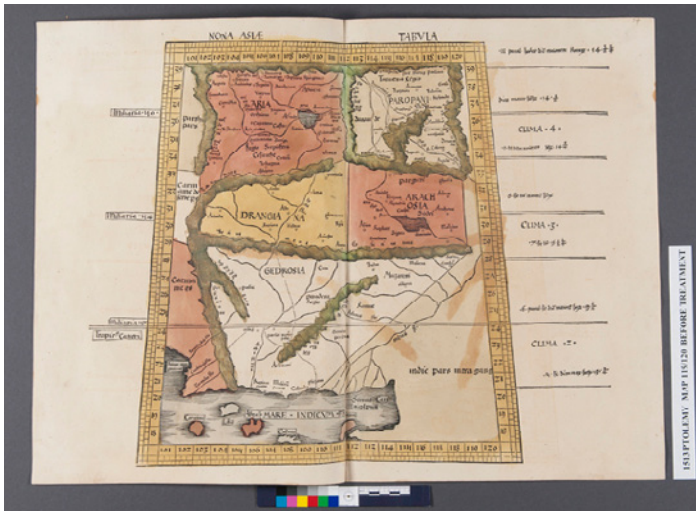


Fig. 2

Atlas, the Crown papers are in very good condition, exhibiting quite white color and expert sheet formation. These watermarks appear identical to those that make up the separate sheets of LC's prized sixteenth century Map of the World printed by Martin Waldseemüller. The Lily papers are in fair to good condition, but the pulp is less evenly processed and dispersed, and the sheet is generally not as white in color. On the other hand, a large portion of the papers without watermarks are in markedly poor condition and show deterioration of the green pigment. Compared to the Crown or Lily papers, this pulp is clearly less well-processed, the formation of the sheet is rather uneven, and the paper is light brown to tan.

Non-invasive, quantitative X-ray fluorescence spectroscopy (XRF) analysis of the papers used in the Rosenwald volume and other LC copies of Ptolemy's *Geographia* strongly suggests a correlation between condition and elemental composition in the paper. The Crown papers have a calcium (Ca) to iron (Fe) ratio of about 16:1. In contrast, Lily and unwatermarked papers in poor condition contain Ca:Fe ratios of about 6:1. This evidence suggests that the presence of a relatively large quantity of Ca and low proportion of Fe, combined with high quality processing, has helped protect maps and colorants from degradation, even in the presence of the copper-based green pigment, which was confirmed by polarizing light microscopy to be verdigris (2). The other colorants appear to be organic-based and

remain unidentified. The difference in inherent paper quality is further supported by our observation that in four different copies of the Atlas, the same maps appear brown, even in uncolored versions.

Records show that in 1938, Philadelphia dealer A.S.W. Rosenbach sold the book to Rosenwald, who subsequently donated it to LC. Cover board pastedowns and repairs on the maps provide us with good evidence that the Atlas had undergone several rebindings including one in the mid-20th century. These conclusions are pertinent to the analytical finding of a heavy brush application of potash alum/gelatin solution on the seven maps in poor condition. This agent was most likely applied during the last rebinding in an attempt to strengthen papers that had become weakened during natural aging. What is remarkable is that this "strengthening" treatment coincides with poor condition of both verdigris and the paper support. This lies in sharp contrast to maps still in good condition, which show the presence of relatively minor amounts of potassium (K) and sulfur, from original preparation for hand-coloring, that remains benign in its influence on aging. In addition, close examination of the restored maps shows that while the verdigris has turned brown in most of these maps, it remains bright in the gutter regions, where a guard paper with a high Ca:Fe ratio plus significant amounts of zinc (Zn), was adhered. These guards were in place before the alum agent was brushed onto select maps, protecting the paper and verdigris pigment in the centerfold from further discoloration both physically and through the beneficial action of Ca- and Zn-containing compounds.

With many of the questions regarding the Atlas' condition and history answered, the current project goals address the conservation treatment approach and methodology. This paper describes the use of quantitative XRF, along with spectral examination, as decision-making tools during treatment. Based on the initial technical examination and analysis, the following treatment plan was established: 1) remove the non-original binding; 2) remove guards from deteriorated maps that need stabilization or that prevent complete opening of folios; 3) remove the potash alum-gelatin strengthening agent from the seven restored maps; 4) reduce discoloration from verdigris offset; 5) restore a better Ca:Fe balance in the conserved maps; 6) treat the altered verdigris

locally to prevent its continued deterioration; and 7) rebind the Atlas in a historically sympathetic binding.

### Method

XRF was conducted using a Bruker Tracer TurboSD spectrometer with a rhodium anode and silicon drift detector. The instrument was operated with vacuum pumping, a titanium filter, and either 15 kV and 55  $\mu$ A or 40 kV and 20  $\mu$ A for 180 seconds. Results were analyzed quantitatively with Bruker Calprocess software and linear calibration from metal-doped samples of Whatman paper developed at LC; due to imperfect calibration standards, quantitative results have up to about 20% uncertainty depending on the element and variation in the paper (4). Initial UV fluorescence examination was done with a hand held UVL-56 Blak-Ray lamp at 366nm. More extensive spectral imaging was conducted on select maps before and during treatment using a Mega Vision Monochrome E6 39 Megapixel camera system and light emitting diodes (LED) illumination at 13 narrow spectral bands from the UV through the infrared range.

### Results and Discussion

Following disbinding and guard removal, conservators tested alum removal in guards taken from the deteriorated maps by blotter washing on a suction table with either a 50% ethanol-modified aqueous solution or a pH 7.5 aqueous solution. XRF measurements before and after treatment showed that the ethanol-modified blotter washing only removed about 40% of the alum, while pH 7.5 water easily removed the agent, as measured by K concentration. After testing the guards, the Nona Asiae Tabula (Fig. 2) was chosen for initial map treatment because it had significant, white alum surface deposits, was the least fragile of the maps in poor condition, and was the easiest to handle.

The conservation treatment involved four separate steps of blotter and suction table washing using various solutions. The first treatment used 50% ethanol and 50% water adjusted to pH 8.0 with  $\text{Ca}(\text{OH})_2$ . XRF measurements indicated that only about 25-30% of the alum agent was removed by this method; however color sensitivity to water led us to try this protocol first. Nevertheless, this solution caused minor color transfer. The second step focused on local treatment of offset staining from verdigris. Here ethylenedi-

amine tetraacetic acid (EDTA) and  $\text{NaBH}_4$  were successful at removing excess copper from the paper and reducing the staining. However, EDTA left a residue in the paper that is visible with UV fluorescence. In the third step, blotters used for washing were wet with aqueous solution brought to pH 8.5 using calcium hydroxide. This was effective for removing the excess alum in the paper overall. By not spraying the recto, we were able to minimize movement of color. The fourth treatment used calcium bicarbonate-saturated blotters in an attempt to increase the amount of calcium left in the paper. Table I describes the succession of steps, the solutions used, and the results obtained; Table II shows XRF results for paper areas, excluding the offset stains.

After treatment, the Nona Asia Tabula map appears significantly brighter, treated staining from verdigris offset is considerably reduced, and the paper feels stronger and more flexible. XRF analysis of the map and blotters before, during and after treatment shows the effective removal of potash alum in the paper as well as copper in areas of verdigris offset. Copper content in areas treated near verdigris does not appear increased, within the margin of error. EDTA residues remain in treated areas, as detected by UV fluorescence, and are the subject of further study.

### Conclusion

The value of combined XRF and spectral analysis as treatment monitoring and decision-making tools is demonstrated as an integral part of the conservation of a 16<sup>th</sup> century atlas with verdigris and old restoration damage. The treatment of one map has been a step-by-step process of trial and review, involving analytical monitoring and compromises. This process has led to formulation of detailed procedures for six other maps in the volume in poor condition, as will be discussed. Current conservation measures include removal of a potash alum-based "strengthening" agent by blotter-washing with pH-adjusted aqueous solutions on a suction table. Development of methodology for reduction of copper staining and possibly also conversion of browned verdigris is in process with the aid of these tools and Raman spectroscopy.

### Acknowledgments

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**TABLE II: Metal Content in Nona Asiae Tabula Map Paper Before and After Treatment As Determined by XRF**

	ave. ppm before treatment (no offset areas)	variation in paper	ave. ppm after treatment step 1	total change	ave. ppm after treatment step 2	total change	ave. ppm after treatment step 3	total change	ave. ppm after treatment step 4	total change
K	11000	12%	7800	(-29%)	8100	(-26%)	1100	(-89%)	980	(-91%)
Ca	4500	9%	4500	nd	4800	nd	4300	nd	5300	slight gain
Fe	730	7%	670	nd	710	nd	730	nd	710	nd
Cu	330	28%	310	nd	340	nd	410	nd	420	nd
Ca										
Fe	6.2		6.7		6.8		5.9		7.5	

nd = not detected



**TABLE I: Suction Table Treatment Process for Nona Asiae Tabula Map**

STEP	VERSO TREATMENT	RECTO TREATMENT	RESULTS
1	Overall spray on verso and blotter #1 infused with 50:50 solution*	Sprayed overall with 50:50 solution*	<ul style="list-style-type: none"> <li>• XRF: alum-K reduced <math>\leq 30\%</math> in paper margin areas, as detected by K</li> <li>• XRF: K detected all over blotter #1, but not in #2</li> </ul>
	Blotters #2-3 infused with 50:50 solution*	Sprayed overall with 50:50 solution*	<ul style="list-style-type: none"> <li>• XRF: no detectable change in Ca, Fe, or Cu content in margin areas of paper</li> <li>• XRF: effect of ammoniated water inconclusive</li> </ul>
		Map margins brushed/sprayed with 50:50 solution*	<ul style="list-style-type: none"> <li>• UV: fluorescent material from map deposited in the blotter overall</li> <li>• UV: Some color sank and transferred to blotters #1-2</li> </ul>
		Areas of offset brushed with dilute pH 9.0 NH <sub>4</sub> OH	<ul style="list-style-type: none"> <li>• Paper brightened overall</li> <li>• Ammoniated water slightly lightened offset staining</li> </ul>
2	Humidification between Goretex;  Blotter #1 infused with aqueous Ca(HCO <sub>3</sub> ) <sub>2</sub> (1.10 g/l in DI water)	Select offset stains in map reserve areas brushed with EDTA** or Ca phytate $\pm$ solutions twice	<ul style="list-style-type: none"> <li>• XRF: Cu reduced <math>\sim 75\%</math> in offset treated with aqueous EDTA, but less with aqueous Ca phytate</li> <li>• XRF: Fe and Ca content in paper unchanged, but Ca reduced in treated offset areas</li> <li>• XRF: alum-K reduced <math>\sim 85-90\%</math> in treated offsets, but not further reduced in paper</li> <li>• XRF: no detectable increase in Cu in paper adjacent to two treated areas within margin of error</li> <li>• UV: fluorescent material transferred overall from map paper to blotters.</li> <li>• UV: EDTA-treated areas and adjacent blotters strongly fluorescent</li> <li>• UV: fluorescent bleach residue completely transferred to adjacent blotters by 3rd blotter</li> <li>• EDTA lightened offset stains, but also lightened some organic colorants</li> <li>• Ca phytate did not markedly lighten offset, but colors unaffected</li> <li>• NaBH<sub>4</sub> lightened offset, in Ca phytate and in EDTA treated areas.</li> </ul>
		Select offset areas in colorants brushed with EDTA** or Ca Phytate $\pm$ solutions twice	
	Blotters #2-4 infused with Ca(HCO <sub>3</sub> ) <sub>2</sub>	Brushing and spraying with 50:50 solution* in treated areas (rinsing)	
		NaBH <sub>4</sub> *** brushed in treated reserve offset areas twice	
		All treated offset areas brushed with 50:50 solution* six times (rinsing)	
		Map image reserve areas and map margins brushed with 50:50 solution* twice	
4	Humidification between Goretex; Blotters #1-3 infused with Ca(HCO <sub>3</sub> ) <sub>2</sub>	Reserve areas and margins: rinsing and deacidification with 50:50 solution* followed by dilute Ca(OH) <sub>2</sub>	<ul style="list-style-type: none"> <li>• XRF: Fe content in paper unchanged</li> <li>• XRF: Cu further reduced to over 90%</li> <li>• XRF: slight gain in Ca uptake possible</li> <li>• UV: fluorescence on map only evident in areas treated with EDTA and NaBH<sub>4</sub></li> <li>• Map pH adjusted from 4.0-4.7 to 6.0-6.5</li> <li>• Tidelines lessened successfully</li> <li>• No visible or UV visible color transfer into blotters</li> </ul>
		Tidelines: sprayed with 50:50 solution*	

\*50:50 solution = 50% ethanol and 50% water adjusted to pH 8.0 with Ca(OH)<sub>2</sub>.

\*\*0.1M ethylenediamine tetra-acetic acid in water adjusted to pH 8.0 with ammonium hydroxide

\*\*\*0.25% sodium borohydride in 50:50 solution\*

$\pm 1.75$  mmol/L calcium phytate according to H. Neevel formula

## Verdigris I: Compromises in Conservation

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Fig. 1: Kyeser, Bellifortis, mid 15<sup>th</sup> century, Cod. 3068

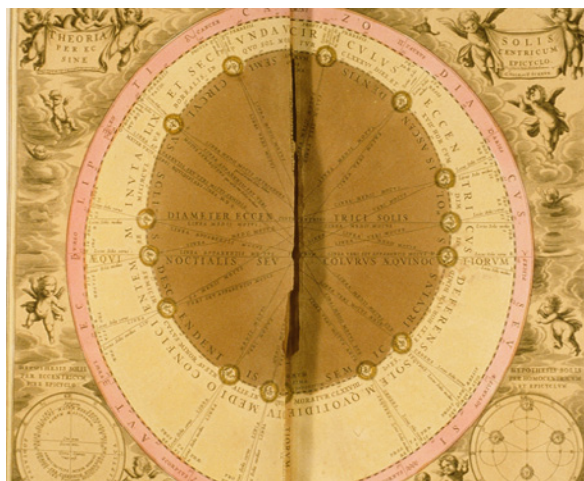


Fig. 2: Cellarius, Atlas Coelesti sue Harmonica Macrocosmica, 1708, FKB 272-25.

Copper green pigments have the potential to cause severe degradation of paper and parchment. Additives, application method and storage conditions influence the visual appearance and chemical stability of the colour. At the Austrian National Library manuscripts, prints and maps coloured with verdigris display different stages of degradation (Fig. 1, 2). Finding stabilising conservation methods and providing conservators with decision making tools was the aim of a research project funded by the forMuse programme of the Austrian Ministry of Science and Research.

Samples were prepared by applying copper acetate pigments mixed with gum arabic on hand made rag paper sized with gelatine. After pre-aging, the first group of samples was subjected to treatments with a variety of solutions including aqueous deacidification, non aqueous deacidification, antioxidants and complexing agents. The solutions were applied by air-brush on the suction table or by brush on the verso. The second group of samples received an application of coated Japanese tissue papers for mechanical reinforcement. For the purpose of comparison

the coated tissue papers were also adhered on rag paper without colour and on Whatman No. 1 filter paper. The coating agents ranged from aqueous to non- aqueous adhesives, and could be activated by water, ethanol or heat. A third group of samples was prepared according to historic references and recipes by the mixture of verdigris with plant dyes, pigments or juices. After preparation and treatment, the three groups of samples were light- and heat-aged.

The effect of the solutions on cellulose was evaluated by analysis of molar mass and carbonyl group content before and after aging. The coated Japanese tissue papers were visually assessed and submitted to simple mechanical testing. Indicator papers were used to monitor migration of copper ions during treatments. LA-ICP-MS (Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry) was performed on selected samples to further evaluate the movements of copper ions. The verdigris samples with different additives were visually compared before and after aging with green colours found in manuscripts, early printed books and maps.

Solutions that have the potential to chemically stabilise verdigris on paper (Ahn, Verdigris II) need to penetrate the paper matrix. In this study the solutions had to be applied by brush in order to have a positive effect on cellulose. Spraying of solutions on the suction table minimised migration of copper ions during treatment. The movements of copper ions could be monitored with indicator papers. The visual observations were confirmed by LA-ICP-MS. Treatment decisions will be a compromise between the risks of migration, the change of media and possible beneficial effects of applied solutions. High humidity during storage and treatment can lead to migration of copper ions and enhance degradation of cellulose.

For mechanical stabilisation of paper degraded by copper green pigments, Japanese papers coated with films of adhesive offer the possibility to support the weakened paper carrier. By using thin and matte adhesive films produced on a silicon mat, in combination with tissue papers, 2-3.7g/m<sup>2</sup>, the visual interference can be reduced. Activation of the adhesive coating with the sponge-blotter-system developed by Jacobi (Jacobi et al. 2011), minimises the risk of migration of copper ions. In this study, coatings with wheat-starch paste-methylcellulose, gelatine and Klucel G in ethanol proved to provide sufficient strength without leading to detrimental effects on the mechanical and visual properties. The use of a specific adhesive or adhesive mixture can be adjusted to the needs of an artefact. Conservators have a range of options to find the best compromise between strength, visual appearance, ease of application and removal.

Verdigris seems to have been frequently applied in mixtures with green and yellow plant colours to produce different shades of green (Fig. 1). The exposure to light represents a risk for these light sensitive compositions. Light seems to play a role in initiating degradation of cellulose in the presence of copper acetate. Plant colours and additives like vinegar, tartaric acid or alum can lead to brown discolorations during aging. The qual-

ity of paper, sizing, method of colour application and environmental factors influence the condition of verdigris. Liquid application of colour, high humidity during storage and the direct effect of water have a negative impact. Treatment decisions will have to balance the previous condition and history of an artefact with the side-effects of an intervention.

The conservation and preservation of verdigris on paper will, in most cases, be the search for an acceptable compromise: between penetration of solutions and migration of copper ions, between the support of degraded paper and visual change, between the complexity of the artefact and the question of access.

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## Verdigris 2: Wet Chemical Treatments which are not Easy to Decide and Apply

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### Introduction

Paper objects with copper pigments are threatened as they may exhibit an accelerated degradation of cellulose and heavy discoloration of the paper depending on the condition of the object. In some cases, the paper eventually becomes very fragile and even handling of the object becomes critical. Paper conservators and scientists have been seeking solutions in many directions – reinforcement, environmental controls, solution treatments, etc. As a part of the forMuse programme of the Austrian Ministry of Science and Research, various solution treatments of paper with verdigris were tested simulating a practical situation that conservators might face in their workshop. In the present study, various chemical treatments of a handmade rag paper containing verdigris bound in gum arabic, will be discussed in comparison to the results obtained from the same rag paper impregnated with copper. The copper impregnation represents a more homogeneous situation which can be better controlled and monitored.

### Methods and Materials

The solutions applied to pre-aged test specimen varied from calcium bicarbonate in water to metal ion complexing agents or antioxidants in ethanol. Spraying on a suction table and brushing on the verso were mainly applied to samples with partially soluble verdigris (Type 1). Only immersion treatment was carried out for the samples that underwent oxidation and impregnation of a fixed content of copper (Type 2) prior to the treatment. After applying accelerated aging, measurements of molar mass and carbonyl group content of samples were performed by GPC (Gel Permeation Chromatography)-Fluorescence-MALLS (Multi Angle Laser Light Scattering)-RI (Refractive Index) system after selective chemical labelling of carbonyl groups.

### Results

None of the alkaline treatments in water nor in a mixture of water and ethanol reduced cellulose degradation significantly for samples of type 1 regardless of the application methods employed. Especially 100% aqueous alkaline treatments degraded the sample much more compared to the untreated control. On the other hand, when those solutions were applied to samples of type 2 different results are obtained: Alkaline treatments with calcium bicarbonate or magnesium propylate were both effective to reduce Mw loss and formation of carbonyl groups. Benzotriazole in ethanol which has been used in the field of metal conservation worked as the most efficient inhibitor of copper-catalyzed degradation of cellulose among the applied chemical solutions, more importantly for both types of the samples although it causes significant discoloration of paper depending on its concentration. It was also found to be effective under photo-oxidative as well as under hot and humid aging conditions. A concentration of 0.5% was high enough to form a benzotriazole-Cu complex by immersion of samples of type 2 in solution while the same concentration of benzotriazole was not yet promising for sample type 1 with a spraying application method.

Calcium phytate treatment followed by a deacidification treatment did not lead to any retardation of cellulose degradation in the presence of copper ions for both types of samples unlike for paper containing iron gall inks ((Neevel 1995; Reißland 1999). Both sample types treated with tetrabutylammonium bromide, known as an antioxidant scavenging hydroxyl radicals, exhibited significant reduction of degradation compared to the untreated control. A single application of ethyl-p-hydroxybenzoate which decreased the degradation rate when it was combined with a non-aqueous deacidification treatment (Henniges et al. 2006) did not show any beneficial effect in terms of molar mass protection of cellulose for both sample types.



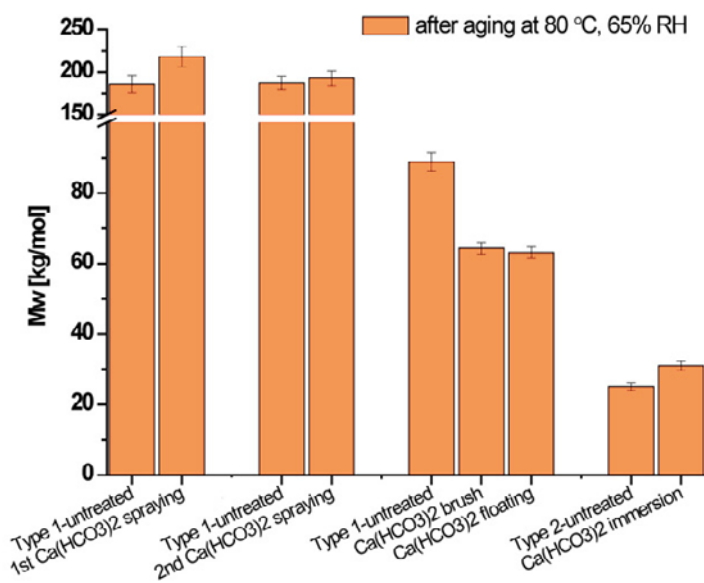


Fig. 1 Molar masses of the control samples and the samples treated with  $\text{Ca}(\text{HCO}_3)_2$  in mixture of water and ethanol (2:1) by various application methods after accelerated aging.

Not only the selection of the chemical treatment is important, but also the application method itself should be taken into consideration depending on the conditions of the samples and the solutions. Spraying of the reagents on a suction table did lead to a large fluctuation of target characteristics, e.g. molar mass (cf. Fig. 1) and is not easy to control when a certain amount of active agent is to deposit homogeneously. Application by brushing the reactive agent on the verso was highly efficient with sample type 1 for the treatment with benzotriazole or tetrabutylammonium bromide. On the other hand, brushing on the verso was found to be not suitable for deacidification treatments since the paper hardly changed its pH.

### Discussion and Conclusions

As the copper impregnated samples of type 2 were treated and analyzed together, the results obtained from samples of type 1 that are close to a practical situation were better understood. The deacidification treatment seems to be a challenge for heavily sized inhomogeneous rag papers with partially-soluble copper pigments independent on the application method. It is always accompanied by migration of copper ions that cannot be overcome with a deacidification treatment alone. Spraying the reagents on a suction table may lead to an inhomogeneous treatment for

such samples, and the underpressure of the suction table needs to be optimized depending on the respective aim, either for generating a minimum migration of copper ions and washing out of degradation products or for impregnation with an active substance. Even with the rather complex set of test samples used in this study, a simple brushing application of benzotriazole or tetrabutylammonium bromide was found to be more promising to reduce copper-induced cellulose degradation. Selection of what and how to treat papers with copper pigments is highly dependent on variables that are not only connected to the paper substrate but also depending on the conditions of the pigment.

### Acknowledgements

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## Integrated Modelling: The Demography of Collections

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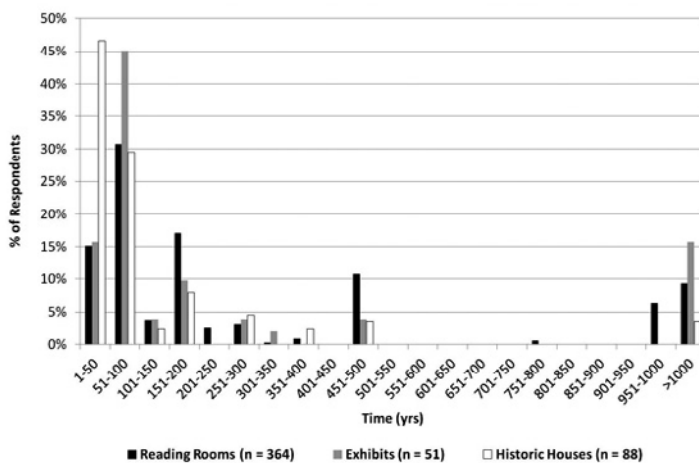


Fig. 1: Frequency of responses to the question 'How long would you like the original document/books you have been using/viewing today to last in a readable state/a good enough state to be displayed?'

The recent BSI: PAS198 (British Standards Institute, 2012) specification for managing environmental conditions for cultural collections requires environmental management to be justified in the context of collection use, significance, degradation and environmental considerations. It introduces the term 'expected collection lifetime'; however, there is currently not much literature available on how this could be determined or what lifetimes could reasonably be expected. In the frame of the Collections Demography project (2010-2013), research was undertaken to assess the expectations of library and archival users, and their attitudes to document use and degradation, to inform the decision on appropriate planning horizons (Dillon et al. 2012a).

This was accomplished using the VALUE (Value and Lifetime – User Engagement) questionnaire (Dillon et al. 2012b), and experiments involving the library and archival users themselves. The

questionnaire was distributed to visitors and readers at a number of institutions to capture how the contexts of use affect their attitudes, reflected in the values which they associate with documents, as it is likely that these affect the expected collection lifetime. In the context of the project, 'value' was operationalized in terms of the benefits that can flow from a collection. These may depend on material change and degradation and environmental management ensures that documents remain fit for the purpose of reading or display until they degrade to an unacceptable level, ie they become 'damaged' (Strlic et al., in press).

The Collections Demography project is attempting to model these processes in an integrated collection model.

### The VALUE questionnaire

Statements were collected in interviews with readers at The National Archives (Kew), and from the literature. The questionnaire also consisted of sections allowing for collection of information on the user (e.g. activities, experience and demographics), the particular document they were using or viewing, what they think is important about the document (i.e. ratings of value statements), and their perspective on the desired lifetime of the document and their opinions on the document's condition, care and use. The analysis was carried out using factor analysis (Tabachnik and Fidell, 2007).

The questionnaire was distributed at the National Archives (Kew), the Capitol Visitor Center (Washington), the Library of Congress, and English Heritage properties (Brodsworth Hall, Kenwood House and Eltham Palace). In total, 543 responses were collected.

The respondents were asked to rate their agreement/disagreement with ca. 60 statements

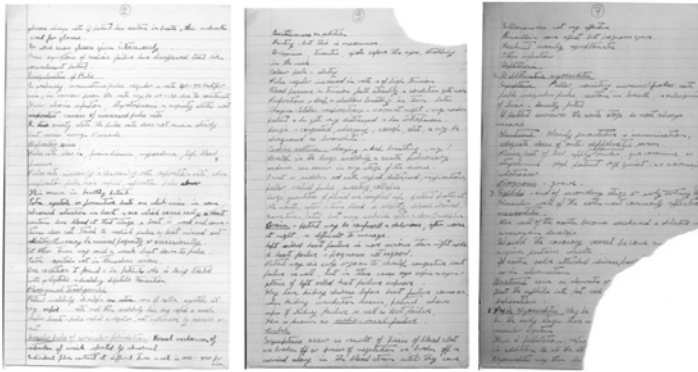


Fig. 2: Examples of differently distressed documents used in fitness-for-purpose workshops, progressively discoloured and with a progressively big missing piece from left to right. The document on the left also has a large tear, stretching across text.

about the document they viewed or read on the day of the visit. Following factor analysis, nine factors were extracted (56% of variance explained), which are summarised in Table 1. The factors are related to personal as well as wider significance of historic archives and libraries.

### Expected collection lifetime

In the VALUE questionnaire, the respondents were additionally asked how long they would like the document they had been using (or viewing, in the context of an exhibition or of a historic library) to last in a usable state. The majority of responses focused on 50, 100, 200 and 500 years, with 86% of respondents giving a response of  $\leq 500$  years (Fig. 1). Interestingly, there was only a small proportion of respondents of the opinion that the documents need to remain in a useable state indefinitely. The results corroborate previous findings focussing on museum and conservation professionals (Lindsay, 2005).

Interestingly, a similar study was recently carried out on the expected lifetime of geological collections among professionals working with natural history collections (Robb, 2012). The results showed that 70% of the respondents expected the objects to last  $\leq 500$  years. The similar figure indicates that the actual material stability (geological collections being generally more chemically stable than paper collections) may not be reflected in the expected collection lifetime.

It is of further interest what users thought could prevent documents from lasting this long. The results showed that readers, as well as visi-

tor to exhibits and historic libraries, generally place most importance on handling as the source of degradation. Environmental conditions and storage were generally thought to be the second most important reason, followed by neglect. These views overlap with general conservation considerations well.

### Wear and tear

Paper conservation research has so far mainly focussed on material change and environmental impacts. There is a solid body of research on chemical degradation of historic paper, leading to the loss of mechanical properties and discoloration, and objects that are potentially unfit for the purpose of reading or display. Properties that might negatively affect the fitness of objects are colour (a direct consequence of chemical degradation) and physical features that reduce the readability of such an object, such as tears and missing pieces, which may accumulate due to use. The process of accumulation of physical change is of significant interest to the Collections Demography model, as it links material properties and instances of use.

The influence of some of the value factors on the decision when a document becomes unfit for use was explored in a series of user workshops, where users were requested to rank the fitness for purpose of differently distressed documents (discoloured, with tears or missing pieces). In this exercise, carried out at The National Archives (Kew), Library of Congress (Washington) and the Wellcome Library (London), 331 users participated. An example of three documents used in these workshops (out of 17 in total, with different combinations of distress) is shown in Fig. 2. It turned out that users are concerned with colour and tears only to a minor extent (irrespective of the purpose, i.e. display or reading), while they generally rank documents as 'unfit' only once a piece of document is missing, containing text. It is important to stress that by unfit, we mean that some users will likely find the accumulated degradation unacceptable. This certainly does not mean that the document becomes unsuitable for use.

Mechanical degradation (wear and tear) can only occur during handling of a document. So far, there has been no study looking into the rate of accumulation of aspects of mechanical distress during handling and a controlled experiment was designed involving handling of



Fig. 3: The consequence of 50 instances of handling for the paper (bound and unbound) with the lowest DP.

objects by readers-volunteers. The objects were either bound books or folders containing loose sheets of paper, resembling archival folders. The aim was to subject each document to instances of handling and monitor the accumulation of physical degradation (tears, missing pieces) during use, which involved turning the pages resembling the process of reading. 25 different books and archival folders were used, with paper of different degree of polymerisation (DP), to investigate how accumulation of mechanical degradation depends on DP.

Only paper with  $DP < 300$  accumulated missing pieces with text at an appreciable rate (Fig. 3). For documents with  $DP > 600$ , missing pieces with text accumulated at an insignificantly low rate and in many cases did not develop missing pieces even after 90 instances of handling. In order for this data to be of use, it needs to be used in the context of the average frequency of document use at the collecting institution, which forms an essential input into the collection model.

### Conclusions

Collections can be seen as a dynamically changing entity, changes depending on external (environment, use), as well as internal impacts (material make-up). Although the rates might be different, the processes of change in collections and those taking place in living populations are similar, so the principles of modelling could also be similar. In the Collections Demography project, we are developing a general stock (population) model, in which a collection could be defined as a group of objects to which a given set of management criteria are applied. This enables the

model to be used for examination and optimisation of different management scenarios (with respect to the environment or use), as suggested in recent environmental management guidance.

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**Table 1: Factor structure of value statements from the VALUE questionnaire**

Factor Name	Description
Future Value	Statements in this factor relate to the potential future value of documents, their significance to society and value to others, altruistic feelings about collections and the survival of documents.
Materials & Sensory Experience	Statements relate to users' sensory experience of documents (mainly visual) and refer to such things as style, design and materials.
Public Value & Evidence	Statements in this factor were based on a set of statements found on the Public Service Quality Group's biannual survey of UK archives [8]. They were found to cluster together in this factor. Statements refer to some of the core roles of government archives in supporting business, administration and the law.
Personal Meaning & Identity	Statements in this factor relate to the way in which original documents may be used in archives and libraries to build understanding of family, community and personal identity, for example by gaining insights into one's personal origins or feeling more connected to other people in the present day.
Understanding the Present	Statements refer to the use of documents to help understand events in the present day and to link the past to the present.
Discovery & Engagement	Statements in this factor refer to the way in which using or viewing original documents can elicit surprise, feed curiosity and stimulate the senses.
Content & Learning	Statements in this factor refer to the information content (i.e. text and images) of documents, what can be learnt from them and their role in enabling understanding of and insight into the past.
Connection to the Past	Statements in this factor reflect an interest in what mattered to people in the past, how documents can help the user or viewer feel connected to people in the past, and how documents are part of history.
Rarity	A small factor with statements relating to the uniqueness of the document and whether it could be replaced if damaged.

## Characterisation of Historical Paper - Possibilities and Limitations

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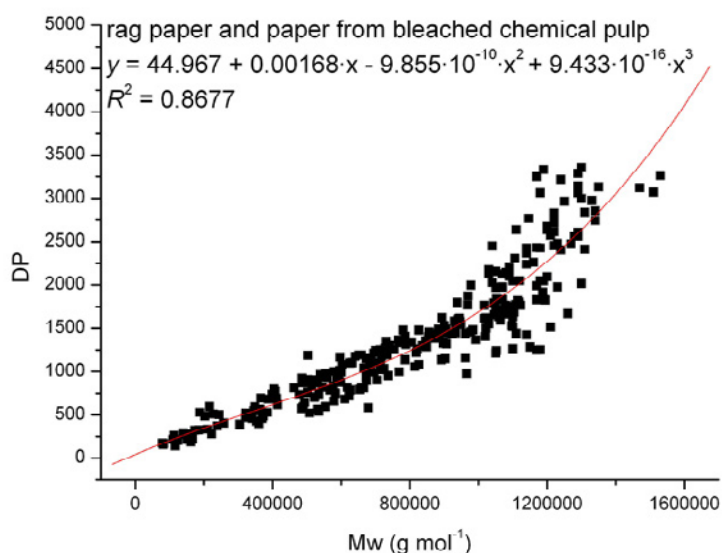


Fig. 1: Correlation between molar mass of carbanilated cellulose and degree of polymerisation of cellulose.  $R^2$  is the coefficient of determination. It describes how well a regression line fits a set of data.  $N$  is the number of data points.

### Introduction

Conservation and preservation decisions often rely on the assessment of the condition of the artefact or the collection. Due to the numerous factors such as destructiveness of the methods, high price and specialised expertise needed, the use of analytical methods is still rather limited. Novel applications of analytical methods targeting cultural heritage materials, such as size exclusion chromatography and Near-Infrared spectroscopy address some of the drawbacks of the traditional chemical characterisation of such materials. This paper discusses advantages and limitations of some characterisation techniques used to assess the condition of historical paper.

### Experimental

The pH of paper was evaluated using traditional cold extraction method (Tappi529 om-11) using a combined glass electrode. Equilibrium pH was determined by repeating the measurement until a constant pH reading was obtained.

Size exclusion chromatography of cellulose derivatised using phenyl isocyanate derivatives was used as described previously (Kolar 2012).

Viscometric determinations of the degree of polymerisation (DP) were performed according to the standard procedure ISO 5351/1.

MORANA NIR 1.0 commercial software application was used to predict paper properties using Labspec NIR256-2.5 Near-Infrared Spectrometer by Ocean Optics. It has a spectral range 900-2500 nm and a sampling interval between 6 and 7 nm. It contains a temperature-regulated InGaAs detector array. The light source is an external tungsten halogen light (HL-2000-FHSA). Data acquisition was performed using a 600  $\mu$  diameter premium grade bifurcated optical cable.

A single ply of the paper to be analysed was placed on several plies of Whatman paper. The spectra were collected using an optical probe.

Independent sample sets were used for calibration and validation. Partial least square analysis was used to model the paper properties. Correlations were optimised using different pre-treatments of the spectra and by selection of wavelengths.

## Discussion and Results

### 1. Condition of paper

Condition of paper is an important information affecting conservation choices. The arsenal of methods includes determination of mechanical properties, viscometric determination of DP, chromatographic determination of molar masses and the use of Near-Infrared spectroscopy.

The use of mechanical properties, such as folding endurance, tearing resistance, and bursting strength are limited due to their destructive nature and a requirement for a large paper sample, often exceeding 10 g. In addition, relative uncertainties of most of these methods are rather high.

It had been demonstrated that mechanical properties correlate with molar mass of cellulose

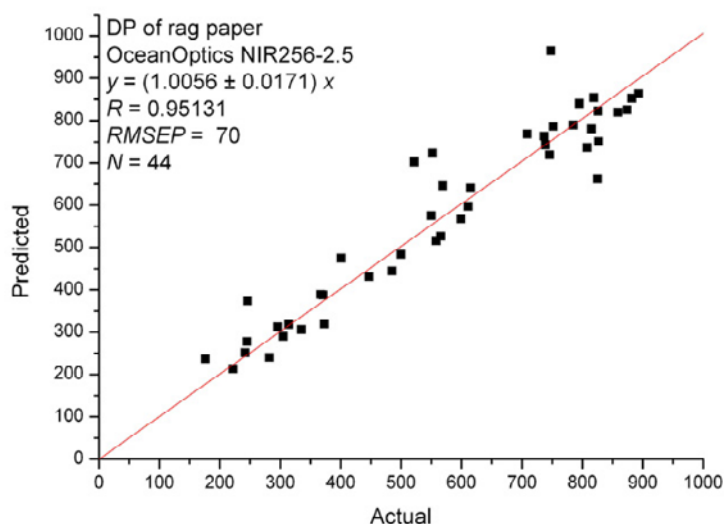


Fig 2. Partial least square prediction of DP of rag paper. RMSEP is root mean square error of prediction. It is defined as the root of the average of the squared differences between the predicted and measured values on the validation objects. R is the correlation coefficient, describing the strength of a linear dependence between two variables. N is the number of data points.

(Zou 1996), giving rise to extensive use of viscometric determinations of degree of polymerisation (average number of monomer units in cellulose, DP) in characterisation of paper. Relative uncertainty is low, around 1% and a few tenths of mg of sample are needed. Although much lower than in the case of mechanical properties, this is an ample amount which prevents the use of the technique on historic materials. Alternatively, molar mass of cellulose may be determined using size exclusion chromatography, either using non derivatised cellulose (e.g. Henniges 2008) or derivatised (e.g. Lojewski 2010). A good correlation is observed between the viscometrically determined DP and the molar mass of carbanilated cellulose (Fig. 1).

It had been shown that in the case when cellulose is derivatised using phenyl isocyanate, a few fibres suffice for characterisation (Støl 2002). Despite the destructive nature of the method, the amount of the sample is small and the method results in no visible damage to the artefact. It also enables evaluation of different stabilisation processes on historical samples containing iron gall ink (Kolar 2012). However, the uncertainty related to the method is larger than in case of viscometry, often exceeding 5%. This is partly due to inhomogeneity of paper, the effect of which is more prominent in smaller samples.

It is also an expensive method requiring highly skilled personnel.

Near- and mid-FT-IR reflectance spectroscopy was used to model DP values obtained using viscometry (Trafela 2007). Quality of prediction is often described with a correlation coefficient R. The closer it is to +1 or -1, the more closely the two variables are related. A good correlation ( $R = 0.9658$ ) between actual and predicted values were obtained using a scientific bench-top spectrometer Perkin-Elmer Spectrum GX (Waltham, MA) which collects spectra between 714 nm ~ 5,000 nm. The same instrument was used in another study, where mechanical properties such as tensile strength after folding ( $R = 0.8845$ ) and tensile strength ( $R = 0.7607$ ) were predicted (Lichtblau 2008). The instrument is not portable and the otherwise non-destructive spectrometric measurements are limited by the small size of the sample which can be used for otherwise non-destructive analysis. Based on the promising predictions a commercial software was developed by MORANA RTD, which enables determination of a range of properties of various papers, such as DP, Mw, pH, alkaline reserve using a reasonably affordable, portable spectrometer which allows for non-destructive data collection using an optical fibre. The software is, were possible, adapted to the requirements of the conservation community, which is often particularly interested in more degraded papers. Thus in addition to the prediction of DP of all rag papers, a separate prediction is made for more degraded papers, decreasing the error associated with the method (Fig. 2).

## 2. pH

Given the importance of pH on stability of paper, pH determination is likely the most often used analytical method in paper conservation studies. Standard method involves immersing 1 g of paper into 70 mL of distilled water and pH is determined after 1 hour (ISO 6588-1:2012). Since destructive sampling is required, researchers have minimized the sample requirements to 30-50  $\mu\text{g}$  by using a micro electrode. Miniaturisation of the procedure decreases the repeatability with acceptable values of 1.0 pH unit (Strlic 2004), which was ascribed to the inhomogeneity of paper.

In the alternative standard (TAPPI T 529 om-09) determination of the surface pH is made up to 30 min after application of a water droplet to the surface of paper. Although non-destructive sam-

pling is required, tide-lines are created due to the application of water. A micro-electrode was used in order to minimize the amount of water needed and consequently, related damage induced by the measurement (Strlic 2005). The electrode is so far not commercially available.

Considering the damage which is induced using the above described methods, a non-destructive method which does not require addition of water would be desirable. Recently, a good correlation ( $R = 0.9573$ ) between measured and predicted pH values were obtained using a scientific bench-top spectrometer described earlier. Using a portable Ocean Optics spectrometer and the above mentioned software, prediction model for all kinds of independent paper samples is characterised by  $R = 0.8802$  and  $RMSEP = 0.73$ .

Although in use for decades, the standard methodology involving pH determination after 1hr of cold extraction does not provide information on whether gelatine sized rag paper is acidic or alkaline, when equilibrium pH is reached. Our study of 150 historical rag samples showed that pH of most of the rag papers with acidic pH, as determined using the standard method, stabilised in alkaline region. This was observed also in our earlier study (Strlic 2004). Determination of the equilibrium pH value would thus be useful in the assessment of the stability of paper. The latter is difficult to determine, as several weeks of measurements may be needed for paper pH to reach equilibrium, while the recently proposed method where the sample in water is stirred at 250 r.p.m. (Strlic 2004) is difficult to implement. Although not as accurate as the determination using a pH meter, NIR spectroscopy may be useful also in this case offering a prediction for the equilibrium pH with  $R = 0.8123$  and  $RMSEP = 0.76$ . Prediction is based on all kinds of paper.

## Conclusions

Inherent features of cultural heritage require a specific approach to its characterisation. It is imperative that the data is collected non-destructively or at worst, micro-destructively. Also, the instrumentation should be portable in order to minimize risks to the heritage due to the transport. The method employed should be characterised by high sensitivity and low detection limits, which reveal the condition, enable determination of provenance, or point to possible future problems and thus allow preservation actions to be taken in time. It is also preferable that the

methods are simple, reliable and accessible.

While we know what we want, none of the existing methods for determination of pH and the condition of paper addresses all of the above mentioned requirements. DP determination is sensitive, affordable and reproducible, yet destructive. Size exclusion chromatography of carbanilated cellulose leaves no visible damage to the artefact, but is instrumentally demanding and expensive. Near infra-red spectroscopy with accompanying software can be simple, fast, portable, relatively affordable, but is associated with a larger uncertainty. The choice of the analytical method will remain subject to the nature of the artefact and the conservation problem, among others. While size exclusion chromatography, when available, may be the method of choice in case of a precious artefact or a limited number of samples to be analysed, NIR spectroscopy may be more appropriate for characterisation of larger sets of artefacts, as well as for rapid characterisation of the artefacts during daily work in conservation departments.

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## Study of Phytate Chelating Treatments Used on Iron Gall Ink Damaged Manuscripts

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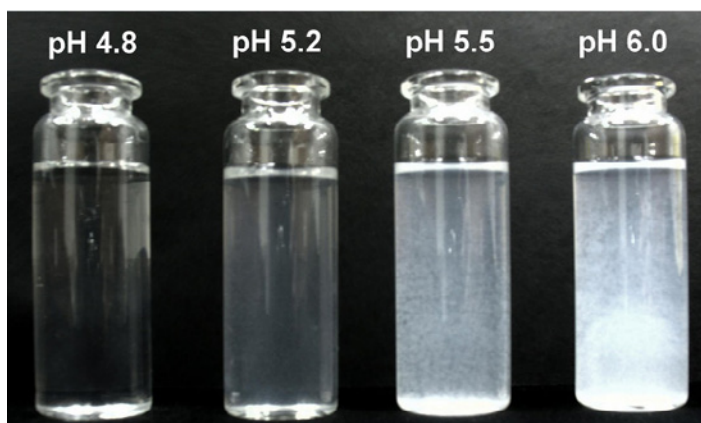


Fig. 1 : Aspect of CP solutions prepared at different pH value

### Introduction

Many historical documents written with iron gall inks are endangered by the corrosive effects of these inks. In this work, a combination of complementary analytical methods was used for the first time in order to study the “calcium phytate” process which is used in conservation studios to stabilize damaged manuscripts (Neevel 1995). This process consists of an antioxidant treatment performed by means of a calcium phytate (CP) solution, followed by a deacidification treatment performed with a calcium hydrogencarbonate (CH) solution. The antioxidant treatment capitalizes on the properties of myo-inositol hexaphosphoric acid (phytic acid) that inhibits iron through chelation. In order to use relatively low acidic solutions, the pH of the calcium phytate solution is increased up to values between 5 and 6, which is in the range of the CP precipitation threshold. This abstract synthesizes a larger work (Rouchon et al 2011a) that was performed on laboratory samples in order to investigate how the calcium phytate precipitate impacts the efficiency of the treatment.

### Experimentals

#### Preparation of laboratory samples

Samples consisted in Whatman no.1 paper sheets impregnated with a diluted iron gall ink prepared with laboratory products<sup>1</sup>. The ink presents a pH of  $3.0 \pm 0.1$  and the iron content deposited in the paper ( $11 \text{ m Mol}\cdot\text{g}^{-1}$ ) remains inferior but close to the iron content of original manuscripts which is usually over  $20 \text{ m Mol}\cdot\text{g}^{-1}$  (Remazeilles et al 2005).

Before treatment, the samples were artificially aged for approximately 6 days in a climatic chamber, using mild ageing conditions ( $70^\circ\text{C}$ , 65% RH) in order to simulate some degradation of the paper and to achieve a decay of approx. 10-15% of mechanical properties.

CP solutions were prepared following the protocol proposed in the nineties (Neevel 1995) and fully described online (<http://irongallink.org>). In order to study the effect of the CP precipitation, four different values of pH were chosen (Fig. 1): 4.8 (transparent solution), 5.2 (turbid solution), 5.5 (white cloudy solution), and 6 (precipitate formation at the bottom of the container). The CH solutions were prepared with a method close to that used in conservation workshops: 1.1 g of calcium carbonate was added to 1 L of commercially available sparkling water<sup>2</sup>. The bottles were closed immediately after addition, then left to rest for 24 hours before use. Only the supernatant was used ( $\text{pH } 5.8 \pm 0.2$ ). The various treatments that were implemented are listed in Table 1. Each immersion was performed using 2 mL of solution per  $1 \text{ cm}^2$  of paper. Afterwards, the samples were aged again for approx. 2 months in the same conditions as before treatment.

#### Analytical methods

As conservation treatments in first place aim to limit physical decay to the paper, mechanical testing appeared meaningful for the evaluation of treatment efficiency. The paper mechanical properties were evaluated with a zero-span

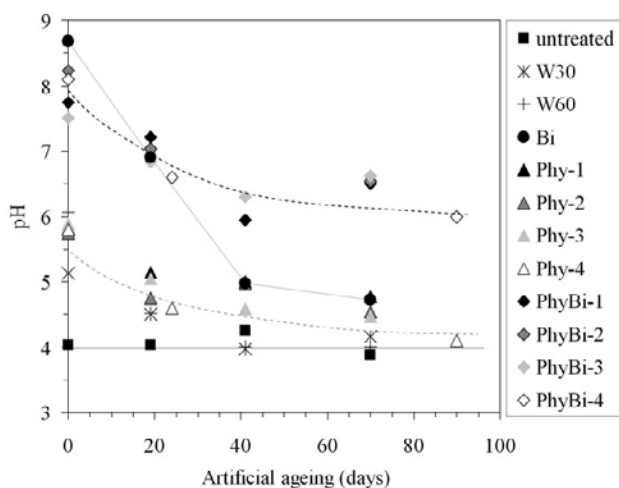


Fig. 2 : Evolution of pH versus artificial ageing

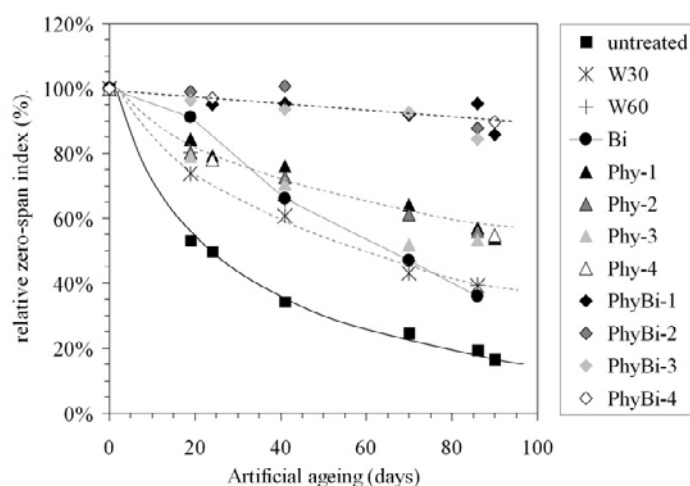


Fig 3. : Mechanical decay of treated samples versus artificial ageing

tensile tester (Pulmac, TS-100) on dried papers, pre-conditioned at 23°C and 50% RH. This test consists in measuring the failure load necessary to break a strip of paper maintained by adjacent jaws. The load is expressed in kg per 15 mm of strip width. For each sample, 10 measurements were performed and the average was considered. Standard deviation were ranging from 2% to 6%.

Mechanical tests were completed with pH measurements performed on cold extracts, prepared with 0.5 g of paper in 25 mL of decarbonated ultrapure water. Additionally, global elemental contents were measured by Inductively Coupled Plasma - Atomic Emission Spectrometry (ICP-AES), and elemental distributions were mapped by Scanning Electron Microscope and Energy Dispersive X-Ray Spectrometer (SEM/EDS) according to a protocol fully described elsewhere (Rouchon et al 2011a).

## Results

### Efficiency of anti-oxidant and deacidification treatments

The evolution of the pH as a function of artificial ageing time is plotted in Fig. 2. The pH of untreated samples remains stable and close to a value of 4 during the degradation. The washing effect of water is noticeable: the removal of soluble acidic compounds from the samples increases the pH by approx. 1 unit. But contrary to untreated samples, the pH of washed samples decreases during artificial ageing and finally re-

covers its initial value.

The deacidification realized by means of the CH solution raises the pH up to alkaline values (close to 8). However, when deacidification is performed employing only bicarbonate (Bi), this effect does not last very long and the pH falls back to a level of approx. 5 during the first month of artificial ageing. This decline is limited when the samples are treated with CP prior to deacidification (PhyBi-1 to PhyBi-4): In these cases, the pH stabilizes around a value of 6 after one month of artificial ageing

Fig. 3 shows that the untreated samples are the most damaged. After three months of artificial ageing, they have lost 80% of their zero span breaking load. In comparison, the samples that were washed in water only (W30 and W60) are less damaged: The removal of soluble compounds delays the paper degradation, however, without stopping it. The benefit of CP solutions is similar for all investigated pH values (Phy-1 to Phy-4) and slightly higher than that of water washing, but these treatments remain of limited efficiency. Similarly, the CH treatment, when used by itself (Bi), gives rise to a short term beneficial effect only.

Contrary to all the above, excellent results were obtained using a combination of CP and CH (PhyBi-1 to PhyBi-4): after 3 months of artificial ageing, only a 10% loss of zero span breaking load is observed, irrespective of the pH of the CP solution that was employed.

### Evaluation of stoichiometric effects (“side effects” is not an appropriate title)

The molar Ca/P ratios of the samples Phy-1 to Phy-4 are similar ( $0.605 \pm 0.05$ ), meaning that in the pH range 4.8 to 6, the CP is deposited in the samples with an average stoichiometry of 3.6 calcium atoms per phytate molecule. This suggests that the precipitate is a mixture of Ca:Phytate 3:1, Ca:Phytate 3.5:1 and Ca:Phytate 4:1, consistently with existing data: The Ca:Phytate n:1 is known to be soluble for low values of n ( $n=1$  and  $n=2$ ), and insoluble for higher n values ( $2 < n$ ) (Graf 1983). The specification of phytate solutions can be calculated versus pH considering the 12 pKa values of this acid (Heighton et al 2008): In the pH range from 5 to 6, three species of phytate, respectively bounded to four, five, and six protons are co-existing in solution, meaning that resp. eight, seven, and six free sites remain available for calcium bounding. If we consider that each calcium can occupy maximum two available phytate sites, and that calcium does not remove bound protons, the resulting Ca:Phytate precipitate stoichiometry should be between 3:1 and 4:1, consistently with the measured value of 3.6:1.

In our experimental procedures, the phytate concentration in the solution is 1.75 mM, and the concentration of iron in solution remains below 0.044 mM, a value estimated under the assumption that all iron present in the paper is dissolved. Phytate is also present in large excess compared to iron. In these conditions, its high affinity toward iron is expected to lead to the formation of soluble iron phytate 1:1 complexes, thus facilitating iron removal from the paper in comparison to pure water. This is not the case. Pure water appears the most efficient for iron removal (50 % of iron is lost). On the contrary, iron is more likely to remain in the paper when CP is present in solution (only 30 % of iron is lost). Far from enhancing iron removal from the samples, the CP solution helps to retain iron in the paper.

In CP solutions, calcium is used at a concentration of 4.4 mM, i.e. in large excess over iron ( $< 0.044$  mM). It is already known that the addition of calcium in iron phytate solutions provokes co-precipitation phenomena (Subba Rao and Narasinga Rao 1983). Similarly, the fact that CP solution helps to retain iron in the paper appears to us related to co-precipitation phenomena. Iron is

present in low concentration and can be incorporated in the calcium:phytate precipitate without noticeably changing its stoichiometry.

It was recently demonstrated on quite similar laboratory samples (Rouchon et al 2011b) that the cellulose depolymerisation was mainly due to oxidative mechanisms provoked by surrounding oxygen. Consequently, the poor efficiency of CP treatment, when performed alone (Phy-1 to Phy-4) refers to the fact that phytate does not inhibit iron at this pH level. The ability of phytate to chelate iron is correlated to its capacity to block all iron coordination sites. This property was evidenced in mild alkaline, but not in acidic conditions. In these conditions protons are obviously competing with calcium and iron for phytate bounding. We think that the iron which remains in the paper after CP treatment is only poorly bound to CP and thus not inhibited. When the CP treatment is followed by deacidification, the pH of the paper rises to approx. 8 and approx. two of the protonated sites of phytate become available (Heighton et al 2008), thus favouring the inhibition of iron through chelation.

### Conclusion

This study confirms that the calcium phytate treatment should necessarily be followed by a calcium hydrogencarbonate deacidification in order to achieve long term stability. It additionally shows that the precipitation of calcium phytate in the treating solution does not significantly impact the efficiency of the treatment. We think that iron is not inhibited in the pH range 5 to 6, because it has to compete with protons and calcium ions to bind phytate. After deacidification, the removal of protons releases approx. two new chelating sites on each phytate molecule, which is probably enough to efficiently inhibit iron.



**Table 1. List of implemented treatments**

Name	distilled water	CP solution	CH solution
W30	2 baths	–	–
W60	4 baths	–	–
Phy-1	–	2 baths (pH 4.8)	–
Phy-2	–	2 baths (pH 5.2)	–
Phy-3	–	2 baths (pH 5.5)	–
Phy-4	–	2 baths (pH 6)	–
Bi	–		2 baths
PhyBi-1	–	2 baths (pH 4.8)	2 baths
PhyBi-2	–	2 baths (pH 5.2)	2 baths
PhyBi-3	–	2 baths (pH 5.5)	2 baths
PhyBi-4	–	2 baths (pH 6)	2 baths

The baths were lasting 15 minutes each, and the solutions were renewed between two baths.

#### Endnotes

- 1 composition of the ink : monohydrate gallic acid (Aldrich, 398225), 0.6 g·L<sup>-1</sup>; heptahydrate Fe(II) sulphate (Aldrich, 215422), 2.66 g·L<sup>-1</sup>; gum arabic (Aldrich, G9752), 6 g·L<sup>-1</sup>.
- 2 Perrier, pH 5.2, composition in mg·L<sup>-1</sup>: Ca<sup>2+</sup>, 155; Mg<sup>2+</sup>, 7; Na<sup>+</sup>, 12; SO<sub>4</sub><sup>2-</sup>, 46; Cl<sup>-</sup>, 25; HCO<sub>3</sub><sup>-</sup>, 445.

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## Practice and Progress in the Conservation, Preservation and Digitization of the Dead Sea Scrolls

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The discovery of the Dead Sea Scrolls in the Judean Desert some sixty years ago, in 1947, is considered one of the greatest archaeological discoveries in modern times. The scrolls were either written or copied in the Land of Israel between 250 bce and 68 ce. They represent the oldest written record of the Old Testament, and contain the earliest copies of every book of the Bible, except for the Book of Esther. This 'Ancient Library' enables us a glance into a period of time pivotal to both Judaism and Christianity. Thanks to these remarkable texts, our knowledge concerning the origins of Judaism and early Christianity has been greatly enriched.

Issues of conservation, preservation and documentation of the Dead Sea Scrolls have concerned both scholars and conservators ever since the scrolls' discovery. The removal of the fragile scrolls from the caves, where they had been preserved for over 2,000 years, interrupted the environmental stability that had ensured their preservation for so long. Since their discovery, the scrolls were damaged by ravages of time, as well as from mishandling and mistreatment.

In 1991, the Israel Antiquities Authority (iaa) advised by leading experts in issues relating to conservation of manuscripts written on parchment and papyrus - established a designated conservation laboratory for the preservation of the Dead Sea Scrolls. The conservation and preserva-

tion of the scrolls has since been an ongoing task due to their extreme brittleness and the need to meet up with the most up-to-date conservation methods.

Currently, the iaa is collaborating with international experts to reevaluate the conservation techniques under use, and to decide upon courses of action for still unresolved issues. The iaa is also engaged in an advanced, large-scale digitization project, which was initiated as part of the conservation efforts. This project includes the development of a monitoring system for the state of preservation of the scrolls and the creation of highest-quality color images and advanced near infra-red images. As the publication of the scrolls is formally completed, the iaa will upload the digitized scroll images online, with their transcriptions, translations, commentaries and bibliography, allowing a free access to all.

The Dead Sea Scrolls are a universal cultural heritage. As such, it is our duty to safeguard the scrolls and preserve them for future generations, sharing them with the public and scholarly community worldwide.

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## The Language of Parchment – Learning about the History of Manuscripts with the Help of Visual Assessment of the Parchment

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### Introduction

Studies of the physical appearance of the parchment, which has been used for writing manuscripts, can provide an interesting supplement to the existing forms of manuscript research and help to create a more complex image of the information recorded in medieval books.

The rocketing development of modern technologies has also brought a great improvement in scientific analyses of materials. In recent years we have been given very detailed and exact information about collagen fibre and amino acids, the basic component of parchment. From microscopically sized samples it is possible to identify the DNA of the animal from whose skin the parchment was produced or to analyse the processes that caused degradation of the collagen fibre. Although this information opens up new horizons in many fields of this research, it is still necessary to interpret the results obtained correctly and within the context of further studies in sciences that support history and namely studies of codicology in order to exploit their potentials to the full.

It is rather paradoxical that on the one hand we can learn almost intimate details about the parchment itself while on the other hand the description of parchment in codicological literature lags far behind, being content with general descriptions of its qualities, often vague and inexact, and it is only occasionally that specific features are noted which are characteristic for different types of parchment and its methods of preparation. It is not rare for these to be presented more like curiosities than important information for a detailed description and further studies of the parchment.

It seems that codicologists are slightly uncertain as to what is to be expected from modern scientific analyses, since their questions in this field are mostly limited to the identification of the types of animal skin from which parchment was made or they expect answers to rather bizarre questions concerning the use of uterine

parchment and other rarities, theories which turn up in literature repeatedly.

In this context it might be thought quite surprising that rather simple non-destructive methods of visual observation of parchment can yield a whole spectrum of interesting information that can enrich our knowledge not only about parchment itself but also about the whole production of parchment manuscripts and their history.

In my master's thesis called "Defects and damage in parchment manuscripts – an aid to visual examination of parchment for writing purposes" (2010), I have focused my research on the different types of imperfections and damage, which can be found in parchment manuscripts. These were examined and described in chapters referring to the ways in which they appeared in parchment. For example, anatomical evidence about the animal from whose skin the parchment was made, evidence of the steps in the process of manufacture of the parchment or the preparation of its surface for the writing and production of the codex. Different forms of aging and damages of parchment as they developed during the long history of the manuscripts were examined and described and their potential as a source of information discussed. In order to be able to recognize differences in the parchments in manuscripts it is also important to understand the methods of their preparation, which differed in the course of time and according to their place of production. Practical experiments with the manufacture of parchment can help to verify some of the theories or hypotheses. Reconstruction of the methods of production of the parchment can also reveal the origin of some of the imperfections that can later be recognized in historical manuscripts.

During my subsequent work with parchment manuscripts I have realized that all these specific "signs or traits" are displaying information that can be brought into line like stones in mosaics which, if set up correctly, can create a more com-



Fig. 1



Fig. 2

plex picture and provide overall information. It might be explained differently by saying that they can be interpreted as some kind of linguistic letters on the parchment. If the parchment of manuscripts could be systematically studied by this means on a larger scale we might find the right combinations and eventually be able to understand this language. Although this might perhaps sound too literary, there is no doubt that it represents a great potential for serious research based on the physical appearance of the parchment in a manuscript.

### Methods

Methods and tools employed for the visual examination are kept quite simple, so that any researcher in manuscript studies would be able to employ them. Different types of lighting might be used in order to recognize remarkable details giving us information about the types of animals, their sizes and the anatomy of the skins

that were used in the manuscripts. A great help is provided in the case of observation of parchment folia by transmitted light. Raking light on the other hand improves the visibility of various traces from tools originating from the production of the parchment.

Digital photography has made it possible to provide later evaluation of details recorded on the computer screen. Pictures obtained by high-resolution digital cameras can be later enlarged or relatively simply manipulated in generally used computer programs in order to ease recognition of even smaller details that can be later matched and compared with similar features on pictures from another folium or even another manuscript. Interesting results are appearing when parchments that were used for the production of manuscripts in the same scriptorium are compared.

More and more manuscripts have recently been digitalised and made available on libraries' web sites. Texts or illustrations may be studied online and browsing through the manuscripts also makes possible a first general observation of the parchment. This can, however, only be used for preselecting some specific folia that show visible irregularities, while for more detailed and complex observation it is still necessary to consult originals and use special techniques of lighting and photography. Occasionally some printed facsimiles still offer more information than available from digital images on the websites.

### Examples of use of visual examination of parchment in manuscripts

A The Hamburg Bible (The Royal Library, Copenhagen, GKS 4, 2<sup>o</sup>) manuscript in large folio size can be used as a good example for studies of the manufacture of parchment and the production of the manuscript. On its large parchment folia we can find an almost complete catalogue of the different types of imperfections, repairs or other signs that are characteristic for parchment produced in the 12<sup>th</sup>/13<sup>th</sup> centuries. The method of formatting this parchment into bifolia and their organisation into quires in the codex display a quite advanced system for eliminating natural irregularities in the parchment. (Fig.1, 2)

B Strikes made by the parchment-maker's knife recorded on the surface of the parchment folia of The Prague Sacramentary from the 8<sup>th</sup>/9<sup>th</sup>



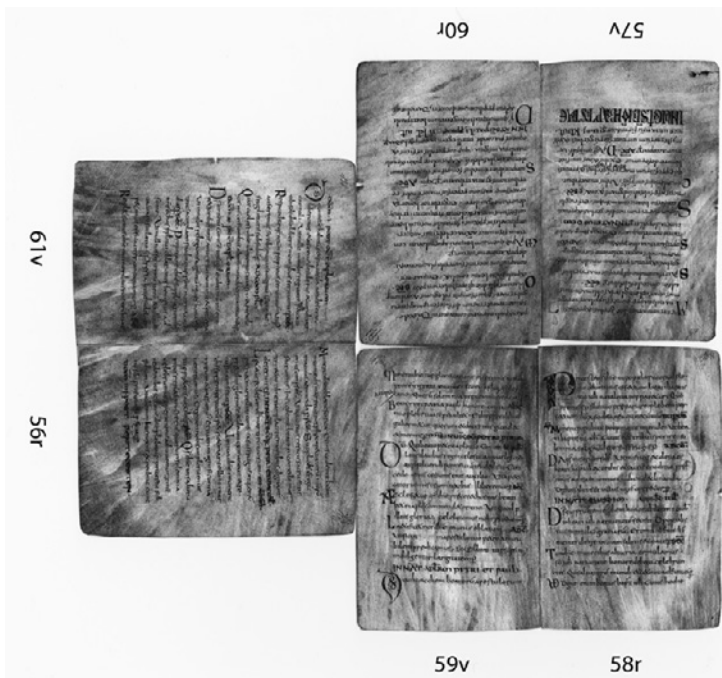


Fig. 3



Fig. 4

centuries (The Prague Castle Archive, Metropolitan Chapter Library, O.83) can help us to reconstruct the manuscript's bifolia back into the shape of the animal from which the skin was made. By this "reverse" method we can also learn interesting information about the sizes of sheep skins and how parchment was folded and divided into bifolia and later distributed and organized in quires (Fig. 3).

- C The codex which includes King Valdemar's Cadastre (The Danish National Archives, C 8) and other manuscripts from the end of 13<sup>th</sup> cen-

tury is rather small in size and brings together slightly different types of parchment, which, thanks to the traces of the parchment-maker's tools and other characteristics, can be identified, compared and partly sorted into certain groups. It is also rather interesting to compare this parchment with the parchment of other codices which were written by the same scribe and preserved in different libraries (Fig. 4).

### Conclusions

Parchment in manuscripts carry, like a vessel travelling through history, in several layers of information from the past. In order to understand these it is necessary to learn its language by carrying out systematic research on the characteristics of different types of parchment and the different signs left on the surface from the process of manufacture or later damage. The clue lies in correct evaluation of the results obtained from visual analyses and combining them into certain patterns.

Some methods are developed and these have already brought interesting results as in the case of several individual manuscripts, but their great potential can be improved by development of specialised computer programs which will enable research into and evaluation of a much larger number of folia and animal skins from which parchment manuscripts have been made.

There is no doubt that highly specialised material analyses can produce relevant information but it is extremely important to target them precisely and effectively. The best effect will be obtained especially by interdisciplinary research involving codicologists and other historians, researchers in manuscripts, who will combine their knowledge with that of experts in other fields such as archaeology, biology, conservation and forensic science.

### Texts for illustrations

Fig. 1: Each bifolio of the second volume in the Hamburg Bible is created from one calfskin. This means that the original spine of the animal was laid down horizontally at right angles to the spine of the book. Backing light made observation of the former rump and spine of the animal easier. Note also the marks of the vertebrae and the U-shaped cut in the area of the former tail.

Fig. 2: Coloured paper strips placed in the first half of the fore edge of the codex mark the original position of the head (yellow) and tail (green) of the animal on the skin. There are several reasons why the spines are distributed in this way through the quires. Parchment is more undulated and thicker in the area of the original neck, spine and rump than in other parts. With this layout one achieves a better balance in the thickness of the text block so that undesirable undulation of the folia is prevented. Spines of the skins of smaller sizes are placed centrally, while spines of larger skins are positioned either further up or down towards the top or bottom of the text block. With this arrangement a larger skin can also be used more economically, since leftovers which are cut away from one side of parchment may be used for the production of smaller manuscript documents.

Fig. 3: One of the reassembled skins from the Prague Sacramentary, a manuscript of quarto size, shows that this skin was large enough to produce only 3 bifolia and not 4 as might be generally expected. This is not so surprising, since the sheepskin from which the parchment was made is quite thin and weak and could easily be mechanically damaged during the flaying of the skin. In addition, raw skin in the course of the parchment-making process may be affected by bacteria

or mould, resulting in the appearance of a large number of small holes. Skin can become mechanically weak and quite large areas have to be removed already before the skin is stretched on the frame.

Fig. 4: Traces of the parchment-maker's knife can be visualised by making a rubbing over a textured surface placed over the parchment folio. This frottage method helps to isolate and record traces of a tool which left on the parchment a unique offprint made by its jagged edge. The obtained "fingerprint" or "bar code" can be later used for recognition of the identical tool on the surface of other parchment folia coming from the identical skin and later placed in a different part of the text block or even another codex. In the case of a smaller manuscript, for example of octavo size, we can expect a very uneven distribution of bifolia originating from one skin in the text block. For their production may also involve leftovers from the production of larger manuscripts.

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## The Use of NIR Spectroscopy to Investigate the Condition of Parchment

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### Abstract

Parchment documents and manuscripts represent an important part of our written heritage, but are prone to a variety of degradative reactions and so are inherently vulnerable. The ability to monitor the condition of parchment and assess the way in which it responds to the environment allows the most appropriate conservation, display and storage strategies to be adopted, and will help to ensure the survival of these artefacts for future generations.

Near infrared (NIR) spectroscopy provides a non-invasive (and, with the correct equipment, potentially *in situ*) method of investigating the chemistry of parchment, and has been used in the work presented here to both assess the progress of two common deterioration mechanisms for this material (gelatinisation and thermally induced cross-linking), as well as to better understand the way in which it responds to changes in the local environment (particularly humidity). Correlations were drawn between physical changes observed in the parchment samples, as they were subjected to degradative reactions or environmental variations, and changes in the spectra measured by derived peak intensity ratios. These ratios then allow similar processes to be monitored in other such materials. A further outcome of this work has involved applying these techniques to assess the differences in behaviour with respect to local conditions between single parchment sheets and books of bound parchment leaves, in conjunction with data recorded by temperature-humidity loggers, and this is of particular interest when compared to similar results for paper.

The work has stemmed from questions posed by objects in the British Library's collection, and has been used to better understand these artefacts and aid collection care decisions. Furthermore, the environmental response data will help to inform strategies for the storage of both individual parchment items and the collection as a whole (not only benefiting their long-term survival but also potentially allowing energy and financial savings).

### Introduction

The British Library's collection contains many thousands of parchment documents and volumes, including such important and prestigious artefacts as the Magna Carta, the Lindisfarne Gospels and the St Cuthbert Gospel. As items such as these are of great historic and cultural significance, preserving them for future generations is of great importance, and to do this it is necessary to understand their current condition and their likely ongoing behaviour. Traditionally this has been the province of the expertise and experience of individual conservators and curators, but with the increasing availability of analytical equipment it is now possible to supplement this knowledge with instrumental techniques that can allow objects to be rapidly investigated and assessed, permitting those items in need of greatest attention to be highlighted and thus selected for attention. With increasing demands on budgets and time, growing collection sizes and, in many institutions, fewer specialist conservation staff, techniques like this which allow resources to be employed most efficiently will come to be of ever greater importance.

Parchment is prone to damage from a variety of causes, including gelatinisation due to exposure to excessive levels of moisture, microbiological attack (usually also linked to humidity), physical damage including general wear-and-tear, embrittlement from desiccation, and distortion and shrinkage caused by the extreme temperatures of fires. Gelatinisation is a common problem for parchment documents, resulting from the hydrolysis of the highly ordered and relatively durable collagen protein to the amorphous and physically weak gelatine. Parchment documents are also significantly more susceptible to the effects of fires than the equivalent paper documents (Fig. 1); the material contains a variety of residual oils and fats which will readily burn if exposed to a flame, and at high temperatures the bulk material will shrink and distort, not only resulting in the loss of information from the document, but also exposing more of the material to

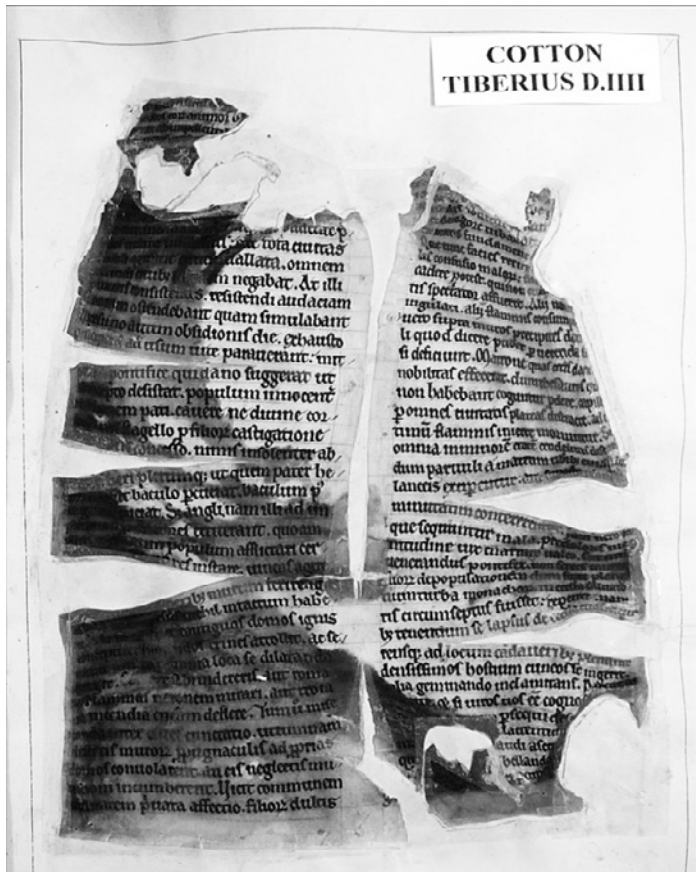


Fig. 1: Fire damage to a parchment manuscript, showing scorching and distortion (the parchment was deliberately cut between lines and columns in the 19<sup>th</sup> C to allow it to be flattened).

the fire (on the other hand paper, unless found as loose sheets, tends to remain as a solid block, which chars around the edges but does not readily burn). One of the collections on which the Library was based, the Cotton collection (originally belonging to the 17<sup>th</sup> century antiquarian Sir Robert Cotton) was involved in two fires, the first in 1731 and the second (smaller) one in 1865, which caused significant damage to many important documents, including Beowulf and a copy of the Magna Carta.

Some cases of these types of damage are readily apparent - taken to an extreme, gelatinisation results in a material with a typical translucent, glossy appearance, and fire damage causes obvious scorching and distortion. Not all degradation is so obvious, and early stages of deterioration can be difficult to detect. Even at such stages, however, these changes can have a significant effect on the stability of the material and will influence the choices of the most suitable con-

servation treatments and storage conditions. For example, gelatinised parchment is particularly prone to further damage from water, whilst thermally damaged material is brittle and prone to physical damage. Therefore it would be of value to the preservation of these materials to have a method of detecting these early signs of damage in order to identify materials at risk and to treat them in the most appropriate manner.

Given the value of the artefacts which may be assets, such a technique would have to be non-sampling and non-invasive to be of use in the field of conservation; ease of use, rapidity of analysis and the potential to carry out the investigation in an in situ manner would also be desirable. Near infrared (NIR) spectroscopy provides a method which fulfils these requirements, and has therefore been investigated as a method characterising the state of parchment.

To this end, a variety of different samples were obtained for investigation. Some of these came from historic sources, and thus represent examples of 'real' ageing and damage; to widen this set of samples, further specimens were prepared by exposing modern parchment to heat, fire or conditions that would induce gelatinisation. These materials were used in conjunction with NIR spectroscopy to investigate measurable changes and thereby develop methods of monitoring such changes in parchment artefacts.

This research has been carried out as part of a larger investigation into the condition, conservation and assessment of parchment based artefacts held in the British Library's collection.

### Method

A number of historic parchment samples in a variety of conditions were collected for assessment. In addition, surrogates were prepared in several ways. Gelatinised specimens were produced by placing several different parchment samples in a high humidity environment (90% RH, 40°C), and removing sections daily over the course of a month. Samples were also exposed to fire to yield specimens which mimicked the fire-damaged parchment of the cotton collection. These materials were stored at 18°C and 50% RH prior to and during analysis.

Spectra were collected from these materials, using a PerkinElmer 'Spectrum 400' spectrometer fitted with an NIR integrating sphere; spectra were recorded over the range 12,000 - 4,000 cm<sup>-1</sup>,



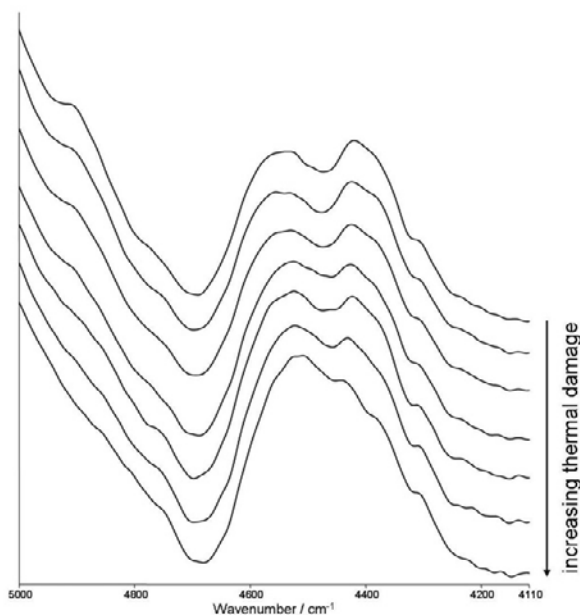


Fig. 2: Changes related to thermal damage in the NIR spectrum.

with a resolution of 16 cm<sup>-1</sup> and averaged over 50 accumulations.

### Results and Discussion

Examining the spectra shows that the thermally damaged samples display a characteristic change in the region 4700 - 4200 cm<sup>-1</sup> (Fig. 2). It can be seen that as the sample suffers thermal damage the strength of the peak at 4420 cm<sup>-1</sup> diminishes with respect to the neighbouring peak at 4540 cm<sup>-1</sup>; furthermore, the shoulder observed at 4920 cm<sup>-1</sup> loses definition. Using these observations, it is possible to derive a spectral intensity ratio that reflects this change and can thus be used to investigate regions of thermal damage:

$$D_D = I_{4540} / I_{4420}$$

Where:  $D_D$  = indicator of thermal damage  
 $I_x$  = intensity at x cm<sup>-1</sup>, above a baseline drawn from 4680 to 4150 cm<sup>-1</sup>.

The changes involved in the early stages of gelatinisation are more subtle, but can be seen in the broad peak at 7300 - 6100 is considered (Fig. 3). The general shape of this peak changes as gelatinisation occurs, with the primary peak at 6860 cm<sup>-1</sup> diminishing and a secondary one at 6685 cm<sup>-1</sup> becoming more apparent. As above, an

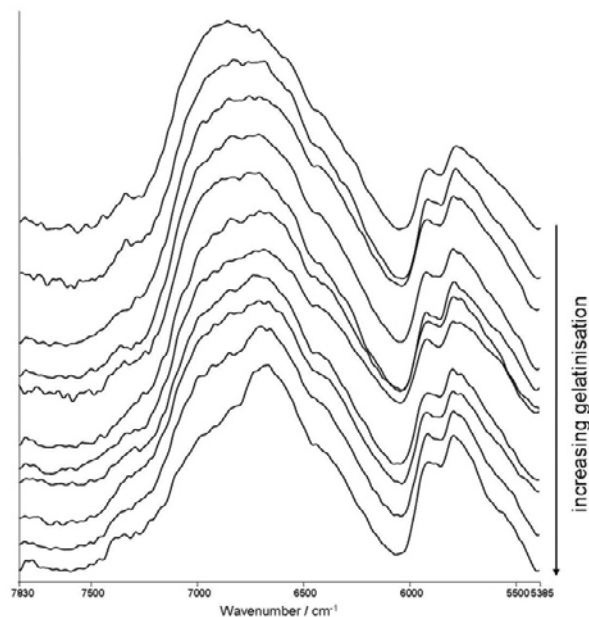


Fig. 3: Changes related to gelatinisation in the NIR spectrum.

intensity ratio based on this observation can be used to assess the degree of gelatinisation in a parchment sample:

$$D_g = I_{6685} / I_{6860}$$

Where:  $D_g$  = indicator of gelatinisation  
 $I_x$  = intensity at x cm<sup>-1</sup>, above a baseline drawn from 7540 to 6030 cm<sup>-1</sup>.

If a sample is prepared in which localised gelatinisation has been encouraged by the use of a dampened swab, or which has been partially burnt, then these ratios can be derived from spectra recorded systematically across the specimen and displayed as a colour scale, indicating the areas in which damage has occurred and thereby demonstrating that this approach can be used to map such damage.

### Conclusion

NIR spectroscopy is a valuable tool for the investigation of historical and cultural artefacts, as it can be used a non-sampling, non-invasive, in situ manner, and is rapid and simple to employ. With this work we have demonstrated how the technique may be used to investigate the state of parchment, in particular the onset of gelatinisation and thermally induced damage. This will

inform decisions on conservation treatments, handling methods and display and storage conditions. Currently this approach is used as a spot analysis technique, but the aim is to developing into an imaging method that will allow parchment manuscripts to be rapidly assessed.

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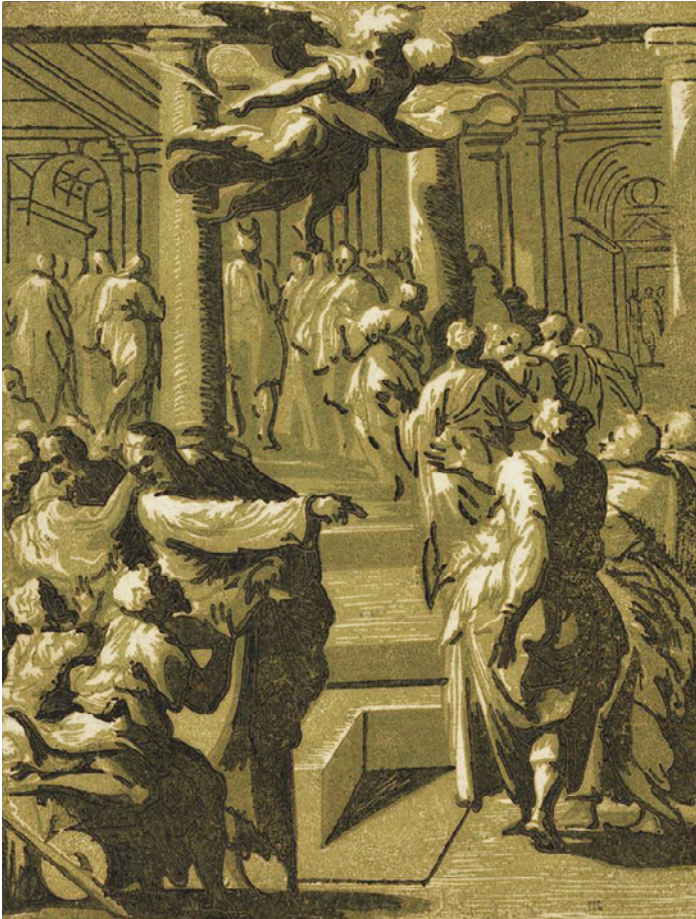
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## Color Printing in 16-17<sup>th</sup>-Century Italian Chiaroscuro Woodcuts: Degradation, Conservation Issues and Exhibition Concerns

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Christ Healing the Paralytic BXII.38.14 by Niccolò Vicentino Library of Congress FP-XVI-V633, no.2

Italian chiaroscuro woodcuts are among the most innovative of Renaissance prints. A woodcut print is made from a wooden plank that is carved in relief, inked, and impressed in paper. Chiaroscuro woodcut prints – named from the Italian term for contrasting light and dark tones – emulate drawings of the period. The design of a chiaroscuro woodcut is distributed over two to five woodblocks that are printed in superimposed layers of colored inks, thus creating transitional passages of shading. These tonal passages are often anchored by a “key” block which carries the primary outlines of the design in black

or dark colored ink. The printmaking process results in an image of complex stratigraphy.

Together, the layered ink colors were usually chosen by the printmaker to create a sense of volume or spatial recession - prime objectives of Renaissance imagery. The rich visual language of the chiaroscuro technique is predicated on the varied and nuanced colored inks and printing effects which give the medium its expressive power. There is a vast literature dedicated to the composition and behavior of printing ink over the centuries, however no study addresses systematically oil-based colored inks as used in 16<sup>th</sup>-17<sup>th</sup> century Italian chiaroscuro woodcuts.

Many centuries after a chiaroscuro woodcut was originally executed, deterioration can affect its legibility, and distort the historical and aesthetic interpretation of the work. Moreover, a correct assessment of condition is fundamental to selecting appropriate conservation and preservation measures.

Colored printing ink can become altered by a number of degradation phenomena. Understanding the durability of vehicles and colorants is central to an accurate reading of chiaroscuro prints. Vehicles for early modern period inks are typically composed of drying oils, with possible admixtures of natural resins. Both share a tendency to become brittle and yellowed with age. Darkness and humidity increase this tendency (Gettens and Stout 1966: 46). Some inks of the period are subject to colorant deterioration. In his valuable study, *A History of Printing Ink, Balls and Rollers 1440-1850*, Colin Bloy distinguishes the light stable pigments – inorganics, earths, and metallic compounds – from the fugitive organic colorants, including indigo and lakes (Bloy 1972: 40). Other pigments are chemically reactive, such as copper acetate, lead carbonate and lead oxide. Breakdown of colored ink also can lead to blanching – a clouding effect. Finally, the paper support may undergo ink-associated damage as well.





Man seen from the back BXII.148.13 by Antonio da Trento Library of Congress FP-XVI-A635, no.12

This paper summarizes what is known about the early modern methods and materials of manufacturing colored printing ink. The study explains how some colorants deployed in these inks degrade. A technical survey of over 1500 Italian chiaroscuro woodcuts, examined in international collections, is complemented by instrumental analysis of several prints. The study focuses on woodcuts that have the qualities of early impressions, making it reasonable that they bear the closest relation to the originator's concept. The research interprets analysis of inks suspected to comprise colorants such as organic pigments, copper acetate, lead carbonate or lead oxide. Logical deductions are drawn from analysis results as regards changes in the visual appearance of select prints, based on the documented behavior of unstable colorants in similar media, such as oil paint. Based on the cumulative evidence, a condition assessment protocol is offered and conservation treatment, storage and exhibition issues for the Italian chiaroscuro woodcut are described.

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# A Study of Dyed Endpapers during Islamic Mediaeval Times in Egypt: Purpose, Materials and Techniques

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Fig. 1: Undyed and dyed paper gathering from a Quran (folios 225mm x 155mm), Mamluk period, fifteenth century, Oriental Institute, Chicago (Bosch and Petherbridge 1981: 39)

The research investigates the use of yellow natural dyes in Egyptian book manuscripts endpapers and their historic sources. It aims to explore whether the traditionally used yellow natural dyes in Arabic endpapers were selected for their colour and for their biocidal properties. The project investigates if bookbinders were knowledgeable of these properties and tries to find out how effective these dyes actually are as biocidal agents.

Interdisciplinary methodologies are used and include 1. The translation of an unpublished Islamic treatise. 2. The use of HPLC for identification of the dyes in three samples. 3. Testing of the antibacterial properties of turmeric, weld, safflower and saffron against three strains of bacteria that have been identified in an Egyptian museum. Turmeric, weld, safflower and saffron were the most commonly used sources of yellow colour during the medieval Islamic period in Egypt. It seems very likely that these four dyes have some useful biocidal properties, which is supported by a laboratory microbial study. Weld (*Reseda lateola*) has been identified in three his-

toric paper samples by simultaneous detection of Luteolin and Apigenin by using HPLC.

## 1. Introduction

In the Islamic mediaeval era, scribes and calligraphers showed a particular interest for coloured papers and many stunning examples and illustrations of their works have survived in museums and galleries around the world (Fig. 1) (Bosch and Petherbridge 1981: 133).

There are many reasons for colouring papers. Probably the artistic appeal could be considered one of these reasons. Moreover, writing on coloured paper could be for health reasons (Minorisky 1959, p.113). Interestingly, coloured papers could have a symbolic significance. For example, a full red colour was considered as privilege in official correspondence of persons of high rank. For instance, al-Qalqashandi, a fourteenth century Egyptian scribe mentioned that official correspondence between the sultan in Egypt and only his two vices for Karak - a city in Jordan famous for its castle - and for Syria were usually written on red papers (al-Qalqashandi 2004, vol.6, p.193).

Paper colouring was thought to be used with the intention of protecting paper from bio-deterioration factors as this was previously employed in China in the tenth century AD, when paper was immersed in a solution of phellodendon, an extract yellow dye from Amur cork tree (Gibbs and Seddon 1998), or immersed in a solution of pepper (*Piper nigrum*) (Zhong 1988).

This work seeks to address significant gaps in technical and historical knowledge about Islamic endpaper dyes and will contribute novel information from previously untranslated Islamic treatises. Further, findings will inform the conservation and preservation practices with regard to book artefacts and help historians learn more about the preparation and techniques used in historic dyes manufacturer.

## 2. Methods

An interdisciplinary methodology is used in the research. This combines a literature review and interpretative analysis, the interrogation of primary historic sources, the technical analysis of artefacts and empirical scientific study.

### 2.1. Historic source

The original source of this research depends mainly on gathering information from an original treatise that has some paper dyeing recipes. The manuscript consulted here is a nineteenth century copy of a medieval manuscript (approximately from 13<sup>th</sup> century to 15<sup>th</sup> century AD) in the Egyptian National Library and Archives – Dar al-Kutub – in Cairo having the title ‘Rsalh Fá Sna’at al-‘Hbar Wghyrha’ (an essay on making inks and other materials). The manuscript colophon states that it was copied on Thursday, 18 Muharram AH 1268 (1851 AD) By Mustafa al-Safti (al-Safti 1851). It explains the materials and the traditional techniques that had been used in developing colouring and dyeing papers in the Islamic mediaeval era.

### 2.2. Analysis of Historic Samples

Three historic samples were analysed by High Performance Liquid Chromatography – Electro-spray Ionisation – Mass Spectrometry (HPLC-ESI-MS) has been used to identify the origin of the dye by comparing retention times of compounds to standards and those prepared from plant extracts with the historic samples. The HPLC used was Thermo Scientific, Hemel Hempstead, UK. The parameters were tuned by previous similar analysis, to the deprotonated quasi-molecular ions of morin and quercetin (Perry, Brown et al. 2011).

The column used was a Gemini ODS, 5 $\mu$ m particle size, 110Å, 150 mm x 2.0 mm I.D (Phenomenex Inc., Torrance, CA, USA) thermostated at 30°C. The gradient elution programme was performed using solvents: A: Acetonitrile + 1% Acetic Acid and B: Water + 5% Acetonitrile + 1% Acetic Acid. For reagents and dyes; the standard flavonoids, isoflavonoids and anthroquinones were of the best purity available obtained from Sigma-Aldrich Inc. (Saint Louis, Missouri, USA) for morin, quercetin, apigenin, kaempferol and genistein, MP Biomedicals Europe (Illkirch, France) for emodin and Carl Roth GmbH (Karlruhe-Rheinhafen, Germany) for rhamnetin, fisetin and luteolin.

The extraction procedures for dyes in the

plant matter were carried out using 100-150 mg of dried plant matter. The extraction procedure of the historic samples differed as the minimum amount of methanol was used (150  $\mu$ l) and 5 – 8 Amberlyst 15 ion exchange resin beads. The samples were then vortexed as before and heated under reflux for 2 hrs. After allowing cooling 70  $\mu$ l of the sample solution was added to 70  $\mu$ l of water and mixed well. 100  $\mu$ l solutions were injected directly into the instrument.

### 2.3. Microbial Study

The antibacterial properties of turmeric, weld, safflower and saffron have been tested against three strains of bacteria; *Bacillus subtilis*, *Micrococcus luteus* and *Bacillus cereus* by using the Cork Borer technique which involves pouring the dye solution into a hole in an agar plate spread with a microbial suspension then measuring the inhibited diameter zone.

## 3. Results

3.1. Investigation of the copied original manuscript (al Safti 1851) indicates that a direct dyeing process was used for paper. Dyeing was achieved by dipping paper sheets directly into a dye bath and this was a job carried out by scribes not papermakers. Al Safti also gives fifteen historical recipes for dyeing paper by using the following plants and materials: henna (two recipes), myrtle, weld, turmeric, white straw, garlic peelings, green fenugreek, red onion skins, lac, sapanwood, cinnabar, verdigris, the ring of pomegranate and finally safflower. Findings from all sources (al-Safti 1851; Baker 1995; Loveday 2001; Graaff 2004; Cardon 2007; Cardon 2009), suggest that turmeric, weld and saffron were the most commonly used sources of yellow colour during the medieval Islamic period in Egypt.

3.2. Three historic samples were taken from dyed endpaper of a manuscript book, originally from Mamluk period (13<sup>th</sup> – 16<sup>th</sup> century AD) that is located at the faculty of medicine’s museum, Cairo University, Egypt. An established method (Perry, Brown et al. 2011) was used to investigate the existence of yellow flavonoids in these three paper samples. The components identified in the first sample were apigenin or genistein at m/z 269, retention time 6.90mins and luteolin at m/z 285, retention time 5.93mins (Fig.2). The components identified in the second sample were apigenin / genistein at m/z 269, retention time 6.68mins.

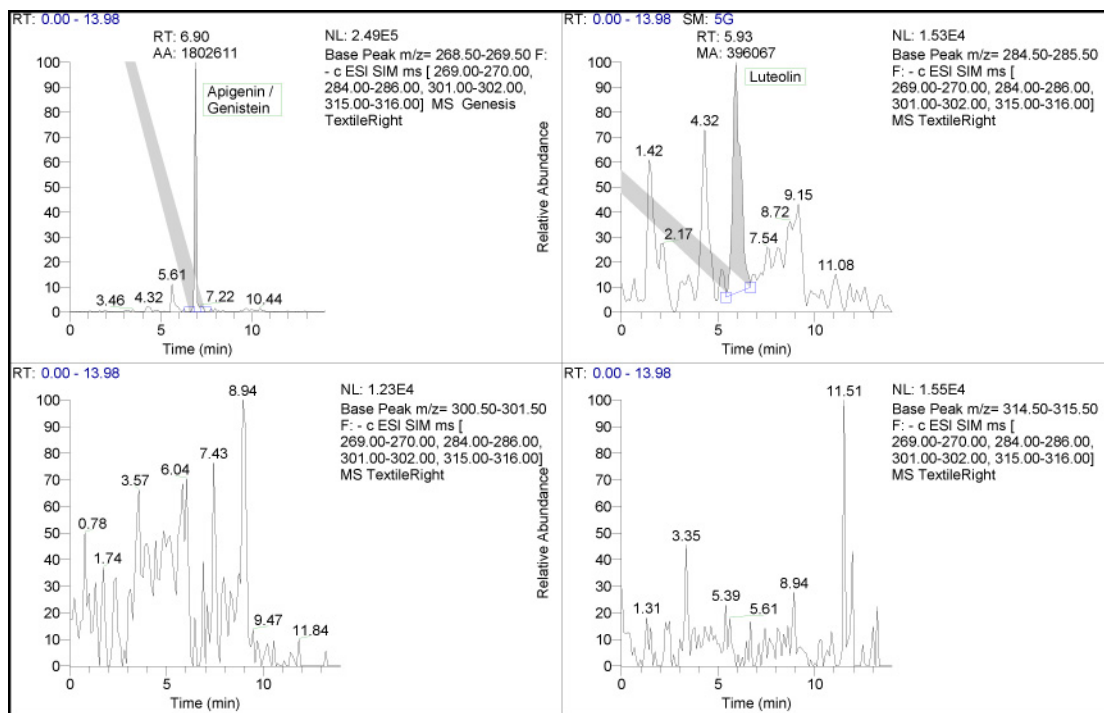


Fig. 2: Chromatogram of the first Sample showing the presence of luteolin and apigenin (or genistein)

The third sample was undyed and from the same book which appeared to show a peak for luteolin at  $m/z$  285, retention time 5.82, this was unexpected, and however, the apigenin or genistein peak was not observed in the undyed sample.

### 3.3. Results from the microbial study, by using Cork Borer technique

Clear zones of inhibition were observed on the agar plates containing the three chosen strains of bacteria after incubation around the punched hole containing safflower dye solution made from a traditional recipe and including lemon juice (Fig. 3). The diameter of the clear zones was measured.

## 4. Discussion

4.1. Four yellow natural dyes (turmeric, weld, safflower and saffron) were selected for special study because of the prevalence of yellow dyed endpapers in Egyptian medieval manuscript books (Fig. 4), noted during extensive handling of collections and because their application was widespread during most historical periods (Baker 1995; Loveday 2001; Graaff 2004; Cardon 2007). To date, there is no conclusive evidence from primary texts, modern scientific publication or any other explanation as to whether yellow dyes

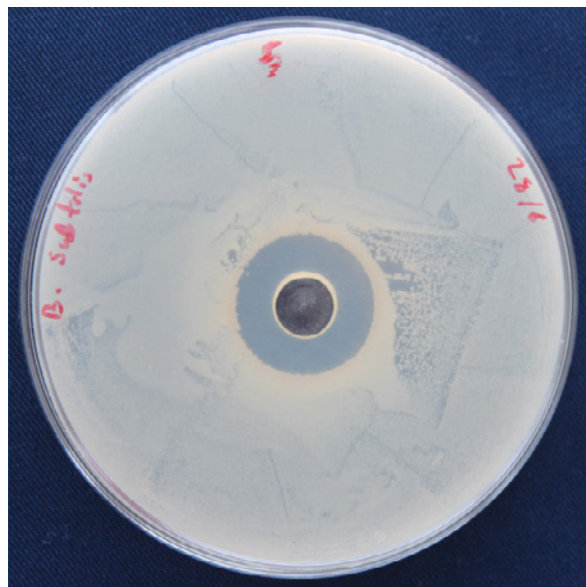


Fig. 3: Cork borer test for the effect of safflower dye against *Bacillus subtilis* grown on nutrient agar medium

were used for any specific purpose.

In the Islamic mediaeval era, papermakers were producing paper ranging in colour from cream to dark cream and either grey or off-white in tone according to its production inputs, there is no record of colour being added to the pulp in



Fig. 4: Dyed endpaper pasted at the front and back cover of a manuscript book, (169 mm x 122 mm), Mamluk period (13<sup>th</sup> – 16<sup>th</sup> century AD), faculty of medicine's museum, Cairo University, Egypt

the initial stages of papermaking manufacturing process (Loveday 2001: 51). The copied original manuscript (al Safti 1851) indicated that the dyes were applied directly to the sheet of paper by scribes.

The copied original manuscript claims that many plants and materials have been used to dye paper (listed above) and gives interesting information in the form of fifteen recipes for preparing these materials. Weld could be an example of these recipes:

“Yellow lemon dye of weld is prepared by taking one pound of seasonal (newly-collected) weld, washed and put in a container of copper with one ounce of wild Natron (Endnote 1). Then, twenty-four pounds of water of the well and is poured over it and kept overnight. [Later on,] it is boiled until it is completely diffused into the water. [Once] heating is stopped, it is filtered, precipitated and then it used for dyeing [the paper], it gives a vegetable-like colour [to the paper] and God is the most Knowledgeable” (al-Safti 1851: 27).

Although the text of the studied manuscript is a copy from 1851 AD, the original may date back to earlier than the 15<sup>th</sup> century AD, and this assumption is supported by its style of writing, Arabic terms and technical information. Moreover, it is to some extent similar to another text about paper dyeing and colouring which is written by a Persian librarian in 1433 AD (Thackston 1990). Furthermore, there is no handmade paper originating from Egypt after the 17<sup>th</sup> century AD (Loveday 2001: 27).

4.2. Analytical results from the three historical samples identified the presence of luteolin and either apigenin or genistein, which co-elute and have the same parent ion mass. According to these results, there are two possible biological sources for the dye used in these samples which are *Genista tinctoria*, common name Dyer's Broom, which contains luteolin and genistein or *Reseda luteola*, common name weld, which contains luteolin and apigenin. To differentiate between these two biological sources, the minor component of chrysoeriol in *Reseda luteola* could be looked at in using a further development of this method, and therefore the identity of dye (expected to be *Reseda luteola*) could be established unequivocally.

4.3. The main reason for choosing the tested bacterial strains is that *Bacillus subtilis* causes serious damage to library materials (Gallo 1985: 38), and *Micrococcus luteus* and *Bacillus cereus* which have been identified in the Faculty of Medicine's museum, Cairo University, Egypt (Ebeid and Amer 2006) where the tested sample had been taken. The main reason for using these three strains of bacteria in the microbial study is to use them as a monitor for biocidal properties in the dyes which have been used in Islamic paper, specifically in endpapers. It seems after measuring inhibition zones that the four dyes chosen have some useful biocidal properties.

## 5. Conclusion

The traditional method of dyeing paper in Islamic mediaeval era has been clarified. Weld was identified in three samples and the microbial study supports the concept that these dyes have some useful biocidal properties. Therefore, it is possible that the dyes were used intentionally to dye endpapers in order to give protection from biological attack.



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# Preservation of Architectural Drawings on Translucent Paper in Brazil: Conservation Methods in Public Institutions

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## Introduction

The discussion proposed in this communication comes from the observations occurred in ongoing research about a methodology for conservation<sup>1</sup> treatment of architectural plans<sup>2</sup> on translucent paper, on the master's degree in Social Memory and Cultural Heritage Federal University of Pelotas. Conservators, who are preserving objects of cultural heritage, must think deeply about the whole process of achieving a conservation treatment, including not only the technical procedure but also the underlying philosophy, assumptions and value judgments inherent in the object, which can contribute to each decision during treatment. To formulate a proposal of conservation treatment, one must first understand the current conditions of the professionals and institutions that preserve the cultural assets.

Translucent paper, popularly known as tracing paper, is found in collections and monetary currency. This type of support can be grouped as follows: architectural plans, technical drawings, maps and drawings of artists.

Currently, it is clear that along with photography, handmade architectural design is regarded as one of the gems that make up an architectural background. The maker uses the architectural language, which is a “graph instrumental, including its processes and techniques of the architect to represent an object, idea or environment through lines on a surface” (Ching, 2006:163).

In the mid-nineteenth century and the twentieth century, traditionally, for the original<sup>3</sup> architectural plans, three different types of paper were used: watercolor paper for ink and pencil drawings; paper pattern, with a coated surface, and translucent paper, popularly known as tracing paper, whose composition varies greatly in quality (price, 2011). Importantly, according to Claude Laroque (1992: 15), before 1870 many architects destroyed their drawings after construction of the building, believing this documentation does not arouse interest beyond problems for storage. Moreover, the documents were taken

to, or even developed further, on the actual construction site, thereby suffering premature deterioration. However, in the twentieth century, original drawings were kept in the office of the architect and only copies were allowed to circulate. However, the architectural plans were stored without due care, nailed, rolled or folded. The use of self-adhesive tape was also common in architectural firms to protect designs around the outer edges of the paper.

Translucent paper has been used for centuries. Traditionally, it was a thin paper impregnated with oil or resin to give translucency, which is its main feature. In the first decades of the nineteenth century, it was available in newsagencies and through suppliers of artists, when French translucent paper, according to the trade catalogs, was considered superior. Many manuals contain instructions on how to make your own paper translucent French. During this period when the architects sought professional recognition, artists used materials of high quality to distinguish the community of arts, differentiating itself from carpenters and house builders (price, 2011: 77).

The industrial production of translucent paper, according to Laroque (1992: 15) began around 1860 in Europe, with Germany as the most important producer. The industry continued to grow with the construction of factories in France, Belgium and Austria. It is noteworthy that after 1865, with the intensification of the process of industrialization, new management techniques were needed and the profession of architecture acquires a management character, with the goal of becoming more “efficient”. “The profession of architect becomes capitalist, with the function of generating a profit” (Lathrop, 1980: 326).

Catani, however, points out that this change in the field of architecture, effected not only the needs of architecture. “In reality, is associated with a broader social process of implementing new forms of production, which began to

demand greater control over the production process on the part of those who held their planning” (Catani, 2006:115). In this context, the function of the technical design should solve the problems of production through the use of a unified graphical language. That means the design should be represented, as clearly as possible, avoiding doubts at the time of execution of the project. In the nineteenth century, the first technical rules of graphical representation of projects were created, seeking a common language to facilitate communication.

As a solution for the production of architecture of that period, translucent paper allowed other media to be copied, and also was extremely helpful during the process of architectural design, since it could be used to redesign and overlay different design options.

In Brazil there are some public institutions that keep architectural drawings on translucent paper, including archives, foundations, universities and libraries. Many of these designs have disappeared due to a lack of awareness about the documentary value that only in recent years began to exist in the country. Before, these drawings were stored without any preservation or archival methodology and simply discarded for lack of space in the institutions. A major problem for the institutions, that keep architectural drawings, are their large and different dimensions, that, due to this peculiarity, are difficult to handle and pack. In the specific case of translucent paper, we perceive much difficulty for conservators, because this material is very susceptible to physical and chemical changes, particularly when exposed to temperature changes, humidity and pollutant gases that exist in the air. Another problem are variations in papermaking, where changes occur in their coloring, texture and flexibility. The visual distinction between manufacturing methods is very difficult to diagnose, which makes conservation work even more challenging and necessary. This research focuses on collections of architectural drawings on translucent paper made between the late nineteenth century to the present day. The objective is to present the main public institutions in Brazil that keep architectural drawings on translucent paper and how they handle these documents. Initially, the presentation does not intend to discuss preservation methods used, but a brief evaluation of what is being done in these institutions.

## Method

For gathering of information, a questionnaire was designed and sent electronically to entities registered in the International Council on Archives - CONARQ. This is a collegial body, linked to the National Archives of the Ministry of Justice, which aims to establish a national policy for public and private archives, as a central office of a National Archives System, overseeing the normative guidance document management and special protection for records. Later, other institutions were inserted that seemed relevant to the search, such as the Faculties of Architecture. In total, questionnaires were sent to 229 institutions.

The questionnaire aims to seek:

- Data from the institution;
- Characterization of the institution;
- Legal nature;
- If it is an institution of custody of translucent paper documents;
- Date of the documents;
- If there already occurs some conservation treatment;
- The treatment applied;
- Problems during treatment;
- Tips for treatments useful for conservation.

## Conclusions

Research is fundamental to start a local knowledge of collections that keep architectural drawings on translucent paper in the country, having the opportunity to create greater awareness and interaction among researchers from various fields and institutions, promoting an exchange of information, beyond seeking the earned value of these documentary drawings. Their conservation is extremely important, as they relate to identity, action and memory of Brazilian architecture, being considered Brazilian Cultural Heritage, in addition to being used as a source for historical research of science, architecture and engineering. Preservation becomes a goal to be achieved by archivists, conservators and especially historians of science.

Importantly, the research is still in progress and will be finalized in March 2013.

### Notes

- 1 According Salvador Muñoz Viñas conservation is “the activity that is to take measures for the fewest changes for as long as possible.”
- 2 In common usage, all graphical documents produced by architects are usually called plans or architectural plants. In this article we will use the term architectural drawing as equivalent.
- 3 The architectural plans done manually in the twentieth century often had copies.

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## Removable Loss Integration in the Re-Treatment of Robert Delaunay's Three Graces, Study for "The City of Paris" at the Albertina, Vienna.

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The case study illustrates core questions that concern loss integration of artworks on paper: defining and refining the treatment goal in discussion with curators; developing a minimally invasive method for loss integration that respects the potential future treatment desires; the technical challenge of creating a visual match for an unevenly discoloured, machine-made paper. The project was carried out as a cooperation between the Museum Albertina and the Staatliche Akademie der Bildenden Künste Stuttgart. The large oil sketch "The three Graces, study for "The City of Paris"" by the French painter Robert Delaunay, measuring ca. 190 x 140 cm (Fig. 1), is one of several preparatory works for the famous painting *The City of Paris* in the Centre Georges Pompidou. It belongs to the Batliner Collection in the Museum Albertina (Inv.Nr. GE29DL). The artwork, drawn on thin, machine-made woodpulp-paper, was apparently torn into several large pieces by the artist himself. After Delaunay's death in 1941, however, the work was reassembled, lined on canvas and mounted on a strainer. The mounting was at least once removed and renewed. The sketch shows many damages, many of them caused by historic restoration treatments such as filled losses, which are visually obtrusive, wrongly overlapping tear edges and aged retouchings. It also had undergone extensive aqueous treatment of which no record exists, most likely including bleaching, which subsequently caused mottled discolouration and brown tide lines along the oil paint edges. Patches of untreated, and therefore even coloured and darker brown paper have remained in isolated areas between paint strokes where treatment had not been dared. This mottled appearance of the original paper was to be matched in the production of an insert. The problem that was addressed in our treatment concerned two large distracting losses resulting from the 1940<sup>ties</sup> damage, one at the right lower edge ca.



Fig. 1: Robert Delaunay, "The three Graces, study for 'The City of Paris' " (Albertina Inv.Nr. GE29DL), 1912, normal light, before treatment (08.07.2010).

49 x 13 cm, the bigger and more prominent one at the lower left edge ca. 46 x 74 cm. They had soon been filled with woodpulp paper inserts that had discoloured to a dark-brown tone contrasting with the original paper colour. The old inserts had been pasted onto the lining, overlapping the edges of the original. Black-and-white photographs of the work in earlier exhibition catalogues starting 1956 already show the paper fillings (Anon. 1956; Schilling and Platte 1962; Jenderko-Sichelschmidt 1976), but indicate that their colour once was much brighter than today. This suggests that the paper darkened in the

course of time under the influence of light, and that the colour of the paper fillings might once have matched the colour of the original paper quite well. Because of their dark brown colour, the old fills are incongruent elements disturbing the original image and thus were attracting the viewer's attention. The museum wanted to exhibit this key work of Delaunay at the Albertina and desired to make it more presentable to the museum visitors. The goal for this treatment was a visual improvement of the affected areas, to be accomplished by an overlay over the old inserts, that would not attempt to reconstruct the missing parts of the image – which would have been impossible due to the fact that no information exists about the missing parts. Rather, areas covered with the dark old paper fillings were to be visually integrated with the rest of the paper. As the removal of the old inserts would not have provided any advantage for the preservation and current treatment of the artwork but would have involved an invasive procedure presenting an unnecessary risk for the original, it was decided to cover the old inserts with new – aesthetically more fitting – ones. This was possible because the old fills were of a thinner paper than the original, leaving room for another layer of paper that would not exceed the thickness of the original. Only the overlapping parts of the old fills were removed from the original to reveal covered areas of the original paper and paint and thus to minimize the area that needed to be retouched. Slightly moistened brushes worked best to swell the paper and starch-based adhesive and lift them with a spatula. Loose remaining fibre residues were removed with a scalpel. Newly revealed original paper and paint areas clarified the previously concealed border of the original design.

### **Key: insert paper choice**

In order to keep the new retouching removable it was to be adhered only at the edges. A thick Japanese kozo paper (Paper Nao, 106 g/m<sup>2</sup>, K14) was chosen for its dimensional stability, even water absorption capability, uniform surface quality and bulky, compressible structure and even chamfering characteristics. It was key that this paper also achieved a close visual match of the original machine-made paper because it shared its smooth, slightly shiny surface.

## **The treatment process involved four main steps.**

### **1. Testing the paper toning materials**

The inserts were cut slightly larger than the loss shape. They were toned in over ten stages to colour-match the original paper. A selection of colourants (reactive paper dyes, direct paper dyes, watercolours, acrylic and airbrush colours) were tested for an easy utilisation such as a regular colour application. The three most promising colourants (Pergasol<sup>®</sup> direkt paper-dyes, Schmincke Akademie<sup>®</sup> Acryl Color and Schmincke Aero Color<sup>®</sup> Professional) were then tested for water solubility; all colourants were adequately insoluble on the insert paper after the dye had dried. An artificial light-aging test following DIN ISO 105-B02 was conducted to check the long-term light stability of the colourants. Before and after the aging process, colour measurements were carried out<sup>1</sup>. Samples of the retouching paper prepared with the colourants were aged for ten days in artificial light in a light aging chamber (Q-Sun Xenon XE-1-BC)<sup>2</sup>. The strong fading of Pergasol<sup>®</sup> direct paper dyes disqualified them for the use as a retouching agent, whereas the acrylic and the airbrush-colourants showed almost no fading. The acrylic colours achieved the best light stability.

### **2. Toning and trimming the insert**

To find the most suitable application method, the acrylic and the airbrush colours were applied with different techniques: dipping in a colour bath, brush application and application with spraying devices used with compressed air (spray gun and airbrush). The best method turned out to be a combination of two steps: first applying a uniform coating and then applying the different mottled irregularities in a second step. To produce the initial uniform colouring, the paper received more than ten applications of diluted acrylic colours (Schmincke Akademie<sup>®</sup> Acryl) applied with a spray gun. Between every application the paper was dried and the colour compared to the original, to adjust the colourant concentration for the next application. In the second step, the mottled toning of the original was imitated by local airbrush and paintbrush colour applications (Schmincke Aero Color<sup>®</sup> Professional). The brush was used to imitate stained and streaky structures – the airbrush was used to produce soft colour gradients, especially at the

edges. To imitate the colour of the original paper, the irregular colour patterns of the adjoining original paper parts were used as an orientation and brought together in the middle of the insert. The inserts were trimmed and chamfered to the exact shape of the loss and received a final toning with watercolours along their edges. During the dyeing processes the colour was observed several times under different light sources to test for metamerism<sup>3</sup>.

### 3. Stabilizing the toned insert by lining and coating

To stabilize the larger insert and to protect it from possible later distortion, in the case of climate changes in the future, the larger insert paper was lined verso with a thin Japanese kozo paper. The Japanese paper had been prepared by coating it with Lascaux<sup>®</sup> 498HV adhesive, and was applied to the verso of the insert by reactivating the adhesive with heat. The lining enhances the dimensional stability of the insert paper and protects it against distortions. The adhesive and the application method were chosen on the basis of tests conducted with insert papers lined with either starch paste, methylcellulose or Lascaux<sup>®</sup> 498HV that had been exposed to cycles of fluctuating humidity (50-95% RH). The samples were measured before, during and after the humidification to check the degree of extension. The test showed that only the samples prepared with Lascaux<sup>®</sup> 498 HV were dimensionally stable when exposed to high relative humidity. Furthermore, to smoothen the surface of the retouching paper after the extensive colouring processes, diluted methyl cellulose (Methocel<sup>®</sup> A4C) was applied with a spray gun and the surface was then dried in contact with a piece of polyester fabric (Bondina<sup>®</sup>).

### 4. Shaping and attaching the inserts

To create a smooth transition from the insert paper to the original, the edges of the insert were chamfered from the back at a width of 5 to 10 mm. Finally, the insert was adhered to the edges with starch paste, minimizing the area of adhesion, at some areas minimally overlapping onto the original by about one millimetre to cover dark stained edges, revealed after removing the former overlapping paper fills. The new inserts remain removable, leaving the historic treatment of the artwork accessible. With the old fills covered, their prominent visual distract-



Fig. 2: Robert Delaunay, "The three Graces, study for 'The City of Paris'", normal light, after treatment (08.08.2012).

tion is eliminated, allowing a more focused perception of the painting (Fig. 2). Both retouched inserts achieve a good colour match with the whole picture. They are in-plane with the original also along their adjoining edges where there is no noticeable step in part due to the conformable nature of the insert paper. The retouched insert surface is very similar to the surface of the original. No metamerism effect was noticed when viewing the insert and the original under different light sources.

### Outcome and outlook

Where the old insert overlapping edges were removed from the original, newly revealed original paper areas and small parts of the picture indicate design details critical to the understanding of the painting. The project required many micro-steps of technical and aesthetic decision-making. Key to its success was the continual, interdisciplinary consensus building in which preservation and aesthetic concerns were communicated in a differentiated way. At this point, the oil sketch will be examined together with

the curators in review of the treatment to date to see whether final adjustments in the retouching need to be made. After that it will be decided whether the oil painting areas should receive any local surface cleaning. Also, similar inserts to compensate other small losses will be decided on when the treated painting undergoes final evaluation.

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### Endnotes

- 1 Datacolor Check Pro, software Tools, measuring conditions: spectral range 360-700 nm, incl. gloss, standard observer angle 10°, LAV, illuminant: daylight D 65
- 2 10 days, 1,1 w/qm x nm, black standard temperature 28°+3°, window glass filter W-IR (X-10761-K)
- 3 Metamerism describes the phenomenon that two colours look identical under specific light conditions, and differ when the light source changes. A metamerism between the original and the retouching paper can occur when different kinds of colours and colour mixtures are used (Poulsson 2008).

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## Simple yet Complicated – An Evaluation of Airbrush Technique Applied to Filling Losses using Cellulose Powders

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### Introduction

Filling losses is a very common practice for paper-based artifacts. This can be performed either by machine using a leafcaster, or it can be done manually, which can be very labor intensive. Many methods have been designed to achieve filling purposes depending on the nature and the condition of the paper objects. Considerations to be observed in filling or compensation of paper-based materials include the character and thickness of the paper object, the quality of the filling materials and the properties of the adhesives, as well as compatibility issues between the paper artifact and filling materials, etc.

In general, filling materials used for this purpose include paper pulp and cellulose powder. Paper can be inserted to compensate for losses using western paper or bast fiber paper, also known as Japanese paper. Paper pulp is another filling material; it could be applied in numerous irregular-shaped loss areas of an artifact if the object can tolerate wet treatment. The paper insert method is mainly performed manually, and paper pulp can be applied manually with the help of a suction disc or performed mechanically using a leafcaster. Both paper and paper pulp as mentioned above are the most commonly repair

materials for filling applications (Paper Conservation Catalog, 2011).

Another filling material – cellulose powder – is also recorded in conservation related literature. It can be used to fill small losses by adding water to powder to form a paste and then applying it to loss areas. One concern about the use of cellulose powder as a filling material is its flexibility after application. In addition, the difficulty of applying cellulose powder evenly is also one of the disadvantages of using it as a filling material. To avoid uneven application, spraying might offer a viable alternative when using cellulose powder to compensate losses.

The spraying method has been adopted as one of treatment techniques for in-painting, humidification and consolidation/fixing, as well as for applying a protective coating layer on the surface of an object (Webb, 1998). This can be done by using various tools such as air mist, a Dahlia sprayer, airbrushes or other methods. Among these spraying tools, the airbrush can yield an even coating for treatment purpose. This paper evaluates an alternative method of filling losses using stable and reversible cellulose powders and airbrush techniques that is regularly used in Asian painting conservation.

### The airbrush applicator

The invention of the airbrush is attributed to Francis Edgar Stanley, who patented the first airbrush in 1876 (Patent Number 182,389). His invention was not used for art works, however, up until 1879 when the first “airbrush” instrument with a hand-operated compressor used for painting-related purposes was developed by Abner Peeler. At that time the airbrush was not at all sophisticated, and it took four more years of development to refine the airbrush device which was marketed by Liberty Walkup.

An airbrush works basically by passing a stream of fast-moving (compressed) air through a Venturi, which reduces the air pressure (suction) to allow liquid or paint to be pulled from an interconnected reservoir. The high velocity of the



Fig. 1: After Mapping the Areas to Be Filled



Fig. 2: Before and After Filling

air stream atomizes the liquid or paint into tiny droplets as it blows past a very fine paint-metering component. Various triggers are designed to control the amount of liquid, allowing an operator to achieve finely smooth blending effects.

Three factors affect the effects of the airbrush technique – the spray distance, the air pressure and the viscosity of the paint. Generally speaking, the airbrush should be placed a distance of 10 to 20 cm from the object to be sprayed. Pressure should be adjusted between 0.1Mpa to 0.2 Mpa in general, although it can be reduced to 0.02Mpa to 0.05Mpa in order to achieve fine, delicate results. The ideal viscosity of the substance used for spray purposes should be maintained between 45 to 60 cp.

For the purposes of this study, three stages were designed to evaluate the applicability of airbrush techniques using cellulose powders for filling purposes: (1) the type of cellulose powder; (2) appropriate viscosity of the powder mixture; and (3) the mixture for spray application.

### Selecting cellulose powders

The first stage of this study involved mixing

cellulose powders with cellulose ethers to determine appropriate types of cellulose powders that spread smoothly and will not block the nozzle during spray operation. Cellulose ethers have been studied extensively for their stability (Bac-ker, 1984; Feller & Wilt, 1990). Three different cellulose fibers with 0.2% methyl cellulose added were selected for evaluation. The formula is described as follows:

1. 0.5 g of Arbocel BC 1000 fiber with 10 g of 0.2% methyl cellulose.
2. 0.5 g of Arbocel BC 200 fiber with 10 g of 0.2% methyl cellulose.
3. 0.5g of microcrystalline cellulose with 10 g of 0.2% methyl cellulose.

A spray test showed that the microcrystalline cellulose powder mixture sprayed smoothly with no blocking effect, and it was the only type of cellulose which could pass through the 0.1mm diameter nozzle of the airbrush. The results showed that microcrystalline cellulose was an appropriate type of cellulose for further study as a filler material.

### Viscosity test

After the first stage, the microcrystalline cellulose powders were then mixed with cellulose ethers and gelatin. Six groups of mixtures, all containing methyl cellulose (MC), carboxymethyl cellulose (CMC), microcrystalline cellulose (MCC), water and ethanol, were divided into two major subgroups depending whether or not gelatin was added. Among the ingredients, ethanol was used to increase mobility and to speed up the drying rate. Gelatin is used as a sizing agent and as dispersing agent in the paper industry. The formulations and ratio by weight are shown as follows and in Table 1.

- A: 2%MC, MCC, water, ethanol
- B: 2%CMC, MCC, water, ethanol
- C: 2%MC, 2%CMC, MCC, water, ethanol
- D: 2%MC, MCC, water, 2%gelatin, ethanol 99%
- E: 2%CMC, MCC, water, 2%gelatin, ethanol 99%
- F: 2%MC, 2%CMC, MCC, water, 2%gelatin, ethanol 99%

Measurement of viscosity was then carried out in order to adjust the viscosity of mixtures to between 40 to 60 cp, which will yield better consistency for spraying effects. A viscosity cup was used for measurements. Drain time for this test was suggested as between 17 to 23 seconds

**Table 1. Ingredients of Powder Mixtures (Weight in grams)**

Ingredients Groups	Cellulose	Binder			Solvent	
	MCC	MC 2%	CMC 2%	Gelatin 2%	Ethanol 99%	Water
A	1	1	-	-	2	2
B	1	-	1	-	2	3,5
C	2	5	1	-	4	5,5
D	1	1	-	2	2	2
E	1	-	1	2	2	5
F	1	2	1	4	4	3

**Table 2. Results of Viscosity Test**

Group	Drain time in Average $\pm$ Standard Deviation (seconds)
A	20.8 $\pm$ 0.8
B	20.2 $\pm$ 0.4
C	23 $\pm$ 0.9
D	19 $\pm$ 0.7
E	19.6 $\pm$ 0.5
F	23 $\pm$ 0.0

at 25°C  $\pm$  2°C, equivalent to 40 to 60 cp at ideal viscosity for airbrush application. The results of the viscosity test are shown in Table 2. The drain time for all tested groups fell in the range of 19 to 23 seconds, which indicates that all of the tested mixtures are suitable for spray application.

### Mixtures for Spray Test

Different amounts of mixtures were designed for spraying at a distance of 15 to 20 cm. In this test, 1oz and 0.5oz of mixtures were sprayed onto a surface of Xuan paper in size of 5cm by 10cm. After spraying, roughness of six groups were measured by using Mitutoyo Surface Roughness SJ-301. The results of test showed that the roughness values of groups A and C were greater. Group F was shown to be the most consistent of all tested groups. In addition, the evenness of the mixture in Group F also appeared to be more controllable for spray application.

### Conservation Implementation

The hand scroll, painted by Lin-can Lee, used for this study was seriously degraded by mold. The treatment process included surface cleaning,

facing, backing removal, first layer of lining, second layer of lining, removing the facing paper, mapping the losses, applying masking to losses, filling losses with airbrush, in-painting and mounting. The method used to fill losses using an airbrush is as follows. Strips of Xuan paper were used to cover holes. Water was then applied on the Xuan paper according to the shape of the hole. Water tear was performed to shape areas to be compensated, shown on Figure 1. Based on the result of this experiment, the powder mixture F was chosen to be used as filling material in accordance with the airbrush technique. After filling, 0.2% gelatin was also sprayed to provide further reinforcement. Before and after filling are shown in Figure 2.

### Conclusion

The results showed that airbrushing can be an efficient way to fill losses of paper. A Chinese hand scroll was successfully restored in a follow-up conservation operation. In conclusion, this study offers an alternative method for filling losses in paper artifacts with special considerations.

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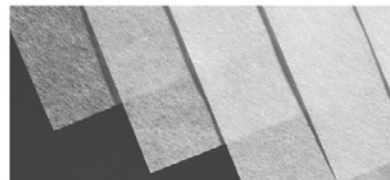
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## Ronald by Franz West. Conservation of a Three-Dimensional Painted Papier Mâché Object

ANDREAS HARTL

Austrian National Library, Conservation Department, Vienna, Austria



Fig. 1: Ronald, recto view

### Introduction<sup>1</sup>

Entitled *Ronald*, the object is shaped like a three dimensional guitar (Fig. 1). It was created in the late 1970's by the Austrian artist Franz West (16 February 1947 – 25 July 2012), and is part of a category of works which he labelled as *Namensbilder*. These objects are dedicated to particular persons and could be described as a kind of portrait.

*Ronald* is one of a group of 17 artworks subtitled *Our Railroad Workers and their Union* (Fig. 2). The associated pieces are works on paper including collages, drawings or overpaintings of newspapers or photographs, and are presented in frames, most of which were created by the artist. All the pieces were made as independent works of art over a period of 20 years.

In 1996, the group in question evolved from a selection of works for the exhibition *Collagen Passstücke Werke 1972-1990* in the Viennese gallery Kalb. It was very common for Franz West to combine works from different periods, and so he also included furniture or sculpture as well as works by other artists. Following this 1996 show, the *Essl Museum of Contemporary Art* in Klosterneuburg, bought *Our Railroad Workers and their Union*.

The technical study and conservation of *Ronald* was subject of a diploma thesis at the Institute for Conservation at the Academy of Fine Arts Vienna in 2011.

### Construction

The whole object is made of *papier mâché* and is shaped as a relief. The lettering *Ronald* is formed

as three-dimensional characters in a different, unidentified material.

*Papier mâché* is a material very commonly used by West. In early years of his career, he used telephone book pages for his raw material. Later, he used mainly newspaper because telephone books were no longer available in the amounts he needed.

The recto view of the guitar shows several layers of paint. Very similar structures of these layers can be found in many comparable *papier mâché* objects. The first layer consists of a grey undercoat followed by layers in yellow and pink, onto which the lettering *Ronald* is applied. A layer of white coats, the name as well as the pink colour was probably the initial surface. This strata can be found on the entire recto of the guitar. The verso is not painted, leaving the *papier mâché* exposed. For improving the stability of the form, a wooden broomstick was worked into the material from the middle of the body, over the neck to the head of the guitar.

### Damage

Due to a massive infestation by biscuit beetles, the *papier mâché* body was almost completely hollowed out and the stability of the object drastically decreased. Because of insect holes, the surface was painted over in extensive areas, using the same material as the initial surface. Afterwards, some of the insect tunnels on the recto's surface were partially overworked with different types of gypsum.

As a result of further structural damage of unknown origin, numerous additional repairs had been undertaken. A fracture runs the length of the body from the bottom to the top edge, at the beginning of the broomstick. Despite previous attempts to repair the crack, it remains a risk.

Because of the extensive degree of damage, *Ronald* was classified as not available for loans. However, for an exhibition in the USA, the group should be shown in its entirety, so the museum and West's atelier agreed to produce a full-size model.



Fig. 2: Our Railroad Workers and their Union, Exhibition catalogue Franz West, To Built a House You Start with the Roof.

### Presentation

The museum is presenting the group in the same arrangement as that created by Franz West at its first exhibition in 1996. There were a few exceptions, as West arranged exhibitions by himself and would sometimes combine different groups of artworks.

*Ronald* is presented in a pine showcase, which is covered at the front and the rear with transparent acrylic glass, fixed with screws. Probably the object was originally not presented in the case. There are indications that the frame was made in order to protect the damaged *Ronald* within the group presentation. At the rear of the guitar screw holes of the supposed previous mounting were found. Like the original artwork, the copy was to be presented unframed.

### Conservation Goals

Part of the project was the examination of the paint layer structure and the earlier repair treatments. An important question was how to treat the object's patina. The correlation between repairs / "patina" and their importance to the history of the object was examined. To find out by whom the earlier repairs had been undertaken, people in Franz West's working environment were interviewed. Furthermore, objects from this

particular group were compared regarding structure and surface appearance. It was not possible to answer this question in the context of this thesis. There were suggestions that the repairs and overworking was done by West himself or, with his permission, by one of his assistants.

As a result a strategy in dealing with the present surface condition was developed. Part of West's concept is that objects can be handled by the owner. The patina which is due to the handling of the object is therefore part of its history. As a result of the research into the artist's *modus operandi*, the surface was accepted in its current condition.

In order to adequately stabilise the *papier mâché* body's structure, two methods had to be combined. During the work, it became evident that it would not be possible to stabilise the entire body from surface to centre. Therefore it was decided that only the surface and the subsurface areas should be treated; while not a complete procedure, it would strengthen the object's structure somewhat.

Another major aspect was to develop measures to optimise the situation for transport, storage and exhibition to prevent further structural deformations when handling the object and to thus minimize damage.

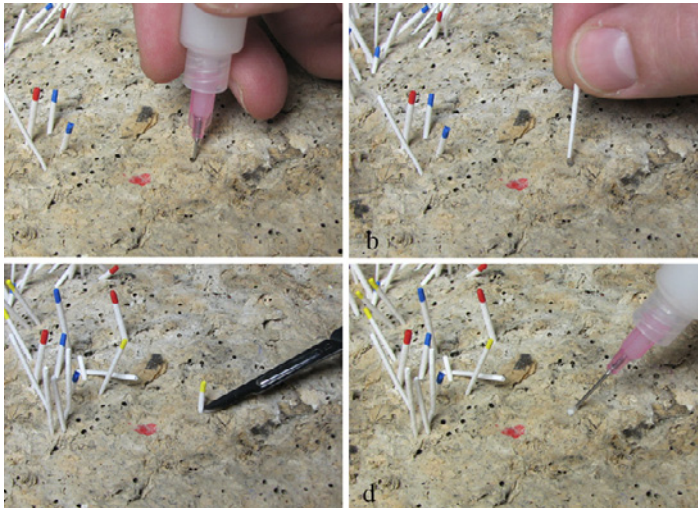


Fig. 3: The implementation of the paper pins.

Because of the instability of the crack in the middle part of the body and the fact that the object was not mounted in the frame, transport and handling cannot be undertaken without a high risk of damage. It was necessary to secure the unstable crack and the object itself inside the frame.

### Treatment

The structural damage is similar to the insect infestation, which can be found on wooden objects. Initially, fillers for wood conservation were tested on mock-ups for their capabilities to adapt to this object. Finally, it was not possible to find a satisfying solution with fillers as they did not match the material properties of *papier mâché*. Fillers generally include high amounts of moisture and need long time to dry which in turn causes the material to swell and soften too strongly.

The method finally applied involves paper pins<sup>2</sup> and a technique used in dentistry, which could be adapted for stabilisation procedures. Ranging in diameter from 0,01mm to 1,2mm, the pins permitted filling and stabilising the insect tunnels very accurately (Fig. 3). To adhere the pins in the insect tunnels, paste was applied with a dosing system by BELO<sup>3</sup>, so it was possible to dispense a defined amount of adhesive and avoid intense weakening of the paper material by too much moisture. It was thus possible to work very quickly and efficiently which was essential for the treatment procedure.

The second part of the stabilisation process was to secure the precarious crack in the body as well as the mounting of the object in the frame. Therefore a grid-shaped “scaffolding” was created to fit seamlessly into the uneven verso surface of the body and the head of the guitar. The support structure is made of thin strips of corrugated board with which the vulnerable area along the crack could be stabilised and the object could be mounted in the show case in one procedure (Fig. 4).

### Notes

- 1 Interview; Andrea Überbacher, West Archive Vienna
- 2 Henry Schein, Paper Pins, Maxima® Hand rolled paper points. Colour coded. Sterile. <http://www.henryscheinbrand.com/product.php?switchlang=de&leader=&product=9002505>
- 3 <http://www.belo-restauro.de/English/Company/Catalogue/Painting/Dosimeter/dosimeter.html>

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Fig. 4: The verso view with the scaffolding made of corrugated cardboard before mounting into the show case.



## The Restoration of Cartoons at the Department of Drawings and Prints in the Louvre

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Fig. 1: Ambassadors' staircase, Château de Versailles, after treatment



Fig. 2: Rolled cartoons before treatment

Charles Le Brun was named Director of the Royal Academy of Painting and Sculpture in Paris in 1663. The following year, he entered the service of Louis XIV, becoming First Painter of the king and chief official responsible for the painted decoration of the royal residences, a position which led him to undertake projects that became emblematic of the reign of the Sun King such as the Hall of Mirrors and the Ambassadors' Staircase at Versailles (Fig 1). This last decoration was destroyed during the reign of Louis XV in 1752; all that remains are the preparatory drawings and

later prints that record the overall composition.

Upon the death of Charles Le Brun in 1690, the superintendent of buildings, art and manufacturing in France, François Michel Le Tellier de Louvois, seized all works of art found in the artist's studio, including works made while he was First Painter as well as works made prior to his appointment.

About 3,000 drawings and 700 cartoons thus entered the royal collection in 1690, spanning more than forty years of the artist's career. The size of the collection is exceptional; it comprises not only composition studies but also drawings after live models as well as cartoons as large as 5 by 3 metres. As exceptional as the drawings' quality is the light they shed on the successive design stages of his grand scale decorative projects. Indeed, in Charles Le Brun's studio, the works were kept together in "packets"<sup>1</sup> which probably served as repository of formal ideas for the instruction and use of his assistants and students. The fact that in certain sheets the drawn lines have been retraced, and that traces of repeated transfer on to the walls can be found, suggest the reuse of specific cartoons. Their early entry into the collection meant that, unlike many other works preserved in the Department of Drawings and Prints, they were never the object of collectors' changing tastes, but were acquired fresh from being used.

The history of the conditions under which the works by Charles Le Brun were conserved, once they had entered the royal collections, is known through archival records and through the traces of changes and damages left on the works themselves. Their state of conservation was regularly noted in the reports that successive keepers of the King's paintings and drawings addressed to the monarch, asking for the means to conserve them. The cartoons were for a long time stored rolled up or folded, and some still are (Fig. 2); they bear stains that indicate water damage at some point and tears that show careless handling.

The small and medium-sized drawings have



been the object of several mounting campaigns, the first of which occurred in the first half of the eighteenth century, at the initiative of Antoine Coppel and of his son Charles, successive keepers of the royal collection of drawings. They concerned about 450 drawings, which were at that time glued on to blue cardboard mounts decorated with strips of gold paper. Much later, in the 1970s, numerous single study sheets were placed in beveled window mounts, within which they are maintained by a hinge on the right side edge. Today, these drawings are the object of a restoration campaign that intends to loosen the hinges that sometimes marked the sheets and to change the mounts, which have become acidic.

Past treatments tell us about the perception that our predecessors had of Charles Le Brun's cartoons. At the time when Garnier d'Isle, Controller General of the Royal buildings<sup>2</sup> could write that at least "the heads, the hands and the feet" should be cut out in order to save them, the importance accorded to the cartoons was due to the renown of their author, Le Brun. Their primary function, to transfer a given composition onto the wall, was no longer valid; cartoons were not regarded as true works of art<sup>3</sup>. In the eighteenth century, one exception, however, is notable: Pierre-Jean Mariette had a head [cut out of a cartoon] stuck on to a blue mount<sup>4</sup>, as he did with the most valuable works in his collection. In the early nineteenth century, the remounting of cartoons on canvas marked a change in the works' perception: it was performed in order to frame and exhibit them in the galleries of the Louvre. At this time, any missing parts of the drawing were completed directly on the coloured margins (Fig. 3).

The first exhibition of Le Brun's cartoons opened in 1866 and lasted for several years. The effects of light, coupled with the deterioration from the mix of adhesives used for the pasting, have caused severe discoloration. These mixtures of flour-based, protein and carbohydrate adhesives age badly; they harden and can take on an orange color. At the time, they were used by painters as well as by picture restorers. Numerous small folds and creases show a deformation of paper and a lack of understanding of paper's expansion and contraction phenomena, which confirms our hypothesis that the remounting of Le Brun's cartoons was realized by painters or picture restorers. In France, the conservation of graphic works of art is a relatively recent



Fig. 3: Missing areas of the drawings completed in the 19<sup>th</sup> century

discipline; formerly it was associated with the practice of mounting and framing small- and medium-sized drawings, while larger formats were associated with the conservation of large-sized paintings.

Between 1992 and 1994, a campaign was started to identify and photograph the cartoons by Charles Le Brun in the collection. Basic restoration work was done on this occasion, consisting of surface cleaning of the ensemble and a provisional consolidation of tears, in order to allow the works to be photographed safely.

The earliest exhibitions at the Louvre Museum were pedagogical in nature; their aim was to allow maximum access to the works. Thereafter, little by little, the role of the museum was redefined; it adopted a more scientific approach to conservation. Today, the museum not only conserves works of art, it also wishes to affirm the historical state they were in at the moment of acquisition.

The works on paper preserved in the Department of Drawings and Prints of the Louvre are made accessible to researchers and interested lay persons in the Department's study room. Consul-

tation presumes that the works are mounted in such a way that both recto and verso can safely be examined. This imperative directs the selection of restoration treatments.

Conserving, displaying, consulting – these demands are sometimes difficult to reconcile, especially for large-sized works. Conservation implies a stable environment and climate, minimal handling, and maximum protection against light and against atmospheric pollution. The solutions needed for exhibition of the work may be temporary; in that case, it is more a question of means, of the time needed for an intervention, of the budget allocated for the restoration, installation and taking down of the work, than an ethical issue. However, consultation of the works on paper requires durable and sustainable solutions to problems of conservation; the works need to be accessible and it must be possible to manipulate them safely.

The approach chosen by the conservation studio at the Department of Drawings and Prints seeks to take into account, in its treatments, to maintain as much as possible the work's authentic character, to enable its exhibition and its consultation, and thus to allow historians to conduct their research.

In the case of Le Brun's cartoons, there is the additional difficulty of the sheer number and heterogeneity of the ensemble. Among the 700 cartoons there are masterpieces, unique items of great historical and artistic importance, as well as more modest works and even copies that were used to transfer the drawing or as teaching material for pupils. However, all share the fact that they are essentially working drawings, carrying the traces of their use.

Since the creation of the conservation studio of the Department of Drawings and Prints in 1989 and following the first restoration campaign, which involved superficial cleaning and consolidations needed to allow an inventory of the collection to be taken, sixty cartoons have been restored. Over the past twenty years, restoration protocols have evolved and the materials used have been updated. Nevertheless, the same inherent logic and the main stages of restoration remain valid. They take into account both the history of the cartoons and their dimensions.

Cartoons that were folded or rolled often suffered so much friction that the radiance of the white chalk heightening and the velvety character of the black chalk lines were lost. If the



Fig. 4: Ambassadors' staircase, Château de Versailles, detail of conservation work

cartoon was pasted onto a backing canvas, on the other hand, it usually is now badly discolored and few traces of the white highlights are left. The stiffness of the *marouflage* and the deterioration of the adhesive justify the cartoon's removal from the canvas backing. Additionally, poor storage conditions were often the cause of distortion of the canvas, extreme dirt, and stains. The difficulty encountered in removing the glue depends on the quality of the adhesive used and its age. Selected solutions involve heat and an alpha-amylase gel.

Consolidation of tears and filling in missing areas are needed in all the cartoons. Folded or rolled works often exhibit more tears, yet their paper is not as distorted as is the case with works that were backed on canvas in the nineteenth century. Some cartoons are lined once or twice. Wheat starch paste and Japanese "minogami" paper are used to line the cartoons (Fig 4).

The large-scale cartoons are, in general, pasted onto a canvas of 'aged' linen prepared with

intermediary sheets of paper. This procedure is frequently adopted with cartoons that were re-mounted on canvas in the nineteenth century. The preparation of the support is done concurrently with the restoration of the work itself. The linen is 'aged' three times to give it the required inertia guaranteeing stability. It is a long but essential process, needed to obtain optimal adhesion of the paper to the canvas. Strain gauge frames are used to absorb the stresses the work may undergo due to climatic variations.

Small-sized works are mounted on acid-free board of either honeycomb structure, or simple lightweight board. Different techniques may be employed: the work may be stretch-mounted on a cardboard, or mounted in such a way that the verso of the sheet remains accessible.

The questions posed by the preservation of the cartoons continue after their restoration. Until few years ago, the cartoons were systematically framed in heavy wooden frames painted black. This has been discontinued since, both to preserve the original character of the cartoons and for reasons of weight during handling. The cartoons are now placed in a light type of frame that is needed for storage or for handling during transport.

The choices made in the restoration of the cartoons of Charles Le Brun remain a matter of importance. The equilibrium between conservation, exhibition and consultation is a delicate one, and both the margins of action and those of the budget are limited. On-going research takes us ever closer to lighter, less invasive manners of mounting, consistent with the preservation of the works' authenticity and their history.

Valentine Dubard for the team of conservators of the Department of Drawings and Prints of the Musée du Louvre

#### Notes

- 1 The 'packets' gathered works according to site and type; patterns were kept separate. See: Beauvais, L. Pinault Sørensen, M. 2000. Musée du Louvre, département des Arts graphiques. Inventaire général des dessins. Ecole française, Charles Le Brun, 1619-1690, 2 vols., Paris, for references to all historical information cited here.
- 2 Statement of 2 June 1749 ; see note 1.
- 3 « Ces cartons de très peu de valeur » (« these cartoons of very little value »), circa 1730, Charles Coypel ; see note 1.
- 4 Department of Drawings and Prints, Inv. 29845.

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## To Remove or Retain? – Extensive Infills and Reworking in a Large - Scale Japanese Wall Painting

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### Introduction

*Dragon and Clouds*, a monumental panoramic wall painting in ink on paper from an unrecorded temple in Japan by the 18<sup>th</sup> century eccentric Soga Shohaku, was acquired by the Museum of Fine Arts, Boston, from the collector William Sturgess Bigelow in 1911. *Hawk*, a companion work by Shohaku, acquired at the same time, is believed to come from the same building. Both works are on identical paper and of the same proportions. Examination confirmed that *Dragon and Clouds* comprised eight separate parts, at least seven of which had originally been mount-

ed as *fusuma*, or sliding doors, as indicated by the losses in the paper where the finger-pulls, or *hikite*, would have been fitted. A central part of the composition between the continuous left four and right four sections is missing. Only two sections of *Hawk* are extant. A photo taken in 1912, shortly after the acquisition of the works, shows how they had been remounted, removed at some point from their door structures and joined in pairs, with white cotton borders and heavy paper linings (Fig. 1).

Both paintings had unusually large and unexplained areas of loss, perhaps due to their hurried removal from architectural setting in already damaged condition. It is possible that they may have come from a neglected or abandoned temple following the *Haibutsu Kishaku* anti-Buddhist movement of the early years of the Meiji period 1868-1874.

Losses in *Dragon and Clouds* had been infilled with paper taken from now-missing sections of *Hawk*. Although the two works were on paper of matching sheet size and manufacture, the infills taken from the 'Hawk' painting were darker in tone and, in places, carried brush strokes and imagery from the artwork (Fig. 2).

It was apparent that missing parts of the image of the dragon painting had been repainted on the infill paper. The repainted areas were discernable, due to the use of an ink of a different hue and sheen to the original. In some places the repainting was skillfully executed, whereas in others the brushwork was clumsy and awkward. Furthermore, elements from the hawk painting that were still visible in places beneath the repainting created a confusing visual mix. When the decision to treat both paintings was taken, it raised the question of what to do with the infills and repainted sections. To remove all infills and retain only the original artwork would have severely broken up the image and made it difficult to read as a cohesive composition. To keep all the historical infills would have retained the distracting elements, the tonal mismatches



Fig. 1



Fig. 2





Fig. 3

and poor brushwork that were so disfiguring to the appearance of the painting in its present condition.

### Method

A damage map of both the paintings was made to record all the original and infilled areas, and group discussions between conservation and curatorial staff were held to reach a consensus of agreement. It was decided to remove the majority of background area in the infills, but to retain repainted sections where the brushwork was acceptable in terms of execution and worked successfully to hold the composition together. These areas were marked out and recorded.

The artworks had been stored rolled for some time before their temporary display once in 1966 and again in the early 1990's. For this purpose, they were treated remedially to put down flaking paper fragments and flatten planar distortions. Subsequent to their display they were put back into storage between large sheets of Plexiglas.

Prior to this, their most recent treatment, the paintings were in an embrittled condition, with flakes of paper lifting from the surface, delamination of the lining papers, and heavy creasing from previous rolling and unrolling. The decision was made to separate the paintings into their individual sections and remount them onto wooden lattice cores with paper sub-linings in a style similar to that of their first mounting format as sliding door panels. This would return them to their original appearance and allow them to be exhibited and stored in a stable and safe manner.

There was overall discolouration and degradation of the support paper, probably a result in part of the heavy sizing that had been applied to allow for the generous application of ink that the artist employed. It was expected that some of the discoloration in the paper would be water-soluble and, if so, should be removed before any later wet treatments, such as re-lining and re-pasting onto a support panel where it might leach or migrate to other areas. The paintings were separated into single sections, each approximately 165.6 cm high and 135.0 cm wide, sprayed with water to relax and allow the paper and its linings to be brushed out flat. Sheets of thin rayon paper were dampened and applied to the face of the artwork to protect the surface and hold any lifting fragments in place. Lightweight blotting paper was dampened and applied to both sides of the artwork, turning the stack and replacing the blotting paper until no further discolouration was removed. The two layers of heavy Japanese lining paper were removed from the back of the painting and it was given a temporary lining of thick rayon paper, then medium weight Sekishu paper to support the embrittled artwork.

After drying, it was possible to assess the slightly lighter colour of the paper and prepare infill papers of a corresponding and suitable tone. The original paper support used for both paintings was a heavy *gampi* (*Diplomorpha sikokiana*) fibre furnish with a kaolin clay loading, known as *maniaishi*. Produced in the Najio district near Kobe, it was a popular choice for wall and door paintings in castles and temples from the late 15<sup>th</sup> century onwards. A similar paper, currently made by the Tanino family, was selected for the infillings. A lighter weight of paper was chosen, then lined with medium weight Mino paper, to allow for easier control during the shaping and handling of the infills. The lined repair paper was dampened and pasted by its outer edges to drying boards in preparation for sizing and toning. Sizing was made with a solution of animal glue, (*nikawa*), 2.5% and alum 0.5% and brushed evenly over the paper surface in both directions and two applications. Colour for toning was prepared from sticks of colour pigments, (*boenogu*), and carbon ink sticks, (*sumi*), ground down with water and the addition of a little animal glue for stability. The colour was applied with a wide, soft brush similar to that used for the sizing, in



Fig. 4

repeated applications until the desired degree of toning was achieved. For the infills in areas with dark ink-washed background, further applications of carbon ink colour were used.

Infill papers of the appropriate tone were selected by consulting the damage map and the artwork, matching for colour, then tracing and cutting roughly to size and marking for placing in position from the verso. For those previous infills in the painting that had repainted areas we wanted to retain, but background elements we wished to remove, we partially cut along the outline with scalpels to produce a clean and clear edge. The paintings were once again dampened and faced with thin rayon paper and water, then laid face down on a double layer of dampened heavy rayon paper to cushion the face of the artwork and prevent it drying out during the infilling and re-lining process. The temporary lining was removed along with unwanted old infills. Where a part of the old infill with repainting was to be retained, the partially pre-cut edge was completely cut through from the back, again with scalpels and the unwanted portion taken away. Newly prepared infills were dampened and put into place, heavy wheat starch paste applied at the overlap, the excess margins reduced with tweezers.

With infilling completed, the paintings were lined with two layers of medium weight Mino paper, the edges wet cut. The grain of the paper

was horizontal for the first lining, vertical for the second. Before the application of the second lining, tears, splits and heavy creases in the artwork were reinforced with medium weight Mino paper, wet-cut across the grain in strips approximately 1.5 cm wide. A border of thick Sekishu paper was added to allow for handling and attaching the artwork to a drying board.

The relined artworks were placed face up on large felts and the facing papers removed. When the surface of the artwork had started to dry, another felt was placed on top, to slow down the drying, promote suppleness and prevent distortion.

The following day the relined section was humidified by spraying with water, brushing out flat, and attaching by its borders to a drying board.

For the remounting of the paintings in the style of sliding doors, wooden lattice cores of Japanese cedar (*Cryptomeria japonica*) and black lacquered wooden trims were ordered. The cores received the traditional six linings of eight layers of paper that are commonly used for folding screens and sliding doors. The verso of the artworks were pasted with a thin paste overall and a heavy paste around the outer edges, then the prepared cores lowered into place. The backs of the screens were covered with a plain silk fabric, pre-lined with dyed paper. Both the painting and lined silk were put on one immediately after the other and dried overnight between felts to slow

down drying and prevent warping of the core. After drying, the lacquered wooden trims were fitted.

In place on their support cores, the paintings were ready for final adjustments to the toning of the new infills. The aim was to bring the infill to a level slightly lighter than the surrounding original. This proved more difficult in some areas than others, particularly where there was a strong contrast or variation from one side of the infill to the other. In this case, a slight gradation made the transition more visually acceptable. Toning was carried out by building up thin washes of colour, applied with soft brushes. Stick colours and carbon ink sticks were used. Large areas in the dark background of *Dragon and Clouds* had been painted with a coarse, velvet-like black that was unlike the ink used in other parts of the painting. It may be that this was a type of ink known as *kezurizumi*, made from shaving dried waste remnants from the production of stick ink and soaking overnight in water. The resulting ink is a thick, rich black that was used for painting paper lanterns and the production of inexpensive printed matter. The stick ink we ground for use in toning the new infills had much finer particles and produced a shinier finish than we required. Alternative carbon black pigments were tested and it was found that peach stone black, cherry stone black, vine black and ivory black produced the required colours and matt finish that we were looking for.

## Conclusions

The progress and degree of toning was constantly monitored and discussed by conservators and curatorial staff. Areas that had been removed were re-assessed and in one case, replaced. Prior discussion and reassessment of what to remove and what to retain was a key factor throughout the treatment of what was a complex mix of original and later imagery. The aim had been to remove obtrusive and distracting repairs whilst retaining repainted portions whose removal would have significantly affected the readability of the overall image.

## Acknowledgements

Thanks go to colleagues who assisted with work on this project; fellow conservators Jacki Elgar, Jing Gao, Yi-Hsia Hsao, John Robbe, Hsin-Chen Tsai, Tatsuya Yamachi and Sukesaku Wakiya, and curator Anne Nishimura Morse.

## Captions

Fig. 1: *Dragon and Clouds*. Acquisition photograph of the four left hand sections, taken in 1912.

\*Museum of Fine Arts, Boston. William Sturgis Bigelow Collection

\*Photograph © Museum of Fine Arts, Boston

Fig. 2: *Dragon and Clouds*. Second section from the right, before and during treatment. Left, before treatment. Note the large repainted infill at lower left, with grass and rocks from the Hawk painting clearly visible. The repainted lower portion of the tail was retained, as was the end of the tail at the right. Right, during treatment. After infilling and relining, before toning of new infills.

\*Museum of Fine Arts, Boston. William Sturgis Bigelow Collection

\*Photograph © Museum of Fine Arts, Boston

Fig. 3: Reviewing extent and degree of toning new infills.

\*Museum of Fine Arts, Boston. William Sturgis Bigelow Collection

\*Photograph © Museum of Fine Arts, Boston

Fig. 4: After treatment. *Dragon and Clouds* on display at the Tokyo National Museum in the exhibition *Japanese Masterpieces* at the Museum of Fine Arts, Boston, 2012.

\*Museum of Fine Arts, Boston. William Sturgis Bigelow Collection

\*Photograph © Museum of Fine Arts, Boston

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# The Migration of Hydroxy Propyl Cellulose During Consolidation of a Painted Wallpaper: A Case Study Using a Fluorescent - Labelled Consolidant

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## Introduction

This paper presents the evaluation of a consolidation method planned for a painted wallpaper in the Neues Museum Berlin in 2007. Five years before, the painted surface had been secured with facings applied with Klucel<sup>®</sup> (hydroxy propyl cellulose) solved in ethanol. A method for their removal and simultaneous consolidation of the weakly bound and partly flaking paint layer was proposed by the conservators in charge and evaluated by researchers at the State Academy of Art and Design Stuttgart with test objects.<sup>1</sup> The penetration behaviour of hydroxy propyl cellulose in the test wallpapers was visualised using fluorescent labelling.<sup>2</sup>

## Original wallpaper and conservation problem

In 2008, the Neues Museum Berlin was restored and reopened for the public after it had been severely damaged in World War II. The ceiling wallpaper is part of the original interior fittings from the 1850s. Originally, maculature and paper supports had been attached to the ceilings of the Mythologischer Saal and afterwards been painted in situ with glue-bound distemper.<sup>3</sup>

After having suffered different damages con-

nected to the partly destroyed museum building, the 250 m<sup>2</sup> of wallpaper were treated by conservators in 2002. The painted surface was secured with facings applied with hydroxy propyl cellulose dissolved in ethanol and the partly detached wall paper removed from the ceilings and transferred to a storage in anticipation of further conservation treatment.

At the beginning of the wall paper's conservation in 2007<sup>4</sup>, it was not possible to remove these facings from parts of the paint surface without risking paint loss. Thus, a method comprising their removal and consolidation of the weakly bound and in parts flaking paint was proposed by the conservators and investigated on test objects specially designed for this study at the State Academy of Art and Design Stuttgart.

## Method and testing

The fluorescent labelling of hydroxy propyl cellulose<sup>5</sup> with Fluorescein-5-isothiocyanate (FITC 'Isomer I') was executed before its application, thus guaranteeing a precise detection of the latter. During the fluorochromization reaction, FITC and hydroxy propyl cellulose formed a stable bond (see Fig. 1). Any free fluorochrome was removed in a subsequent dialysis.

The non-fluorescing test wallpaper was produced by glueing together two layers of paper with wheat starch paste which were then painted with several layers of glue-bound ultramarine (see Fig. 2).<sup>6</sup> The test wallpapers were treated with a fluorescent-labelled hydroxy propyl cellulose (corresponding to the first conservation treatment in 2002): Facings consisting of Japanese tissue<sup>7</sup> were attached to the paint layer of the test objects with a ten per cent solution of the labelled cellulose ether in ethanol. Having allowed a sufficient period of drying, it was now tried to remove the papers and at the same time use the facings' adhesive to consolidate the paint layer (corresponding to the current conservation treatment). The conservators in charge suggested that the hydroxy propyl cellulose should be treated

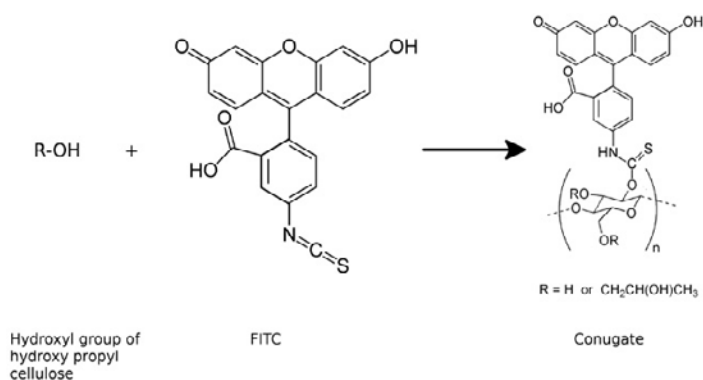


Fig. 1: Fluorochromization reaction between hydroxy propyl cellulose and FITC 'Isomer I', forming a stable, fluorescing conjugate.



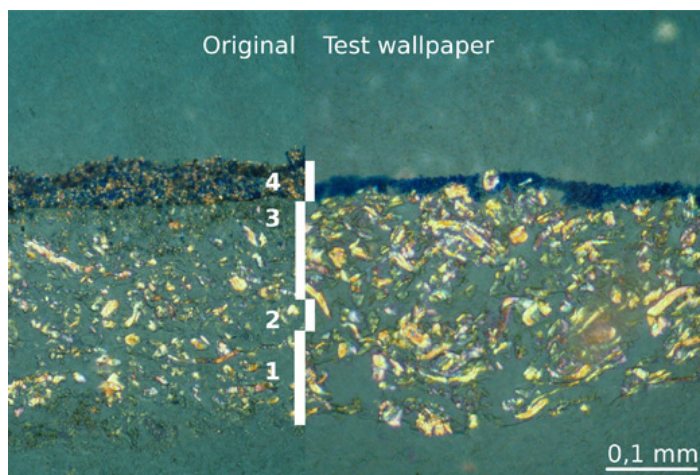


Fig. 2: Photos in visible light of thin sections (8  $\mu\text{m}$ ) of the original wallpaper (left) and the test wallpaper (right). Layers: 1 Paper support, lower layer; 2 wheat starch layer; 3 Paper support, upper layer; 4 paint layer.

with ethanol and the dissolved consolidant be transported into the paint layer and between paint layer and paper support by means of low pressure, avoiding however the impregnation of the paper support. Application method and residence time of the solvent, as well as exposure to low pressure were varied (an overview of the conservation treatments can be seen in Table 1).

After the consolidation method had been tested, samples were cut out, embedded in Technovit 2000 LC and cut with a microtome into 8  $\mu\text{m}$  thick layers. The thin sections were examined with fluorescence microscopy using a filter set specially designed for FITC. The non-fluorescing test wallpaper appeared black while the labelled hydroxy propyl cellulose exhibited a bright green fluorescence. The thin sections allowed for a

sharp view of the cross sections and a clear detection of the fluorescing consolidant within the sample while weak auto fluorescences of the materials were eliminated.

## Results

It was shown that different migration depths could be achieved by varying the application method of ethanol and by the time the test objects remained on the suction table (see Fig. 3).

Best results were achieved when only applying the ethanol from the front and removing the test objects from low pressure as soon as the facing had been removed (treatments A and C). The consolidant accumulated between support and paint layer as well as within the weakly bound paint (visible in higher magnification). Exposing the sample to low pressure before the facing's removal (2 min. in treatment C) had only little impact on the migration depth. Applying the ethanol also from the back (treatment B) resulted in the undesired effect of a slightly deeper penetration of the consolidant; however, the consolidant migrated mostly between paint layer and support as well as into the paint layer. Leaving the test object on the suction table after the removal of the facing (treatment D) lead to the complete penetration of the consolidant into the paper support while it was not any longer visible on or within the paint layer. This treatment was thus eliminated as an option.

Based on these findings, it was possible to choose the appropriate parameters for the hydroxy propyl cellulose to migrate into the weakly bound paint and accumulate between paint layer and support without risking impregnation of the paper support.

The application of fluorescent-labelled consolidant on test objects designed for the conserva-

Test painting	Ethanol application	Removal of facing on suction table	Left to dry on suction table
A	from the front (5 min swelling)	immediately	no
B	from the front and from the back (5 min swelling)	immediately	no
C	from the front (5 min swelling)	after 2 min	no
D	from the front (5 min swelling)	after 2 min	yes

Table 1 Conservation Methods tested

tion issue allowed a visualisation and an evaluation of the method without endangering the object itself.

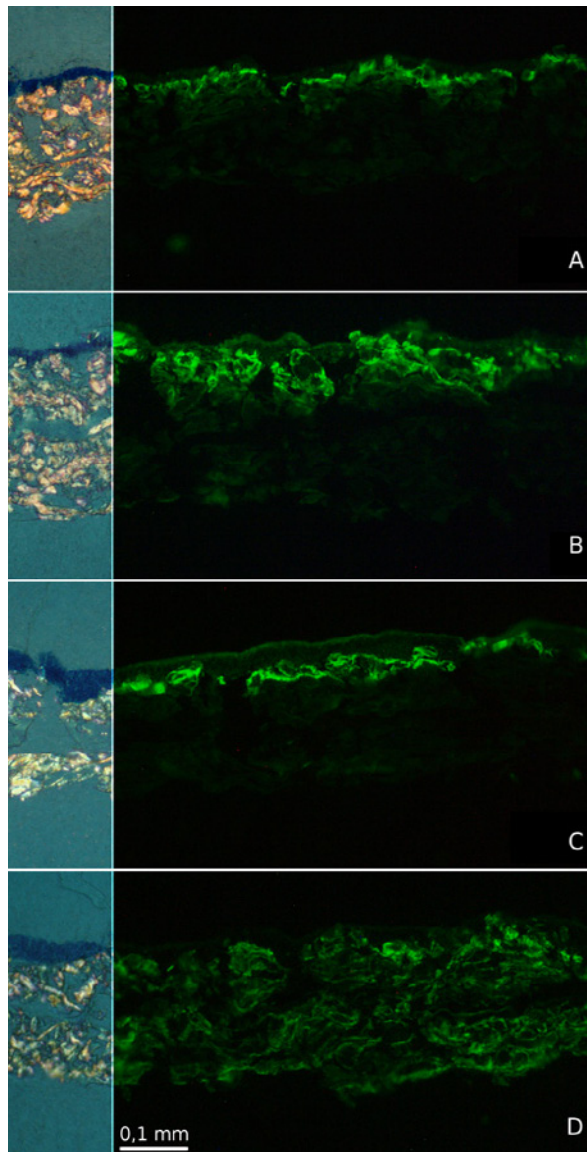


Fig. 3: Penetration behaviour of hydroxy propyl cellulose (Klucel® MF) in a test wallpaper: samples photographed with filter set adapted to FITC, hydroxy propyl cellulose appears green while the sample itself is black, small sections in visible light on the left for orientation. Results of tested treatments A-D (see Table 1) are described in the text.

#### Endnotes

- 1 This study was carried out in the scope of Karolina Soppa's PhD project that studies the behaviour of consolidants using fluorescent labelling.
- 2 The method is described in more detail in: Soppa, K., Laaser, T., Krekel, C. 2011. 'Visualizing the Penetration of Consolidants Using Fluorescent Labelling'. Paper presented at the CCI-Symposium 2011: Adhesives and Consolidants for Conservation - Research and Applications, Ottawa. Available at: <http://www.cci-icc.gc.ca/symposium/2011/Paper%2017%20-%20Soppa%20et%20al.%20-%20English.pdf>.
- 3 Original technique and the conservation are described in detail in: Lucker, T. 2009. 'Decken- und Architravtapeten im Mythologischen Saal'. In *Das Neue Museum Berlin - Konservieren, Restaurieren, Weiterbauen im Welterbe, Staatliche Museen zu Berlin et al. (ed.) 220-2*. Leipzig: E. A. Seemann.
- 4 The 2007 conservation campaign was carried out by Restaurierung am Oberbaum, Berlin.
- 5 Klucel® MF, Hercules Inc., Aqualon.
- 6 Handmade, acid-free and non-ageing, 90g/sqm paper, 15% wheat starch paste to glue paper layers together. Paint: ultramarine pasted with water, then mixed with 2% solution of bone glue.
- 7 Japanese tissue, 11 g/m<sup>2</sup>, Deffner & Johann.

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## Poster Presentations

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ICOM-CC Graphic Document  
Working Group - Interim Meeting

Austrian National Library, Vienna  
17 - 19 April 2013



# Ethical Considerations Concerning the Conservation and Restoration of a Herbarium from the 19<sup>th</sup> Century

MAGDALENA GREUDA

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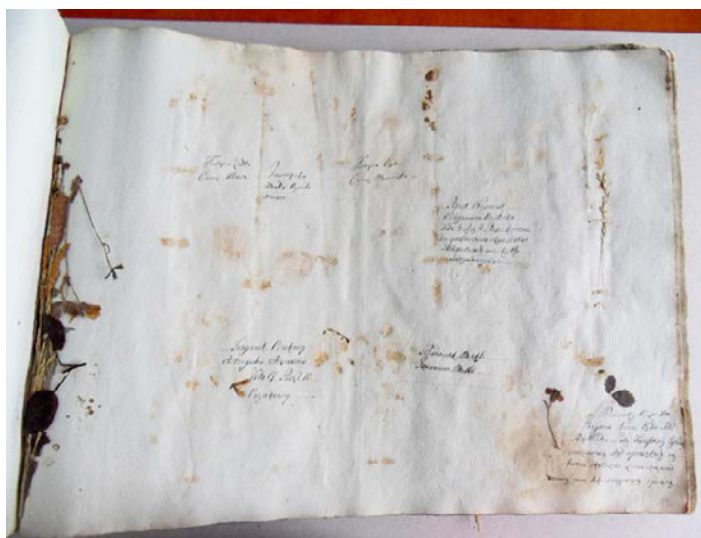


Fig. 1: Page 15 before treatment.

## Introduction

After two years of efforts to get financial support, the Reverend Krzysztof Kluk Museum of Agriculture in Ciechanowiec ordered the conservation of a herbarium from their collection. The artifact's history and origin were little known, and the author of the herbarium was anonymous. The curator wanted to submit the item for historical botanist research but was afraid of making it accessible for anybody due to its very poor condition. There was a clue for dating hidden in the paper: a watermark with the date 1816. The style of the Linnaean system for taxonomy assignment used in the herbarium suggested it was created before 1850<sup>1</sup>. Nevertheless, these were only mere pieces of information concerning the history of the artifact and the owner was interested in further research. The conservation treatment was intended to enable safe handling and submission of the item for future examination.

## Condition of the item

The herbarium has the form of an album and is a compilation of various types of plant specimens, arranged on large sheets of a greenish laid paper.

The sheets are sewn on four rigid cords, bound in cardboard binding with a woodblock printed paper. On every page, 4 to 10 specimens, are located irregularly, most of them have short handwritten descriptions. Particular specimens have longer specifications containing Polish and Latin names, taxonomy assignment and some notes on usage, some of which are very colorful. The specimens are attached to the paper using narrow strips of white laid paper. The larger leaves and petals were pasted to the paper support.

The herbarium was seriously damaged prior to conservation treatment. Severe damages were found on almost all the elements of the item: only half of the front cover remained; the construction of the whole block was dismantled; the covers' cardboard was spongy and stratified and there were a lot of losses in the outer layers of the paper. The remains of woodblock printed paper showed heavy discoloration and the pattern was hardly visible. The spine lost its proper shape. The paper sheets were torn at the edges, were creased and spongy. There were a lot of brown stains in the paper, mostly repeating the shape of the plants, which is probably the effect of poisoning the plants done in order to repel pests.

However bad the condition of the paper part of the item, the most serious problem concerned the specimens. The majority of plants had fallen off their places and moved to the area of the spine which caused damages to brittle plants. The damages were of different extent, from little cracks to severe breakages or even crushing. Nevertheless, still a lot of specimens remained in one piece, yet out of the intended place (Fig. 1).

The plants were brittle, often incomplete, partially crumbled and a lot of specimens swung when attached at one point to the sheet.

## Issues taken into consideration and conservation planning

Any handling was actually risky and might cause further damages or loss of plant material. The main goal of the conservation of such an item

was basically to reinforce the structure of the artifact to prevent it from further deterioration and mechanical damages.

The priority of the owner was to bring the item to a condition that would enable scientific research, and identify the origin and the history of the herbarium. Moreover, the item was supposed to be exhibited. This meant that all the loose material can no longer stay between the sheets of paper and it was necessary to find a solution for the more than half of the specimens loosely laying on the pages.

What did this mean for conservation? It soon turned out that the professional knowledge of paper conservation is not sufficient to complete a treatment that would meet the owner's expectations. The Museum of Agriculture in Ciechanowiec doesn't employ a paper conservator. All the processes should be completed during this particular treatment. The conservation studio was remote from the Museum's location and there was no possibility of frequent consultation meetings. From the conservator's perspective it was a matter of scientific responsibility. The questions to face first were: shall the conservator match the loose plants to a particular place in the herbarium using a botanic encyclopedia and intuition or should he put all the loose material in a buffered envelope and send it back to the owner? What if he confuses the plants? What if he attaches them and makes it difficult to work with for a botanist researcher who will find out that somebody made some terrible mistake? Will the researcher then be able to safely remove the specimen from the sheet and attach it onto the

right sheet without any damage to the specimen and the whole item?

The only method to solve the problem of the loose plant material was close cooperation between the conservator and an ethnobotanist, notably since there were a lot of specimens belonging to the same taxonomic family and several plants were apparently not lying on "their" sheets but were dislocated in the distance of a few pages. Specialist's advice seemed to be more than necessary.

### Treatment

Before the conservation treatment the herbarium was carefully documented, including page-by-page photographing which proved to be an extremely helpful tool from the very beginning.

The binding and the book block were disassembled. Dismantling revealed fragments of the woodblock printed paper that were not discolored, which enabled the later reconstruction. Originally there were no numbers on the pages, so the conservator made the pagination. After slitting the sewing, each page was treated as follows: the loose plants and plant particles were taken out from the area of spine, the whole loose plants and possibly identifiable plant fragments were put into envelopes numbered after the number page on which they were found. Dirt, plant crumbles and insect remains were removed and the sheet was separated from the block.

Pages were dry cleaned. Brittleness of plant specimens excluded the possibility of extensive wet processes like washing, so only local wet treatment of the paper was considered when applicable. The brown stains on the paper support were not planned to be removed as this might have been damage the plants. Furthermore, the stains were considered an identifying factor, helpful in matching some of the loose plants or identifying the lost material. The sheets were deacidified from the back with Bookkeeper Spray which is a surface deacidifying agent and provides non-aqueous deacidification. This was considered the safest solution both for the paper and plants as there are no clear guidelines for the deacidification of plant material. The pH rose from 5-6.30 before to 6.5-8 after conservation.

Paper support needed strengthening which was provided by applying 2% methyl cellulose solution from the back of the sheet. After application the sheet was turned upside down and any excess methylcellulose on the plants was gently



Fig. 2: Plant fragments from page 5 prepared for matching.



Fig. 3: Specimen mounting supported with dyed Japanese tissue.

removed with damp cotton swab. Then the paper tears were mended and the paper losses were infilled.

The flexibility of plants changed dramatically due to the change of humidity and was expected to get low again during drying under pressure. The sheets were then pressed under a soft layer of felt, which gave good results for most of the sheets. The ones for which this method didn't work well were put in the press, between several layers of Whatman blotting paper sheets, after humidification in Gore-Tex®.

After flattening the sheets it was possible to start the process of matching. The first attempt was to match on a particular page the plants that used to lie on its surface in the area of the spine. If some plant didn't match any description or trace of plant on the page, the conservator searched for the right place on the other sheets. All the matches and the fragments that were difficult to identify were photographed (Fig. 2). The matching process was reviewed with ethnobotany professor Lukasz Luczaj from University of Rzeszów. This cooperation made it possible to match about 90% of specimens. The rest was uncertain due to the lack of description or the condition of the specimen remains.

The specimens that were not identified and/or remained loose were put together in the buffered paper envelope and treated as a separate attachment to the item.

The plants were mounted onto the paper using the original white paper strips and rice starch paste. If the paper strips were not sufficient for that purpose, the attachment was sup-

ported with light Japanese tissue, died greenish matching the colour of the paper support (Fig. 3, 4). If the large leaves or petals were detaching from the sheet, they were pasted with a spot of rice starch paste onto the sheet.

The block of the album was resewn. The binding and the woodblock printed paper were reconstructed.

The herbarium was again documented after the treatment, page by page.

### Conclusions

The conservation of the Museum of Agriculture's herbarium was a challenging and demanding task. It required careful observation all the time and reevaluation of methods commonly used in paper conservation. During the treatment both conservator and ethnobotanist were seeking for the most satisfying solution that is safe for the plant material and at the same time enables handling and exhibiting the item. In addition the herbarium was intended to be a subject of further scientific research. The idea to return the plants to their places seemed to be the best



Fig. 4: Page 15 after treatment.



one. It required a lot of examination, deciphering original descriptions that were not free from mistake and occasionally very puzzling. All resulted in a very careful matching of the plants to the handwritten text or to the identifiable traces on the paper.

A good photographic documentation is very important, which in these kinds of treatment may be crucial, especially if the conservator is consulting his work with other specialists and uses email as the fastest way to exchange the information. Good, extensive documentation also allows the evaluation of all stages of conservation treatment in terms of later botanist research. Some specimens were wrongly assigned by the author of the herbarium. This may be proven only by the pictures made before conservation.

The interdisciplinary character of conservation may be very satisfying if you find a good specialist that you cooperate with. This kind of cooperation may also help to overcome technical problems which appeared in this case (issues concerning the remoteness from the owner and impossibility of frequent precise consultation).

This artifact proved to be in need of extensive intervention. Attempts to evade plant matching would result in making the artifact almost a useless sample instead of a historical source for botanists. Of course, it would make it less attractive for the exhibition purposes, too.

Herbaria are specific items and there is not much research on the influence of conservation treatment methods to plant material. It would be desirable to examine the mutual influence of different features of paper and plant materials and the effects of conservation on specimens <sup>2</sup>.

The treatment was fascinating and yet provoked questions, such as the legal extent and unusual practice and the large influence of the conservator on treatment decisions.

### Acknowledgements

I would like to thank professor Lukasz Luczaj for his support during puzzle matching of plant specimens.

### Notes

- 1 Consultation with prof. Piotr Köhler from the Botany Institute, Cracow
- 2 The literature on managing the herbaria covers mostly the problems of preservation and pest management, e.g. Herbarium Handbook by D. Bridson and L. Forman, 2010, Kew Publishing, or "The effects of freezing and freeze-drying on natural history specimens" by ML. Florian, Collection Forum, vol. 6, no. 2, 1990. There rather few articles concerning conservation methods.

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## Conservation of a Book of Hours from Mafra's National Palace collection: Between Technique and Ethics

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Fig. 1: Manuscript of the cofre no. 24, dated ca. 1420 and ca. 1470, in use in Autun the Funeral Procession. Image © PNF

### Introduction

One of the characteristics of the Books of ours produced in Europe in the 15th century is the richness of the materials used in the decoration of the devotional images, representing the social and economic power of its owner and transforming them into luxury objects. This was one reason why these books became “best-sellers”, carefully donated from generation to generation. The core point of this article is the presentation of the ethical approach for the conservation of a French Book of Hours dating from the early 15th century, now stored in the Library of the 18th century Mafra National Palace (Lisbon, Portugal), based on the study and comprehension of the techniques and materials used. In fact, for the full appreciation and understanding of the work involved in the construction of the Book of ours and the development of a conservation strategy, it is crucial to know which materials were used, determine their conservation status, and attest

the interventions suffered throughout its existence.

An interdisciplinary team studied the historic context of this prayer book, its techniques and material composition, its conservation condition, and decided the curative conservation approach (Araújo, 2012). In this article we intend to describe all the steps taken and explain the decision making, taking into account conservation ethics.

### Identification

A brief look at the Book of Hours, cofre no. 24 Figure 1: The original codex's body dated from ca. 1420 and three leaves were added later, in the second half of the 15th century. This manuscript, in ‘Use of Autun’, measures 197 mm x 135 mm x 50 mm and consists of 181 parchment leaves, with 14 lines of text, written in Latin and French. Among those, there are 14 leaves with illuminations, on a text of three, four, or five lines.

The Books of ours of Mafra Library has French origins and different characteristics, both in technique and building of colors. The manuscript of cofre no. 24 is, from a material point of view, the most luxurious and decorative in the collection. However, it is also the most deteriorated one. The bookbinding is a full calf brown leather, gold decorated on the spine with the inscription: Heures de Votes (Hours of Votes). The bookbinding was probably produced later in Portugal, since its features and decorative materials are typical of the late 18th / early 19th centuries.

Our analysis aimed to identify the materials, the color production techniques and develop a palette, an element that may allow the characterization of a particular workshop or artist. The study was focused on two colors, pink and blue, that according to a study carried out earlier (Villega-Petit, 2007) were two pigments (Brazilwood lake and lapis lazuli), mainly used by several Pari-



Fig. 2: Manuscript of the cofre no. 24: Deformation in the text block caused by the binding.

sian illuminators of the 15<sup>th</sup> century. This manuscript, kept inside a strongbox in the Library of the Mafra National Palace, characterized by low and stable temperature levels, is now in reasonable conservation conditions.

### The problem

We came across a codex that had suffered several interventions at the level of bookbinding, which was replaced in late 18<sup>th</sup> early 19<sup>th</sup> centuries, contributing to the overall deterioration of the manuscript (Figure 2). The deteriorated bookbinding, that is accompanying the manuscript, no longer meets its essential goal, enabling the safe and secure manuscript's handling. We took into account two hypotheses when considering the need to rebind the codex: <sup>1</sup> recovering the 18<sup>th</sup>/19<sup>th</sup> century binding; <sup>2</sup> making a new binding following the original 15<sup>th</sup> century style. It seemed more appropriate to choose the first



Fig. 3: The body of the book is currently composed by 23 sections, from which five presented modifications. In section II, three original leaves were removed, resulting in discontinuity of text.

option, since there was no evidence of an early bookbinding. Proper conservation of the current bookbinding would stabilize the movement of the parchment sheets and therefore it is the first step for the stabilization of the pictorial layers.

In sections V, XV, and XX one folium was removed and replaced, probably in the second half of the 15<sup>th</sup> century, by two thicker parchments, with illuminations. In the case of the first two the illuminations were assembled in a puzzle like fashion. Finally, in the case of section XXIII, it presented a 'collage' of four leaves along the hinge area. The changes led to an imbalance of the whole and contributed to the deformation of the body of the book and degradation of the binding structure, affecting the entire codex. However, sections III, VII and XVIII, which were originally designed for the absence of a folium, also contributed to this disparity. Regarding the text block, two hypotheses were discussed by the team and with the Mafra curators: <sup>1</sup> insertion of a sheet of parchment on the all signatures that presented unevenness; <sup>2</sup> inclusion of only three sheets of parchment on section II, since this was the only truncated section. The last option was chosen, respecting the original historical evidence and the principle of minimum intervention.

### Conservation condition

Deterioration was observed on the leather cover, namely surface soil, general wear, and missing areas of card and leather, especially in the spine and board corners, some caused by insects. The tight binding, related to the production period, was affected by incorrect handling causing stress on the spine and breaking the sewing. This meant that the manuscript was dismantled, with several loose signatures.

In general, the support of parchment seems stable under visual damage assessment (using IDAP parameters; IDAP, 2008), but shows surface dirt and residues of animal glue, especially along the bifolia hinge area. Also observed were some gaps, caused by the sewing tension, and, in smaller amounts, tears in the fore edge of leaves. While in acceptable condition, the text showed areas of ink fading and areas of loose pigment due to poor adhesion of the different pictorial layers to the support.

This condition is most evident in green, blue and white colors, probably due to the grain size of these pigments or low amount of binder. However, the hygroscopicity of parchment leads to its





Fig. 4: Pigments

movement and consequently to these kind of pathologies. In the manuscript we can also observe the presence of abundant gold and, in some leaves, the presence of silver, widely applied in the backgrounds of the illuminations. The first, applied as gold leaf, is damaged but it is the silver that presents extensive degradation and darkening due to its oxidation, totally distorting the original appearance of the whole decorated leaves.

## Results

### Analysis of materials and techniques

A systematic analysis of the illuminations was made to better understand the pictorial surface, to gather information about the color construction techniques in illuminated leaves, and to check for the presence of some surface material such as varnish. In addition to macro and micro photographic records and observation under a binocular microscope, we used in situ non-destructive techniques, such as the Energy-Dispersive X-Ray Fluorescence Spectroscopy,  $\mu$ -Raman Spectroscopy, Fiber Optic Reflectance Spectroscopy and, when necessary,  $\mu$ -Fourier Transform Infrared Spectroscopy. For the latter, samples were collected in micro-selected areas, under a microscope, completely invisible to the naked eye.

In general, the materials and techniques used were in agreement with what we know from 15th century's illuminated manuscripts (Bacci et al., 2009; Picollo et al., 2011). We can also add that it is a luxurious palette with beautiful, precious and lasting colors (Melo et al., 2012a). To the pigments (Figure 4) already used in medieval illuminated manuscripts of the 12th and 13th centuries two new dyes were added, Brazilwood lake (Vitorino, 2012) and gamboge. Also two yellow synthetic pigments were added, lead-tin yellow (type I) ( $\text{Pb}_2\text{SnO}_4$ ) and gold mosaics ( $\text{SnS}_2$ ) plus a basic copper sulfate, green, that we suggest to be a brochantite ( $\text{Cu}_4\text{SO}_4(\text{OH})$ ), or a mixture thereof with langite ( $\text{CuSO}_4 \cdot 3\text{Cu}(\text{OH})_2 \cdot 2\text{H}_2\text{O}$ ).

The different colors are temperate with vegetable binder (polysaccharide such as arabic gum), protein (e.g., egg white or parchment glue) or a mixture of both, which is consistent with the materials and methods described in the treatises (Melo et al., 2012b).

In general, we can say that the colors analyzed are the original artist's since, apart the leaves added later in the 15th century, no other alteration or restoration signs were observed. This fact reinforces the proposal for intervention of the manuscript that focused only on general cleaning and rebinding.

## Treatment

The aim of the treatment was to preserve and stabilize, physically and chemically, the text block and binding, without neglecting the material integrity of the object and its meaning, while maintaining cultural evidence with a spiritual dimension. According to the principle of minimum intervention and respecting the principle of maximum retrievability, stable materials and methods were used which, in addition, would not impede future treatments.

A complete photographic survey was conducted for further information and in order to register the remedial conservation process, allowing comparisons between the state before and after the intervention. The treatment consisted of the different phases described below.

The first step was cleaning general dirt that was mainly concentrated along the leaves hinge by mechanical means, using soft brushes, smoke sponge and spatulas.

Afterwards, as the glue layer present along the leaves hinge was too thick and the use of mechanical means to remove it could contribute to the increase of gaps and tears, we decided to remove dirt with a swab dipped in a solution of 50% H<sub>2</sub>O/50% CH<sub>3</sub>CH<sub>2</sub>OH, softening the glue and allowing its removal, without causing further damage in the leaves.

Subsequently, the bifolia and the deteriorated folium hinges were strengthened. In the first case, to strengthen the outer bifolia, a strip of parchment with a thickness identical to the original one was pasted with wheat starch paste. Simultaneously, in the inner bifolia, a strip of synthetic collagen was pasted to ensure its resistance during the sewing.

Only large missing areas were filled. The replacement of the three truncated leaves was made with the inclusion of three new parchment sheets with similar characteristics of the original ones but in a perfectly recognizable way, respecting the authenticity of the work and evidences of its individual history.

After mechanical cleaning, the fly-leaves and paste-down papers were subject to a deionized-water bath. At room temperature there were no satisfactory results, since the paper exhibited impermeable zones, so the temperature was gradually increased (not exceeding 40°C). Afterwards, an increase in whiteness was observed during deacidification in a calcium hydroxide bath to create an alkaline reserve. The strengthening

of these papers with Japanese paper and wheat starch paste was then made, allowing further sewing and pasting-down.

Throughout the treatment, the bifolia were kept under controlled weight in order to maintain the shape in which they would be sewn. On the other hand, leaves with creases and without substantial illuminations were subjected to an ultrasonic humidification and were left in the press, with moderate weight, cushioned with blotters.

After consolidating the bookbinding's leather with Klucel G<sup>®</sup> solution, 2% -CH<sub>2</sub>CH(OH)CH<sub>3</sub> /98% CH<sub>3</sub>CH<sub>2</sub>OH, it was cleaned with a bistoury and spatulas.

The remedial conservation measures achieved a major goal: avoiding the increase in size of the manuscript spine. The rebinding phase, already in process, requires leaving the necessary space along the joint for full protection of the text block.

## Conclusion

Throughout the treatment of the text block the main concern was interfering as little as possible with historical evidence, while ensuring the physical and chemical stability of the whole, and the reversibility of the materials and techniques applied. During rebinding we will follow a similar philosophy in terms of criteria and conservation aims.

The treatment required complex decisions covering different areas of knowledge such as history of ownership, past and present conservation and restoration techniques, as well as authenticity and work ethics issues.

In short, this was a rich and representative case study of what is possible to find in the world of graphic documents, covering a vast range of materials (from paper, to skins, and rich illuminations) and different historical periods (15<sup>th</sup> century text versus an 18th/19th century binding), providing interesting challenges in terms of decision making.

## Acknowledgments

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## Notes

- 1 Brazilwood lake, lapis lazuli ( $\text{Na}_8(\text{Al}_6\text{Si}_6\text{O}_{24})\text{Sn}$ ), vermilion ( $\text{HgS}$ ), minium ( $\text{Pb}_3\text{O}_4$ ) orpiment ( $\text{As}_2\text{S}_3$ ), gamboge, lead-tin yellow type I ( $\text{Pb}_2\text{SnO}_4$ ), mosaic gold ( $\text{SnS}_2$ ), indigo, azurite ( $2\text{CuCO}_3\cdot\text{Cu}(\text{OH})_2$ ), malachite ( $\text{CuCO}_3\cdot\text{Cu}(\text{OH})_2$ ) basic copper sulphate ( $\text{Cu}_4\text{SO}_4(\text{OH})_6\cdot 2\text{H}_2\text{O}$ ), white lead ( $2\text{PbCO}_3\cdot\text{Pb}(\text{OH})_2$ ) and carbon black (C).

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# The Conservation and Digitization of Jain Manuscripts at the Victoria and Albert Museum

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Fig. 1

## Introduction

The Victoria and Albert Museum has a collection of Svetambara Jain manuscript pages from western India, including numerous examples dating from the mid 15<sup>th</sup> to early 16<sup>th</sup> centuries, which form a core part of the V&A's collection of early paintings from the Indian sub-continent.

Many of the manuscript pages in the V&A collection are richly illustrated, having been acquired as works of art. Among these is a nearly complete *Uttarakhyayanasutra* manuscript of the mid 15<sup>th</sup> century (Figure 1). This relatively early example contains very fine illustrations. The *Uttarakhyayanasutra* instructs Jain monks how to behave and expounds certain Jain ideas, but also contains many parables and explanatory stories. The *Kalpasutra*, of which the V&A has one almost complete copy and several pages from dispersed manuscripts, all dating from the 15<sup>th</sup> and 16<sup>th</sup> centuries, is the most commonly illustrated text (Figure 2). It gives a history of the 24 Jain saviours and later teachers as well as rules for monks in the rainy season, when the text is recited and worshipped at the Paryushan festival. Both texts form part of the canon of the Svetambara sect. Members of the laity commissioned cop-

ies of manuscripts, which were given to temple libraries and thus preserved. The donors gained religious merit from this activity. By the late 15<sup>th</sup> century expensive colours such as gold and ultramarine blue had become prevalent.

The Jain religion dates back at least 2,500 years and is fundamentally concerned with liberation of the soul from an endless cycle of birth, life, death and rebirth by the elimination of karma. All living beings are believed to have souls and partly in order to avoid accumulating harmful karma it is considered very important to avoid causing them injury or hardship. Non-violence to all beings is therefore the central and most recognised principle of Jainism and accordingly Jains are strictly vegetarian.

## Digitization and Conservation

The decision to conserve and digitize these manuscripts in 2010 was prompted by the proposal to redisplay a selection of Jain works of art in conjunction with the JAINpedia website (<http://beta.jainpedia.org/>) project digitizing Jain manuscripts in UK collections. The aim of this initiative was to make these delicate artefacts accessible for the public via the JAINpedia and



Fig. 2



Fig. 3

V&A websites and to conserve and mount the pages in order to allow them to be safely handled by scholars and researchers and displayed in the Nehru Gallery of Indian art, where they are periodically changed. The conservation work was made possible by generous contributions from the Institute of Jainology and the V&A Jain Art Fund.

The earliest Jain illuminated manuscripts were written and painted on prepared palm-leaves, bound with cords, and the folios were encased in decorated wooden covers.

Ahmedabad and Patan in Gujarat were major centres of Jain manuscript production. From the 12<sup>th</sup> century, the support changed progressively after the introduction of paper into western India from Iran, but the format of the palm-leaf manuscripts continued to be reflected to some extent in the long, rather narrow shape of the pages of paper manuscripts. The manuscripts are read by turning the pages about the horizontal axis, unlike Islamic and European books. Although the practice of piercing palm leaves for the binding cords was abandoned with paper

pages, which would easily have torn, decorative marks continued to be painted on the pages in the positions where holes would have been.

The fragility of the folios is largely a result of the extensive use of green verdigris (copper acetate) as a pigment. The copper degradation is evident on most of the illustrated folios, but is also observed on many of the text only pages (Figure 3). In both cases, acid hydrolysis and accelerated oxidation caused by the presence of copper acetate has resulted in both discolouration of the green pigment to a dull brown, and extensive discolouration, embrittlement and even disintegration of the paper substrate in areas where the pigment was applied.

A suitable conservation treatment for retarding such corrosion must address both the hydrolytic and oxidative processes at the same time. Studies have demonstrated that a combination of the complexing agent calcium phytate and an aqueous solution of calcium hydrogencarbonate are most effective in retarding corrosion (Potthast et al, 2008.). However, while this method may be considered appropriate for the treatment of iron and copper corrosion on Western manuscripts, such an interventive treatment is rarely, if ever, possible for richly painted Indian manuscripts on laminated papers.

The similarity of the verdigris damage to that caused by some iron gall inks lead the authors to consider the use of gelatine (isinglas) as an adhesive. However as Jainism specifically prohibits the use of animal products, it was necessary to find a synthetic alternative which would act as an adhesive. Japanese Tengujo tissue and thin Minogami papers were coated with a 2 % solution of methyl cellulose adhesive brushed on a Mylar, the Japanese paper applied on it and brushed through a Hollitex with a Nadebake. After drying, this coated tissue was then reactivated with a minimal amount of moisture and then applied to the copper damaged areas, minimising the amount of moisture introduced to the paper during repair. Wherever possible the tissue was cut larger than the area of damage and applied to the verso, therefore only adhered to areas of relatively strong paper. Some old repairs were partly obscuring the text. The main criterium to decide to remove them or not was dictated by the need to restore the legibility of the text. Conventional





Fig. 4

Japanese paper and wheat starch paste were used to reinforce the most extensive insect damage and losses. The folios were then inlaid into a toned, hand-made paper of a similar thickness and colour to the paper of the manuscript to allow a safe and easy handling.

The approach to both conservation and mounting of the manuscripts were decided after discussions with the curator of the Asian collection at the V&A, with a careful consideration of the importance of these early texts to followers of Jainism and a shared awareness of the risks posed to the original material by handling.

Historically, the display of the Indian pictorial collection at the V&A has been centred around individual paintings rather than entire manuscripts, and so it seemed logical to inlay the folios in an appropriate paper, and mount them in standard sized window mounts. In order to save much-needed storage space and also for aesthetic reasons, it was decided to mount three folios in each mount, which has the additional benefit of helping the viewer to see that the folios belong to larger manuscripts. With this method, a manuscript can be viewed in its original sequence, while at the same time being protected from unnecessary handling that could lead to further damage and loss to the already deteriorated folios. The mounted manuscripts are then stored in Solander boxes in the Indian Study Room at the V&A and can now be used for both periodic display in the Nehru gallery of Indian art at the Museum, and for close study by scholars (Figure 4).

## Captions

Fig. 1: Folio from an *Uttaradhyayanasutra* manuscript: King SreNika and the ascetic, showing the inlay method  
Opaque watercolour on paper; Cambay, Gujarat, about 1460; © Victoria and Albert Museum, London

Fig. 2: Folio from a *Kalpasutra* manuscript: Neminatha's birth (left) and his renunciation to become a monk on seeing the frightened animals about to be sacrificed for his wedding feast (right)  
Opaque watercolour on paper  
Gujarat, India, early 16<sup>th</sup> century  
© Victoria and Albert Museum, London

Fig. 3: Folio from an *Uttaradhyayanasutra* manuscript: the story of king ISukara, detail showing verdigris damage  
Opaque watercolour on paper  
Cambay, Gujarat, about 1460  
© Victoria and Albert Museum, London

Fig. 4: Folios from an *Uttaradhyayanasutra* manuscript showing the mounting and storage methods used  
Opaque watercolour on paper  
Cambay, Gujarat, about 1460  
© Victoria and Albert Museum, London

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## The Microflora Inhabiting *Leonardo da Vinci's Self Portrait*: a Fungal Role in Foxing Spots

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### Introduction

Leonardo da Vinci's famous self portrait is made in red chalk on paper. It is housed at the Royal Library in Turin, Italy. The drawing is strongly affected by foxing spots. The damage presumably occurred between 1890 and 1950. The portrait has been recently brought to ICRCPAL (Rome) for scientific analyses.

According to Corte et al. (2003) foxing is a modification of paper occurring in the form of brown, brown-reddish or yellowish spots, the origin of which has not yet been clearly explained. In fact, despite the extensive research that has been done in this field, no conclusive results exist to the cause of foxing. There are two different theories concerning its development: the biotic theory, according to which the stains are the result of the activity of micro-organisms (Choi 2007, and references therein) and the abiotic theory, entailing chemical phenomena such as oxidizing and/or heavy metals deposits (Cain and Miller 1982). In particular, the deterioration of paper has been linked to the presence of metals in the pulp, and paper yellowing/browning is supposed to be caused by cellulose oxidation catalysed by metals. There is moreover a quite clear relationship between the occurrence of these modifications and environmental conditions (Gallo and Pasquariello 1989).

Recent investigations have studied the role of fungi in foxing by light and electron microscopy (Florin and Manning 2000). These studies found that in some cases the initial cause of foxing was a group of spores of conidia that had been deposited on the surface of the paper prior to printing and had germinated in situ during the slow drying of the paper.

Arai et al. (1990) proposed the following process for the formation of foxing: absolute tonophilic fungi conidia and or ascospores attach to paper, germinate and grow their hyphae. The hyphae form colonies around dust particles.

These fungi metabolize mainly malic acid, cello-oligosaccharides and aminobutyric acid in the colonies. These components react chemically together on the materials at Aw 0.80 and 20-35°C forming brown products and oxidative reactions on paper that result in localised foxing spots.

From old books and manuscripts showing the characteristic foxing discoloration more than 60 fungus cultures were identified by ordinary light microscopy and the most common encountered species are *Eurotium*, *Aspergillus* and *Penicillium* species.

The brown-rusty spots that deface Leonardo da Vinci's portrait have all the characteristics of foxing, and some of them show a blue-yellow fluorescence that is also typical of both biological and chemical foxing (Choi 2007).

The knowledge of the nature of the stains is a question of great concern because future conservation treatments and actions towards the famous object would better be based on scientific data. Furthermore, the delicate object has been poorly studied from the "biological" point of view: only a couple of swab sampling undergoing culture-dependent techniques was performed between 1960 and 2000, and no significant results were obtained at that time.

With the aim to address the problem and assess the current microbiological risk of the drawing, we performed a study on Leonardo da Vinci's self portrait based on non-invasive sampling using diverse membrane filters and swabs, and a combination of SEM-EDS imaging culturing and molecular techniques.

### Methods

#### Sampling

One of the main problems encountered in the study of Leonardo da Vinci's self portrait was the execution of the sampling. Clearly no micro fragments could be removed since this action may have caused further damage to the object or



Fig. 1

a loss of information for future research. Therefore only totally non-invasive techniques were adopted. Different types of swabs and adhesive tapes were employed in sampling fungal or bacterial elements from paper (Figure 1). Wooden cotton sterile swabs were used to collect biological particles from the surface of the drawing. Porous membranes of different materials (nylon, polycarbonate or cellulose nitrate) with a natural electrostatic charge were also used to collect fungal aerial hyphae, conidiophora or fruiting structures, together with a few damaged fibres from the substrata. These objects, that can be valuable in diagnostic phases, cling to the charged surface of membranes and can be gently pulled from the mat. Both membranes and swabs can be used for direct observation with an electronic scanning microscope or used to perform molecular analysis.

#### SEM-EDX technique

Single fibres dust and surface material recovered with membranes or sampled with cotton swabs were analysed using a variable pressure SEM instrument (EVO50, Carl-Zeiss Electron Microscopy Group) fitted with a detector for electron backscattered diffraction (BSD). Only following an initial observation of the samples using SEM in VP mode at 20 kV were some of the samples coated in gold (using a Baltec Sputter Coater) and then subjected to further analysis in high vacuum (HV) mode. Sputtering was performed under an Argon gas flow at a working distance of 50 mm at 0.05 mbar, and a current of 40 mA for 60 seconds, so as to create a film of gold of about 15

nm thicknesses. Reference elemental intensities acquired from pure compounds (standards) are commonly used to calibrate SEM-EDX systems. In the case study presented here, conventional ZAF correction integrated into the Oxford INCA 250 microanalysis package was applied to the spectrum dataset (Oxford Instruments).

#### Molecular analysis

Porous membranes and cotton swabs were directly used for DNA extraction using the Fast DNA SPIN kit for soil (Bio 101) with modifications. DNA crude extracts were further used for PCR-DGGE fingerprint analysis of the bacterial 16S rDNA (Schabereiter-Gurtner et al., 2001) and the Internal Transcribed Regions (ITS) (Michaelsen et al., 2006). Clone libraries from these amplified fragments were screened by DGGE and selected clones sequenced (Schabereiter-Gurtner et al., 2001).

#### Conclusions

In the specific case of certain filamentous fungi, the fruiting body shape, conidia size and ornamentation can lead to positive identification at least at the genus level. The fungal species *Eurotium halophilicum* (C.M. Chr., Papav. & C.R. Benj. 1959) was found in foxing spots especially on the back of the drawing by means of SEM (Zeiss EVO 50- High Vacuum) imaging (Figure 2). Conidia appeared in different sampling points single or in groups, slightly ovate, echinulate with prominent scars and conidiophores finely covered with a layer of hairy structures (Figure 2). Microscopic features of fungal structures as observed by SEM are consistent with those determined by Christensen et al. (1959) in the original description of *E. halophilicum* and by Montanari et al. (2012). *E. halophilicum* is an obligate xerophilic organism with a high tolerance to water stress: the minimum observed water activity ( $A_w$ ) for germination and growing is 0,675, the lowest for any *Eurotium* species. Its occurrence is associated with air-dust (Montanari et al., 2012 and references therein) or house-dust in association with mites and *Aspergillus penicillioides*, and storage of dry food. *E. halophilicum* is reported as associated to foxing spots by Florian and Manning (2000) who published a SEM picture of the fungus without identifying it; with library material by Michaelsen et al. (2010) who found the fungus by DGGE-fingerprinting, without culturing it; and by Montanari et al. (2012) who isolated several

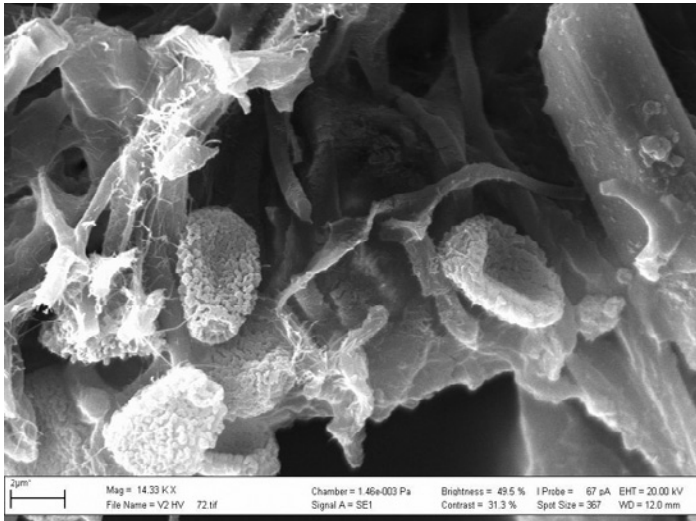


Fig. 2

strains of this species from library materials freshly infected.

This finding is consistent with the hypothesis that absolute tonophilic fungi germinate on paper metabolising mainly organic acids, oligosaccharides and proteic compounds. These components react chemically together on the materials at a low water activity forming brown products and oxidative reactions on paper that result in localised foxing spots. SEM imaging showed also the presence of other fungal species, not only as single spores, but as propagules and small mycelial masses.

DGGE-fingerprinting, a molecular technique based on direct extraction of DNA from environmental samples, allowed the comparison of different sampling techniques and DNA extraction protocols enabling the optimization of tools for the analysis of such valuable object. In addition, a complete screening of the biodiversity of the fungal community inhabiting the portrait (on the face and on the reverse side) was obtained and showed the putative differences in microbial composition among different samples indicating, in general, a higher biodiversity as initially suspected. Additional phylogenetic analyses revealed the presence of fungi with well known cellulolytic activities, with potential for the destruction of the investigated material.

## Acknowledgments

The authors would like to thank Dr. Maria Cristina Misiti, Director of the Istituto Centrale per il Restauro e la Conservazione del Patrimonio Archivistico e Librario in Rome and the Royal Library in Turin, Italy for the opportunity of studying the precious portrait. G. Piñar and the molecular analyses performed in this study were financed by the Austrian Science Fund (FWF) project "Elise-Richter V194-B20"

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#### Figure captions

Figure 1. Sampling approach to obtain fungal spores from Leonardo da Vinci's self portrait. Application of porous membranes (picture by D. Corciulo, ICRC-PAL).

Figure 2. Scanning electron microscopy (SEM) image of conidia belonging to the fungal species *E. halophilicum*, collected by swab sampling in foxing spots on the back of the drawing. Image obtained with a Zeiss SEM EVO 50 in High Vacuum mode on a gold sputtered sample, operating at an accelerating voltage of 20 kV equipped with a detector for secondary electrons (SE).

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## Microorganisms in Books – First Results of the EU Project “Men and Books” KATJA STERFLINGER | PATRICIA ENGEL

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Fig. 1: Book contaminated by darkly pigmented fungal mycelium and damaged by insects.

### Introduction

The EU project “Men and Books” deals with bound volumes of the Archives of the Protestant Parish of the Holy Trinity in Swidnica, where 12.000 individual items are stored. This archive is one of the most valuable for the history of Protestantism in Silesia, Bohemia, Moravia and Austria. Due to the climate, many of the books were attacked by microorganisms – mainly fungi. During the 1990s the books in Swidnica were fumigated with ethylene oxide. In conservation literature the use of ethylene oxide for book-disinfection is discussed highly controversially<sup>1</sup> (see also Meyer & Petersen, 2006) and it still remains an open question whether or not ethylene oxide is a good choice for book-fumigation. Without doubt fungi in archives are dangerous for both, men and books. However, some of the methods for disinfection are threatening both, books and humans. Therefore it was the aim of the study (a) to analyse if there is an active fungal community on the ethylene oxide treated books and (b) to

investigate possible remains of ethylene oxide that might still have an impact on the microbial community and protect the books against microbial attack but might also be health threatening for the reader of those volumes. 76 books, 44 manuscripts and 32 prints were selected for the project. They represent an essential corpus in terms of their information value. For microbiological analysis 20 samples were taken from various materials in 10 different books including textiles, different paper types, cardboard, leather and parchment (Table 1). Samples were taken for cultivation of fungi onto media and for genomic analysis in order to be able to detect both the viable and non-viable fungal community (being aware that the former ethylene oxide treatment might inhibit the PCR-amplification of the DNA).

### Materials and Methods

#### Isolation of fungi from books

Considering the high cultural and artistic value of the books, only non-invasive techniques were used for sampling: Porous membranes of different materials (nylon, polycarbonate or cellulose nitrate) with a natural electrostatic charge were used to collect fungal aerial hyphae, conidia spores and fruiting structures, together with a few damaged fibres or small flakes from the substrata. Membranes were smoothly attached to the materials' surfaces for several seconds, removed and directly applied to cultural medium (2% MEA, DG 18) or stored in a sterile tube for DNA extraction and further molecular analysis. Plates were incubated at 22°C for 7 days. Fungal cultures were purified by several transfers onto fresh medium.

#### Measurement of ethylene oxide concentrations from books

For the selection of books several parameters were relevant: (1) moment of fumigation (2) material composition, (3) age of the book, (4) size of

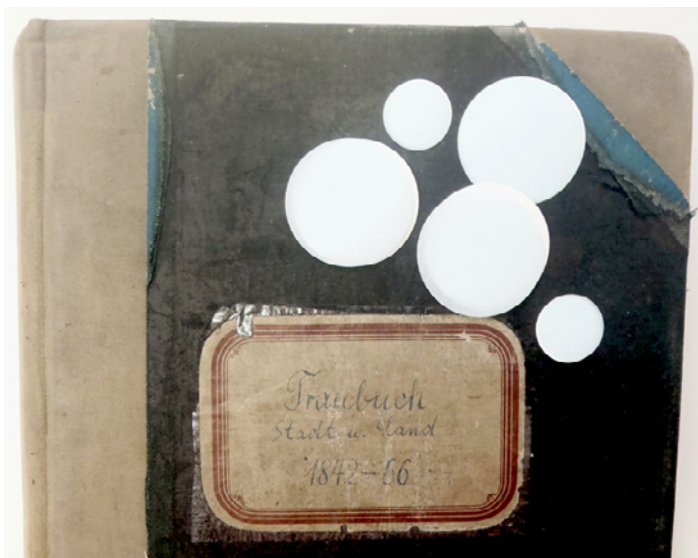


Fig. 2: Sampling of books by cellulose nitrate membranes.

the book. The books for ethylene oxide measurement were chosen aiming to get a representative average of all these features. This is especially important when it comes to transfer data into application Europe-wide and on an “average archive” at the end of the project. 28 volumes bound in leather, parchment, paper and textiles, dating from the 18<sup>th</sup>, 19<sup>th</sup> and 20<sup>th</sup> century, thus representing also different sorts of paper as book block, ranging from folio to quart were selected by the Parish in Swidnica and brought to the European Research Centre for Book and Paper Conservation-Restoration in Horn. There these books were put into a chamber of inert synthetic material of 1 m<sup>3</sup> volume and stored under closed conditions for 60 days at 20°C and 50% R. H.

Two different analytical methods were chosen to detect the off gassing ethylene oxide, a digital handheld device, Dräger X-am 5000, which turned out to be too rough (measuring range 0 - 200 ppm, resolution 0.5 ppm, smallest possible detection 1 ppm; expected concentration below) and a GC/FID. For the later the measurement was passive with ORSA-tubes filled with activated carbon. The measurement lasted for 336 hours. Then the tubes were taken out, closed and sent to gas chromatography. The analysis was made with GC/FID with retention time catalogues and quantification via external calibration function. This standard working instruction is a modified NIOSH 1612. Working conditions: Gaschromato-

graph “Doppelsäulengerät Sichromat 1-4”; Injektion: split/splitless; 2.5 µL splitted auf 2 wide-bore columns, 250°C, Columns: 30 m OPTIMA-WAX; 0.53 mm \* 1.0 µm and 30 m OPTIMA 1; 0.53 mm \* 1.0 µm, Both detectors FID (250°C), Carrier gas Nitrogen: 2.5 mL/min, burning gas synth. air: 300 mL/min, Hydrogen: 25 mL/min, stove temperature 45°C isotherm 10 min, 45°C to 180°C in 5°C/min; 180°C isotherm 13 min, 180°C to 200°C in 10°C/min, 200°C isotherm 13 min.

## Results and conclusions

The books in Swidnica were fumigated with ethylene oxide in the 1990s. Nowadays, after 20 years, no ethylene oxide could be detected with the methods described above. A risk for human health is thus rather improbable.

The results of the fungal sampling are shown in Table 1. From some samples, especially from the inner part of the books, no fungi could be isolated. Only very few fungi that are directly related to the destruction of the materials where isolated (Sterflinger, 2010; Sterflinger & Pinzari, 2011): *Nigrospora* and *Alternaria* are known to degrade cellulose and *Scedosporium* is a keratinolytic fungus, able to degrade leather. Species of *Scedosporium* are known to be pathogenic for humans, causing a skin infection called phyaehyphomycosis (de Hoog et al., 2000). Most abundant were species of the genus *Cladosporium* which were isolated from nearly all samples except for some inner parts of books. *Cladosporium*, however, is not regarded a true contaminant of books and cannot be related to the phenomenology of the sampled areas. *Cladosporium* rather is an environmental fungus which is extremely common in the air and spores of which settle down in dirt and dust. Thus, these fungi are isolated readily from the materials because of the spore load and not because they are actively growing and established on the books. Typical contaminants of humid paper, like species of *Chaetomium* or *Trichoderma* are missing.

As a preliminary conclusion from the project it can be stated that the fungal community isolated 15-20 years after fumigation can only to a small extend be related to the biogenic fungal phenomena like white and dark floccose spots and areas visible on and in the books. It can be concluded that this is due to the ethylene oxide treatment that killed especially those fungi that formed

hyaline white mycelia on and in the books. Hyaline, non pigmented fungi are generally more susceptible to biocides than darkly pigmented fungi. Most of the fungi that were isolated now can either be related to air borne spores or belong to darkly pigmented species that might have had a higher resistance against the ethylene oxide treatment. Although the amount of ethylene oxide degassing from the books was under the detection level, certain prevention against re-colonization by fungi seems likely also after 15-20 years. The analysis of the non-viable fungal community based on DNA extraction could help to support this hypothesis. However, ethylene oxide fumigation might have intercalated into the DNA of the original fungal micro-flora thus hampering this type of analysis.

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#### Notes

- 1 EN 1422 and EN 550, which allow the use of ethylene oxide for sterilization of certain medicine materials. Since 1981 Germany law which forbade to fumigate food with ethylene oxide. For books no regulations exist.

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**Table 1: List of books and materials sampled for microbiological analysis with morphological identification of cultivable fungi.\***

Signature of the book		description	fungus isolates according to morphological identification
00029	1	leather, inner part of back side book cover, white fungal mycelium	Aureobasidium sp. Cladosporium spp. Penicillium sp. Scedosporium sp.
	2	leather, front of book cover, white floccose mycelium	Cladosporium spp. Eurotium rubrum
00084	3	leather, inner part of book cover	no cultivable fungi
	4	leather, book cover	no cultivable fungi
R0184	5	suede, outside of book cover, white to yellowish, granular colonies	Cladosporium spp. Penicillium sp.
	6	leather, inner side of book cover	Alternaria sp. Cladosporium sp. Eurotium sp. Penicillium sp. Scedosporium sp.
	7	textile, glued part inside of book, white fungal colonies	no cultivable fungi
	8	paper inside, white fungal colonies	Cladosporium sp. Penicillium sp.
R0103	9	paper inside, fist page behind book cover, white fungal colonies	no cultivable fungi
02426	10	paper inside of book, dark spots	Cladosporium sp.
R0176	11	paper inside of book, dark spots	no cultivable fungi
	12	paper, inner part of book cover	Cladosporium sp.
R0232	13	paper inside of book, dark stains and colonies	no cultivable fungi
	14	textile, book cover, white spots and areas	no cultivable fungi
	15	textile, book cover, white spots	Cladosporium sp. Nigrospora sp. Penicillium sp.
R0029	16	parchment, book cover	Cladosporium sp. Eurotium sp. Penicillium sp.
08122	17	parchment, book spine	Alternaria sp. Cladopsorium sp.
R0103	18	textile, outside	Penicillium sp. dark pigmented fungus with meristematic growth Penicillium sp. white sterile mycelium
01695	19	paper inside of book	Cladosporium sp. red-brown sterile mycelium
reference	20	reference from sampling environment (table in book center Horn)	Cladosporium spp.

\* The molecular identification of all stains by sequencing of the barcode region (ITI-5.8S-ITSII) is in progress.



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## Deconstructing the Reconstruction

EWA PAUL | ANNA GRZECHNIK  
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### Introduction

Broadsides are single sheets printed on one side, used as public announcements or advertisements. These official notices of laws and regulations or execution lists became the common 'newscasts' during the war. Such paper objects were produced quickly and inexpensively to meet the need of the moment. Due to their ephemeral characteristics and poor thin paper, broadsides often vanished as quickly as they were produced. (Website source: 'Broadsides') A poster is a type of broadside, a composition of pictures and words, or words alone but with a distinct graphic expression. Similarly its main task is to spark interest in a person passing by.

This poster highlights the conservation treatments of two war-time broadsides, one a poster 'Do Broni' and the other a war-time Nazi announcement; both are part of the Warsaw Rising Museum (WRM) collection. The poster also describes the reasons to reverse the poster's previous restoration, a selection of loss compensation methods and how these methods complement the historical value of the artifacts.

'The urge to preserve is a result of the view that the artwork is a valuable object (...). But decisions regarding what to preserve (...) are based on which of the artwork's attributed values are recognized as more important'(Schintzel 1999: 44).

At the core of this issue there is a conflict between the artifacts' historic and aesthetic values. While it is important to take into consideration the aesthetic aspect of the artifact, as it usually guides any intervention, one must not forget its historical value, both the moment at which it was created and its passage through time. This is a dilemma every conservator encounters and it is as unavoidable as it is unresolvable because some subjectivity will always influence the decision making (Poulsson 2010); '... it will be up to the conservator to decide how far to take a conservation treatment, whether that treatment involves stabilisation only or is of more interventive character. The objective must be to achieve the great-

est effect with the least amount of interference' (Poulsson 2010:107).

### Background

The Warsaw Rising Museum along with its modern conservation studio opened its doors to the public in the fall of 2004. To make sure that all the artifacts were ready for the opening day treatments of some were contracted out to private conservation labs. The legendary Warsaw Rising poster entitled, 'Do Broni w Szeregach AK' (translation: To Arms in the Ranks of the Home Army), underwent a treatment in 1996.

In 1944 Mieczyslaw Jurgielewicz and Edmund Burke created this 70 x100 cm chromolithograph. Their assignment came from the 4th Press and Publishing Division of the Home Army Information and Propaganda Bureau. Just as the Warsaw Rising was starting, copies of this poster called on citizens of Warsaw to take up arms and to join the Rising (Gola 2012:454).

The WRM archive owns a few photographs documenting 'Do Broni' posters on the streets of Warsaw in 1944. Historical institutions value well-documented objects with interesting provenance and this particular poster has an interesting story. On August 1, 1944, the start of the Rising, a Polish scout named Jadwiga Komatowska posted it onto a building at 49 Nowy Swiat Street in Warsaw. When the Home Army was retreating from the area on September 13, Komatowska took it down and hid it in a nearby trench in the building's courtyard. In January 1945 she dug it up and stored it until it was later presented to the WRM. The story of this artifact demonstrates that sometimes losses and damage within an object are important and ought to be treated as its integral part.

### Evaluation and treatment

After evaluating an extensive reconstructive restoration which 'Do Broni' had undergone (Fig. 1), the WRM conservators, Anna Grzechnik and Dorota Rakowska, found its results to be overbearing and heavy-handed. This restoration treatment was done without much consideration for



Fig. 1: Poster 'Do Broni' after reconstructive restoration 1994



Fig. 2: Poster 'Do Broni' after the additions were removed

the historical significance of the object, rather it only approached the artifact's aesthetic value, impaired due to parts of its design missing. The conservators agreed that a "deconstruction" of this restoration would be necessary.

There were also some structural questions with this restoration treatment. The poster became stiff and inflexible because of the ill-matched thickness of backing paper used for lining it. Large losses were made disturbingly obtrusive by the in-fills which were made a few tones too light and mismatched color used for the reconstruction of the lettering.

Deconstruction started with the removal of the backing paper. The artifact was humidified in a Gore-Tex and spun polyester 'sandwich' to allow for a slow introduction of moisture. The backing paper was carefully peeled off and the added repairs were removed with various spatulas and locally applied moisture. The adhesive was reduced mechanically.

The poor condition of the original paper support was revealed and it showed that only three fourths of the paper support had survived (Fig. 2). The paper support was structurally weakened and stained by mold and other degradation factors. The artifact suffered extensive losses to

both lower corners and along its sides. Several loose fragments had to be reconnected with the main section of the poster with small paper tabs to keep them in place. Most tears and abrasions within the ink layer ran through the center fold line and had signs of direct retouching. In some places the color matching was off significantly, especially in the red ink areas where pinkish over paint became evident.

To remove the surface grime and dust, the front was gently dry-cleaned with eraser crumbs and a soft brush. The back was cleaned with small wads of cotton wool and deionized water to remove any residual adhesive. The object was then humidified gently and blotter washed.

The large losses posed a problem; in-fills were prepared from Japanese paper of an appropriate weight but their color had to be toned down. The toning became a complicated trial and error exercise but with the help of 'hellion textile dyes' some even tones of warm beige and tan colors were obtained. Unfortunately several sheets of toned tissue were needed to fill all the losses, and not all of them turned the identical shade of tan.

The poster was then lined with a large sheet of kozo paper and wheat starch paste adhesive mixed with some thin methyl cellulose to extend the working time. The lining process was



Fig. 3: Poster after 2012 conservation treatment

completed with the help of two large sheets of Mylar serving as transferring aides. The object was then placed for 30 minutes under moderate weights in a 'sandwich' of blotter paper, spun polyester and a sheet of woolen felt. The blotters were changed a few times. When the poster was dry and flat, pieces of toned paper shaped to fit the areas of loss were attached with wheat starch paste from the front.

Small losses within the ink layer were re-touched with dry pigments, pastel pencils and Winston Newton watercolors. The objective was to make the main area of the image visually cohesive but not to reconstruct the image or the lettering (Fig. 3). Retouching proved to be tricky in the areas where previous intervention had taken place but overall successfully unified the main image.

The Nazi announcement broadside was printed in the 1940s in Krakow on a thin, pink machine-made paper (Fig. 4). This propaganda poster consists primarily of historical text and minimal visual elements. Therefore the goal of the treatment was to stabilize the object with minimal aesthetic intervention. Just as in the case of 'Do Broni', the condition of the object was poor. The paper support was dimensionally unstable, had numerous tears and losses along its main folds

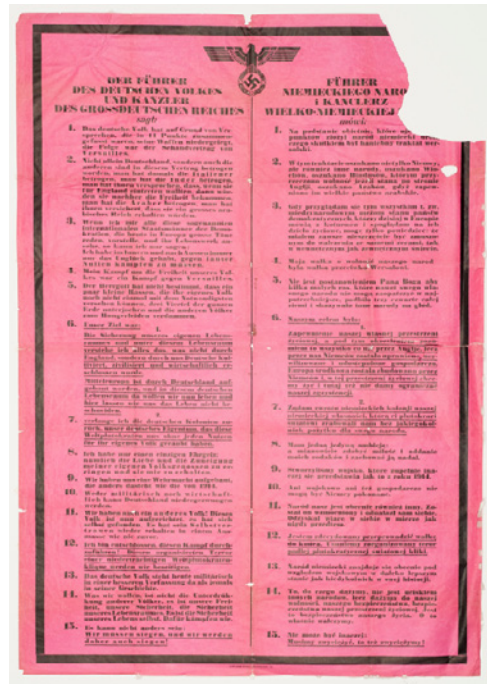


Fig. 4: Nazi broadside before treatment

and had its upper right-hand corner completely missing.

Although at first glance this treatment seemed similar to the treatment of 'Do Broni', it proved to have its own challenges. The pink color of the broadside was unstable, so only blotter washing was possible. As in the previous treatment, lining was necessary to stabilise the very weak and brittle original support. First, all the folded areas were reinforced from the back with thin strips of Japanese paper and wheat starch paste. Some of these areas were very brittle and abraded. After a matching color was identified, an infill for the missing corner was created and attached from the back with wheat starch paste. As before, the lining process was aided by two large sheets of Mylar serving as transferring aides. Unfortunately the first lining procedure was unsuccessful. The paper chosen for the backing was too thick and the dimensionally unstable original support expanded too much during the treatment and as a result did not attach well to the backing paper. A combination of a few factors made the second lining successful: It was done with a thinner kozo paper. The original object was humidified for a shorter time. After the lining paper was adhered to the back of the original, the back was 'massaged' with bone folders over thin blotters in the folded areas. To further reduce the creases

along its main folds the object was gently humidified and carefully stretched for a short time. The color of the missing corner was well matched which made the new infill look good. We debated the idea of adding black stripes to the border on the attached corner. Thin strips of black paper were cut out to serve as a mock up frame. These strips completed the frame along the objects' perimeter, and visually unified this object.

Although it was an aesthetic choice, the missing black frame was added in the end as it made the added corner less visible. Subjectively speaking, only then the greatest effect was achieved with the least amount of interference (Poulsson 2010:107).

### Conclusion

The extent of the loss compensation depends on the goals of the treatment and the values attached to the artifact, but also the individual and subjective attitude of a conservator. The primary goal of these treatments and conservation in general, is not to make an object look new or whole again, rather it is to stabilise it and reduce the damage that distracts from the design. If the artwork is considered to be of historical value, then its authenticity is vital, and the conservation will focus on stabilising its physical aspect first and foremost (Poulsson 2008:63). Some conservators may choose to employ minimal loss integration methods so that evidence of the objects' loss and age, although still present, will recede to the background. Often, the artwork is considered important because of its aesthetic quality. Then 'retouching may be used as means to preserve the legibility and the composition of the image. It may be considered a necessary or unnecessary evil (...) No matter how it is regarded, retouching has been and still is (...) a part of paper conservators' repertoire (...) and subjective criteria will always influence the decision taken...' (Poulsson 2008:107).

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## Conservators' Investigation of Chinoiserie in Wilanow Palace

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In the collection of Wilanow Palace there is a large and varied set of Chinese paintings and woodcuts on paper dating from the second half of the eighteenth century and the turn of the nineteenth century, which are unique in Poland and which functioned as decorative wallpaper in the palace. They were mostly used as wall decorations for the Chinese Suite located in the central part of the palace. This suite, which consists of five rooms and a small hallway, was furnished by the contemporary palace owner, Count Stanislaw Kostka Potocki at the beginning of the nineteenth century. After the Second World War, during conservation works, eighteenth century frescoes were discovered in the Chinese Suite. A decision was made to restore the eighteenth century décor, whereas Chinese decorative elements were taken off the walls and underwent conservation. From then on they have been kept in the palace museum's storage. Fifty-five objects of different kinds have been preserved. Some of them are typical export Chinese wallpapers and paintings, while others are traditional Chinese folk artworks which had a ceremonial or decorative function and were used as wallpaper.

The fashion for *chinoiserie* in Poland, like in the other countries of Europe, had flourished from the seventeenth century. Chinese tapestries were mentioned as early as in the first preserved inventory of Wilanow Palace made in 1696. Wallpaper from China was very fashionable in Poland in the eighteenth century. Unfortunately, it has only been preserved in three palaces. It is not known precisely when the decorations of the Wilanow complex were brought to Poland. Both Duchess Lubomirska, who was Count Potocki's mother-in-law and the former owner of Wilanow (she bequeathed the palace to her daughter and son-in-law in the late 1890s), and Count Potocki were avid collectors of Chinese artwork. The Chinese Suite was described in detail in the inventory of the palace made in 1832. It is known from the previous inventory made in 1793 that Chinese wallpaper had been hung on the walls of different rooms. The so-called Chinese Suite

was furnished by Stanislaw Kostka Potocki at the beginning of the nineteenth century.

The set of decorations can be divided into two basic groups. The first one consists of nine panels on yellow paper, six of which are medallion, print-room style wallpapers depicting porcelain and silk production, while the remaining ones are: a representation of a Chinese lady and woodcuts. It is not currently known in which rooms they were hung. The second group comprises 46 individual paintings which were separated from the surrounding wallpapers when they were being taken off the walls or they were stuck onto the wall individually or mounted on stretcher bars.

This collection can be divided into several thematic groups. Some of these objects are fragments of export wallpapers dating from the eighteenth century, which are genre works and landscapes depicting scenes of everyday life of the Chinese people. Others are separate, full-length figure images of Chinese women or woodcuts depicting groups of women with children indoors or outdoors. The set also contains small New Year woodcut prints and others which are thematically or stylistically different from the rest.

The whole set was covered by a research and conservation programme aimed to describe the objects in historical, iconographic and technological terms as well as to determine their state of deterioration, develop conservation methodology and carry out a model conservation of two selected objects. On this poster, we present the results of identification tests conducted on two selected objects which were made by using significantly different techniques.

Preserved documents relating to the history of the first of the analysed objects (Fig. 1) do not provide answers to questions that have been raised. Information contained in the three existing inventories are too general to be associated with a specific object, and the documentation concerning conservation works conducted after the war is incomplete. Establishing the

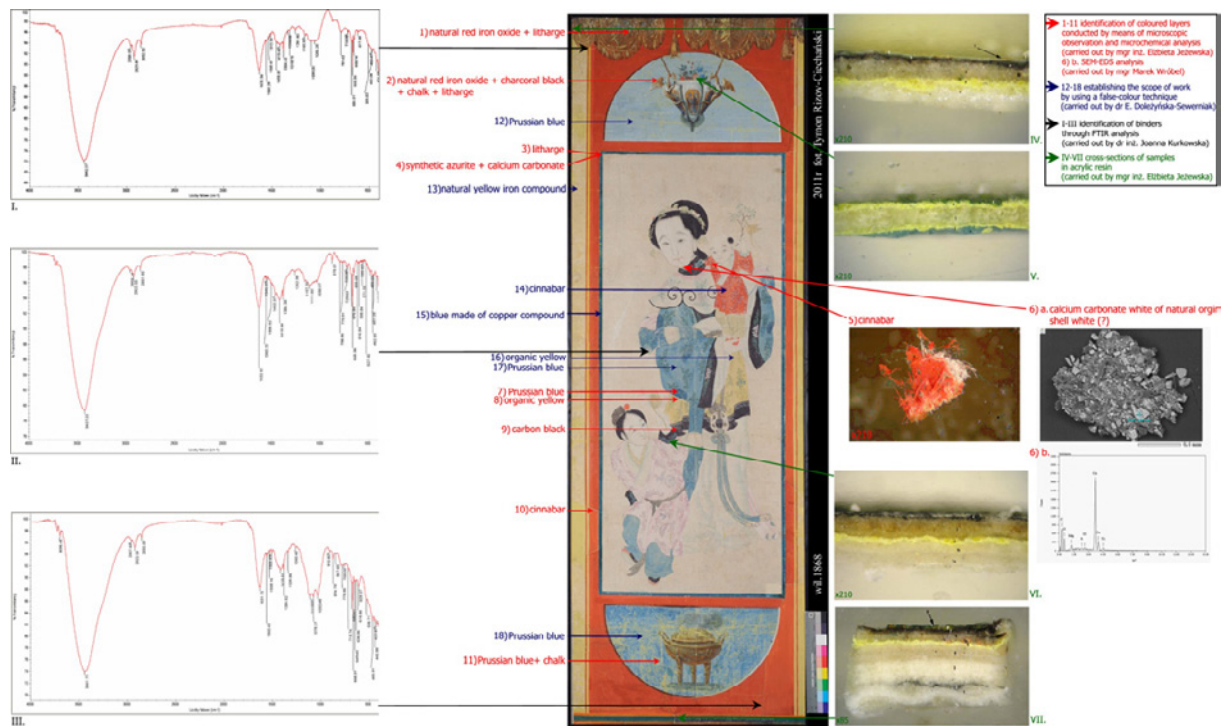


Fig. 1: A woman with two children, Wilanow Palace Museum, photo by T. Rizov-Ciechanski

time when the object was made and brought to Wilanow as well as its location within the palace turned out to be an incredibly difficult task.

The object is a long panel with a representation of a *nianhua* type, bordered with an imitative nineteenth century hand-painted decoration depicting vases and a valance. In the centre of the composition is a lady clad in an outfit from the Ming era with two boys. This is a popular theme in *Chinese New Year prints* representing the wish to have many prominent sons. It was made in China, probably by using a hand-primed, woodcut technique of printing contour lines or, as Prof. Feng Jicai from the Feng Jicai Literature & Art Institute of Tianjin University in China has suggested, it was entirely painted. Its dimensions are 251x83 cm. In the Wilanow collection there is a similar separate object with dimensions of 158x64 cm. Such an attribution required to be supported by complementary technological and iconographic research.

Stratigraphic studies were carried out in four different locations (Fig.1.IV-VII). The analysis showed that the number of layers ranges from four to nine, whereas the object's thickness from 0.266 to 0.824 mm (1.034 mm with the canvas layer). An analysis of fibre composition

showed that both the paper which constitutes the surface of the Chinese object and the first lining layer were made of paper mulberry (*Broussonetia Papyrifera*). It was probably *xuan zhi* (*xuan* paper). The second lining layer consists of paper mulberry, *Edgeworthia gardineri*, and rice straw. It was all stuck on 10 sheets of handmade paper made from flax fibres and connected by means of joining overlapping edges with starch paste. This paper is evenly covered with a yellow layer which has been identified as a mixture of glutin glue and litharge, where the painted layer was directly applied. The object was relined on canvas and mounted on the stretcher.

Preliminary determination of binders was performed by microchemical methods. Starch was identified as a binder between subsequent layers of paper and the canvas with Lugol's iodine test. The lack of stains after the application of Sudan Black B excluded the possibility of using oil binders or natural resins. Stains that appeared after using Ponceau S, which indicates the presence of proteins, might have been caused by starch penetrating the adjacent layers because of gravity and material porosity. Results obtained by using these methods, especially with regard to the layers where calcium carbonate or gypsum

had been used, may be false-positive as these substances are good dye absorbents. Due to the limitations of the methods, it was necessary to perform further identification by using FTIR analysis. The first samples were obtained using swabs soaked in water, which allowed for selective isolation of substances which are the most water-soluble – plant gums, which also constitute the object's top layer. It is probably the layer with which the object was coated in its entirety during conservation works in the 50s. The comparison of the obtained spectra with the spectra for substances in standard samples taken with a scalpel (Fig.1.I-III) provided a probable picture of animal glue content with a small addition of plant gums.

In order to preliminarily establish the scope of work, non-destructive studies were carried out by using false-colour infrared photography. The difference between the infrared image (in the range of 500-900 nm) and a part of the visible spectrum indicated the presence of specific pigments (Fig.1.12-18). Prussian blue, ferrite and organic yellow as well as cinnabar were identified. Further studies were recommended, that were based on reflected-light microscope observation, water smears viewed in transmitted light, microcrystalline and drop reactions to test the presence of selected inorganic ions as well as analysis of the elemental composition of samples performed using the scanning electron microscope. Raman spectroscopy also proved useful. Eleven pigments were identified (Fig.1.1-11), three of which will be described in more detail.

Blue pigment showed up as very small particle groupings in cloudy, greenish blue areas. The pigment was base-sensitive and it vanished after adding a base solution. Ferric ions were present in the obtained solution. This means that Prussian blue had been used. Prussian blue was identified both in the Chinese image and European border (Fig.1.11). This pigment was obtained in 1704. After 1750 it was brought to China by the East India Company. After 1825 it was produced in Canton.

Red pigment showed high resistance to acid and base reagents. No solubility was observed. A very distinctive microscopic view revealed large, angular and intense red grains. Characteristic parallel striations were observed among the red grains of natural cinnabar. Cinnabar was identified in the border and the image's part depicting the boy's attire (Fig.1.5). It is a natural pigment



Fig. 2: A woman under a blossoming tree, Wilanow Palace Museum, photo by T. Rizov-Ciechanski

obtained by grinding the mineral and it was used in the ancient China as early as in the sixth and fifth century BC. It is called *zhu sha*. Rich cinnabar deposits are located in southern Chinese provinces. The method of manufacturing its artificial form, that is dry-process vermilion – *yin zhu*, was also developed in China at the beginning of our era.

Microscopic observation of whites from the woman's face suggested that there might be two white pigments. Apart from very large, angular and colourless grains, very small, non-characteristic particles were observed as transmitting a very small amount of light (Fig.1.6.a). The reaction with diluted hydrochloric acid revealed partial solubility. Some gas was released but a substantial part of the sample was left intact. SEM-EDS analysis (Fig.1.6.b) revealed mostly calcium, carbon and oxygen, thus evidencing the presence





Fig. 3: A woman under a blossoming tree, Wilanow Palace Museum, photo by T. Rizov-Ciechanski, a fragment and a close-up of a glittering background

of calcium carbonate. Also, a certain quantity of titanium, magnesium as well as traces of sulphur and chlorine were detected. The presence of titanium combined with partial resistance to acid as well as of very small particles viewed in transmitted light might indicate that there was a titanium dioxide white pigment which may have come from overpaints. The presence of magnesium can be connected with calcium carbonate (magnesium content of calcite). Large calcium carbonate particles make it possible to conclude that a naturally derived calcite was used (for example, coming from a limestone or shells). The presence of anogenic limestone was excluded because it has a very different microscopic morphology.

Mineral forms of carbonate were widely used throughout the world. The Chinese tradition of calcining and slaking crustacean shells in order to obtain shell white dates back to antiquity. Titanium white is a synthetic pigment that has been produced on a larger scale since 1920. The fact that it was used means that there were conservation interventions that took place in the European area at a later time.

The second object (Fig. 2) depicting “A woman under a blossoming tree” was an element of a wall decoration in the Chinese Cabinet, a part of Count Potocki’s Chinese Suite which was furnished first. Three other similar objects were also used as the cabinet’s decoration. It is not known when they were brought to Wilanow or whether

they were reused to decorate the cabinet and if they had not been used as a decorative element in another room before.

It is a representation which is typical of Chinese art exported to Europe. Thematically and technically similar woodcuts are located in the Schloss Favorite palace in Rastatt. The large object (163 x 90 cm) was made by using the woodcut technique, with painted parts (the objects from Rastatt were identified as woodcuts by F. Wappenschmidt), or it may have been only painted. It dates back to the second half of the eighteenth century, to the Qianlong period.

A sheet of paper was used as a surface; it was obtained by gluing the overlapping edges of five sheets of paper made from *Broussonetia Papyrifera* fibres and then it was lined with three sheets of paper, which was also made from *Broussonetia Papyrifera*.

The paper was dyed yellow and covered with a glittery substance (Fig. 3), the composition of which is still being subjected to additional studies, and dusted with metallic powder. Colours were applied onto a surface prepared in this way.

Initially it was suspected that the surface was dusted with powdered metallic tin and sprinkled with ink or paint as there were clearly different colours. Analyses performed using the XRF method did not reveal any other metals (gold, silver), whereas tin was found in all studied locations. In order to confirm the results, studies were carried out by using the SEM-EDS mapping technique. In the tested sample of paper, all dots, also the black and brown ones, contained tin, but no pigments or organic compounds were identified. The size of the dots ranged between 0.02 and 0.4 mm. The sample was analysed using Raman spectroscopy. Tin oxide was identified in small, dark brown dots.

The layers of colour were applied using paints with an emulsion binder containing glutin glue and vegetable oil (FTIR analysis showed that there were lipid and protein substances). Colours, which were slightly transparent, were applied in very thin layers (the layers were 0.007–0.049 mm thick). In the paints, for example calcium carbonate, copper green, white lead, smalt, orpiment, organic red, and minium were identified.

The performed studies and analyses were aimed at establishing the work’s substance. Complementary studies of the objects’ content and



function will provide a holistic picture of the phenomenon, which will be a basis for making crucial decisions concerning conservation. When selecting the methods of dealing with works that combine oriental and European traditions, compromises will be inevitable, which will make it an interesting challenge.

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## A Systematic Approach to Condition Assessment and Treatment of Chinese Handscrolls

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Fig. 1: Patriarchs of Chan Buddhism showing sharp creases before treatment. (Freer Gallery of Art, Smithsonian Institution, Washington, DC: Gift of Charles Lang Freer, F1909.229)

### Introduction

Chinese handscrolls make up a large part of the Chinese painting collection at the Freer Gallery of Art and Arthur M. Sackler Gallery. The number, size, and structural complexity of these functional objects, combined with ongoing exhibition schedules and viewing requests from visiting scholars, make conservation treatment essential to the care of the scrolls. The Freer|Sackler is one of only a handful of museums with full-time conservation staff specializing in Chinese paintings. Xiangmei Gu, senior Chinese painting conservator, has been responsible for the examination, care, and treatment of the handscrolls in the collection for over twenty years. Most museums and institutions with collections of Chinese handscrolls, however, do not have a conservator on staff trained in the conservation and mounting of these objects. As a result, conducting condition assessments and developing treatment proposals can be intimidating. This paper will outline the basic structure of the handscroll and discuss the systematic decision-making process followed by Ms. Gu and the conservators in the East Asian Painting Conservation Studio at

the Freer|Sackler when addressing condition problems associated with Chinese handscrolls. This systematic approach can serve as a guide for other conservators and museum professionals who are less familiar with the conservation of handscrolls, in the care of their collections. The decision-making process is as follows: (1) identification of condition problems; (2) ranking of conditions problems by severity and by fragility of the painting; (3) treatment options and (4) prioritizing treatment solutions that stabilize and ensure the safety of the object over intensely invasive treatments.

### Background

The handscroll is one of the most important formats for Chinese painting and calligraphy. The handscroll is a complex structure composed of multiple layers, multiple sections, and different materials. The layers include the paint layer, the painted substrate(s), the first lining, and additional backing linings. The sections include, from right to left: a brocade cover, frontispiece, the painting and endpiece for titles, inscriptions, and colophons. These sections are divided by wide silk borders and often framed with attached thin, paper borders. The different materials include paper, woven silk cloth, paste, wood, a silken cord, and a jade or ivory toggle. The lining support layers, brocade cover, silk borders, and silken cord are considered part of the mounting. The mounting serves as the overall scroll structure to make a continuous handscroll. All of these components are interdependent and form a single art object.

The handscroll is a functional object designed to be unrolled and rolled. The left end of the handscroll is rolled into a tube with decorative caps inset at the top and bottom. The right edge of the handscroll is reinforced with a thin wooden stave to which a cord and toggle are attached to secure the scroll when rolled. The rolled format allows the painting to be easily handled, transported, and stored.



Fig. 2: Patriarchs of Chan Buddhism, after treatment. Creases reinforced and surface humidified and flattened using minor treatment. (Freer Gallery of Art, Smithsonian Institution, Washington, DC: Gift of Charles Lang Freer, F1909.229)

Although handscrolls are usually exhibited fully unrolled, the handscroll as a personal, functional object requires the viewer to continuously unroll and roll the scroll to reveal lengths of the painting that an individual can manage. The handscroll is an elegant and convenient design, but repeated handling often results in wear and damage. In addition, the quality of the materials and how the handscroll was originally assembled can also affect its overall balance, flexibility, and long-term stability. Conservators work to identify and treat problems to prevent further damage.

The systematic approach used by the Freer|Sackler involves identifying common condition problems, understanding the cause(s) of each problem, considering and prioritizing treatment options, and determining the potential damage to the handscroll if left untreated.

### Problem Identification

Conservators at the Freer|Sackler have experience identifying condition problems and characterizing the weaknesses in the overall structure of the handscroll that give rise to them.

Poor housing and environmental conditions, the use of low-quality materials, and the unsuccessful integration by the mounter of the various complex components of the handscroll lead to common condition problems that include foxing, brittleness, undulation, creases and splits, delamination of the laminate structure, separating joins, and paint loss.

The following condition problems typically

occur during storage, when the object is rolled. Sharp vertical creases throughout the handscroll can indicate that the paper and silk are degraded, acidic, and brittle. When creases are primarily located on the section of the painting, weakness is often associated with deterioration of the painted substrate and potential imbalance between the painting and its surrounding mounting. Sharp creases confined to the joins in the mount generally indicate weakness in the structure due to inappropriate width and thickness of the join and a paste layer that is too thick or strong. Minor creases and splits that do not extend to the center of the scroll, but repeat along the edges of the scroll, that appear tight and curl up, indicate damage caused by uneven shrinkage of the borders.

Common condition problems resulting from poor or excessive handling include wear of the cover silk, splits in the mounting attached to the wooden stave, torn cords, and broken or missing toggles. Poor handling can lead to crushed edges and edge splits. Unlike the damage caused by uneven shrinkage of the borders, edge splits caused by poor handling are common to a scroll that appears planar when unrolled.

As a result of the scroll format and the nature of its use, many typical condition problems will repeat across the entire length of a scroll. Identifying condition problems and observing their location and patterns of repetition in relationship to other parts of the scroll can help one to understand the cause(s) of damage and determine appropriate treatment. Depending on the condition issues and their severity, conservation solutions range from minor, localized treatment to complete remounting.

### Problem Ranking

After identifying condition problems, conservators determine whether the scroll can be handled and displayed. Condition problems considered high priority are those when the stability of the media and the flexibility of the support layers are compromised during handling or exhibition. Friable paint, delamination, brittleness, and severe creases and splits should be addressed and treated before further handling.

Some minor problems are also considered high priority if continued use of the handscroll is anticipated because they will lead to further damage if left untreated. Weak edges, tiny tears, minor losses, and crushed edges, combined with



Fig. 3: Map of the Yellow River showing a large tear before treatment. (Freer Gallery of Art, Smithsonian Institution, Washington, DC: Gift of Charles Lang Freer, F1909.220)



Fig. 4: Map of the Yellow River, after treatment. Tear repaired using partial remounting. (Freer Gallery of Art, Smithsonian Institution, Washington, DC: Gift of Charles Lang Freer, F1909.220)

repeated and unsafe handling, will lead to large tears in the painting.

### Treatment Options

The Freer|Sackler groups conservation treatment of handscrolls into three categories: (1) minor treatment; (2) intermediate treatment including partial remounting; and (3) complete remounting. If possible, minimal intervention should be the first option.

Minor treatment can include minor consolidation of loose paint or ink, surface cleaning, reattaching lifted support layers, strip reinforcements, repair of small tears, infill of lost material on the brocade cover, and repair of lost or damaged cords and toggles. Minor treatment requires sparing use and localized application of water to minimize the potential for distortion of the absorbent paper layers.

Strip reinforcements are used to stabilize creases and minor tears. Different thicknesses of Chinese Xuan paper and Japanese Mino paper are pre-cut into narrow strips. A narrow strip of paper is pasted and applied to the crease or tear on the backside of the handscroll. Strip rein-

forcements can be used to temporarily stabilize a handscroll that still requires further treatment, or can be applied as a permanent solution when there are few creases and tears or they are limited to the mount joins. Successful strip reinforcements depend upon the conservator's skillful use of the appropriate papers and paste consistency, otherwise, these repairs may cause additional damage.

Humidifying and flattening handscrolls under weight is a minor treatment for addressing undulations or the upward bowing of scrolls when unrolled. The Freer|Sackler uses a controlled moisture humidifying and flattening technique that is similar to what is known in western conservation as friction drying. Controlled introduction of moisture into the support makes the scroll more flexible, evens out areas where strip repairs were applied, and can restore bonding strength between the mounting layers by softening and reactivating the paste, while minimizing the potential for water-induced stains and distortions.

When minor treatment is inadequate for stabilizing condition problems, partial remount-



ing techniques, which build upon fundamental mounting practices, should be considered. Partial remounting includes reusing or replacing cover silks, repairing major tears, compensating for unevenness and imbalance in the mounting structure, and replacing the final backing layer. For example, severe tears and imbalance in the mounting structure can be addressed with a partial remounting treatment in which sections of the original backing paper are removed and replaced with new backing support. This approach allows serious condition problems to be locally treated without completely dismantling the handscroll. Partial remounting requires the skills used to remount old paintings and should be carried out by a trained specialist.

Complete remounting should be the last treatment option when a handscroll is in poor condition and can no longer be handled and displayed safely. Complete remounting may be necessary when the old mounting and support layers are brittle, severely creased, delaminating, and no longer function to protect the painting. Specialists trained in traditional methods of conservation and mounting techniques of handscrolls should be consulted to carry out complete remounting.

### Prioritization of Treatment Solutions

In most cases, treatment options for handscrolls, from minor treatment to complete remounting, reflect a balance between the needs of the handscroll and the resources available to the conservator. Time requirements for proper treatment, available working space and facilities, appropriate materials, and the expertise of specialists are factors that influence treatment decisions. Minor treatment and partial remounting can be appropriate preservation solutions even for handscrolls in poor condition, when the time, resources, and expertise required for complete remounting are unavailable.

Two Ming (1368-1644) dynasty paintings on silk from the Freer|Sackler collection, *Patriarchs of Chan Buddhism* (Fig. 1-2) and *Map of the Yellow River* (Fig. 3-4), are examples of paintings that would have been completely remounted under the standard of traditional practice, but were successfully stabilized using less invasive treatment methods.

*Patriarchs of Chan Buddhism* was in fair condition except for several severe vertical creases that rose into high peaks across the length of

the handscroll. It required treatment for safe exhibition, but frequent handling or further display after exhibition was unlikely. Given the time constraints, the fairly stable condition of the primary support, and expected infrequent handling and display following the exhibition, minor treatment was the most appropriate treatment solution. One- or two-layered strip reinforcements were applied to reduce the creases. For shallow creases, one layer of paper provided enough support, but for deep creases, two layers of paper were used to add extra support. After applying the strip reinforcements, the handscroll was humidified and dried under weight to flatten it and make it more flexible.

*Map of the Yellow River* was in good condition overall, but had a large vertical tear that made handling unsafe. Tears of this degree are often addressed with complete remounting, but a partial remounting treatment was carried out instead because of the painting's overall good condition. In addition, the blue and green paint were thickly applied and could easily be disturbed during complete remounting. The partial remounting treatment included removing the backing layers around the area of the tear using localized application of water, mending the break, integrating new backing papers to achieve the thickness and flexibility of the original support layers, and overall humidifying and flattening. In this case, partial remounting offered a more stable and long-term solution than minor treatment, but avoided the risks of complete remounting.

### Conclusion

This systematic approach to assessing the condition of and determining treatment options for handscrolls is used by the conservators in the East Asian Painting Conservation Studio at the Freer|Sackler to successfully manage the needs of the collection while keeping in mind the limitations of time and other resources. Recognizing that many other institutions face additional limitations and do not have conservators who specialize in Chinese paintings, this paper summarizes the most common condition problems of handscrolls and some of the treatment options that are available. It is hoped that this paper will provide basic guidance on the structure and problems of handscrolls and build awareness for the sound management and preservation of these repeatedly handled objects. Like

all conservation treatment decisions, this approach defines the appropriate intervention as a balance between the condition of the handscroll and the conservator's resources. The information presented in this paper can serve as a basis for future discussions on the specific treatments of handscrolls.

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# Applications of Image Processing Software to Archival Material

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## Introduction

Images of archival material are useful to both conservators for monitoring changes and to researchers for detailed analysis and permanent access to collection items. Digitisation projects generate huge volumes of image data. Images can be enhanced and manipulated with image processing software to suit the specific needs of the user. This allows historical documents and other collection items to be studied without the risk of damage to the primary source.

ImageJ is a powerful public domain Java-based image processing package. The nature of open source software allows for the constant update and availability of new plugins and recordable macros designed for specific tasks. ImageJ's built-in editor and a Java compiler allow for the development of custom acquisition, analysis and processing plugins.

In this study the applications of image processing software to archival material are described highlighting the wealth of information that can be obtained from images.

## ImageJ

ImageJ was originally designed for the purpose of medical imaging by the National Institutes for Health by Wayne Rasband, but has since found applications in many fields. It can be run on any computer with a Java 5 or later virtual machine, as an online applet or as a downloadable application (Microsoft Windows, Mac OS, Mac OSX, Linux, Sharp Zaurus PDA).

ImageJ offers features similar to commercially

available image processing software packages such as brightness/contrast adjustment, frequency domain filtering, binarisation and particle analysis.

## ImageJ Applications to Cultural Heritage

### 1. Image File Distribution

**File Format Conversions:** The sharing and distribution of large image files generated by digitisation projects is often hampered by both the sender and recipient's ability to convert between file formats. ImageJ is a versatile image processing program which can open and convert between TIFF, GIF, JPEG, PNG, DICOM, BMP, PGM and FITS images. Plugins can be installed to allow RAW image files, images in ASCII format and images which are loaded over the network using a URL to be opened and manipulated. This versatility allows any image format to be converted into the users preferred format for storage and archival purposes.

### 2. Digital Image Enhancement

**Brightness/Contrast Adjustment:** Important features in a collection item are often obscured due to poor environment lighting during image capture. ImageJ supports 8-bit, 16-bit and 32-bit grayscale images, and 8-bit and 32-bit colour images. The brightness and contrast of an image can be interactively altered serving to optimise features and enhance regions which are shrouded in darkness (Fig. 1).

However, when the brightness and contrast of the original image is altered, information is lost; the modified image has a reduced greyscale range. Therefore although the modified image appears more pleasing to the human eye (i.e. the differences between foreground and background seem more evident), the original actually contains more information and is of a higher quality (Faigenbaum et al. 2012).

### 3. Metadata Generation

**Set and apply scale:** Accurately recording the size of a collection item is an important part of metadata documentation. ImageJ can be used to

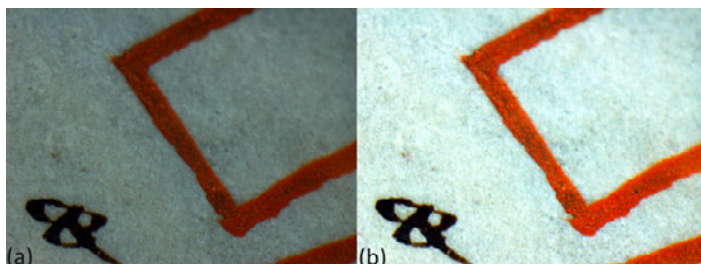


Fig. 1



Fig. 2

incorporate scale bars in images. Without user intervention distances and areas on a digital plane are expressed in pixels and square pixels. Once the distance in pixels is known then the preferred unit ( $\mu\text{m}$ , mm, etc.) can be added. Any future measurements made on the image will present quantities in the newly assigned unit.

#### 4. Watermark Extraction

**Bandpass filter:** The subject of interest of an image for a particular user can sometimes be obscured by other features such as a watermark hidden under lines of text. Bandpass filters can be used in ImageJ to filter out unwanted pixel structures. An upper size limit filters out large structures (shading correction) and a lower limit filters out small structures (smoothing). ImageJ uses a Gaussian filter in Fourier space allowing isolation of important features for research.

There is an extra option to suppress horizontal or vertical stripes, which is similar to subtracting an image that is only blurred in the horizontal or vertical direction in the original.

#### 5. Colour Management

**RGB Pixel Values:** Colour charts should always be included in the image capture procedure to ensure that the RGB pixel values of the object being imaged can be compared to a standard. This is important in cultural heritage for the accurate preservation of colour in collection items, specifically photographic collections and illuminated manuscripts.

Colour is expressed as an RGB triplet (r,g,b), each component of which can vary from zero to a defined maximum value. This value can be determined with ImageJ. If all of the RGB components of an image are at zero, then the image is

black. Conversely if all of the RGB values are at a maximum, then the image is white.

#### 6. Provenance Determination

**Colour Space Converter:** Converting images from the RGB to other colour spaces can reveal hidden text and help determine the provenance of archival material. Colour can be specified by three parameters in a colour space and there are mathematical relationships that enable the parameters of one colour space to be transformed into another. The colour of an image is most often described in terms of the percentage of red, green and blue hues combined. Images such as these exist in RGB colour space, but there are other ways to describe the colour of a pixel using different colour spaces. Alternative ways of describing colour numerically are useful for making certain calculations easier and making colour identification more intuitive such as by describing colours by their hue, saturation and luminance.

Two ImageJ plugins allow for the conversion of a standard RGB image into another colour space called 'Colour Transformer' (Barilla 2012) and 'Colour Space Converter' (Schwartzwald 2007). ImageJ can generate as many as fifty-two combinations of the original image in different colour spaces.

#### 7. Degradation Monitoring

**Stacks:** Degradation features in a collection item can be monitored over time by comparing sequential images. An image stack is a collection of images of the same size and bit depth usually taken over the same region of interest where the scene is not changing due to motion. ImageJ can display these spatially or temporally related



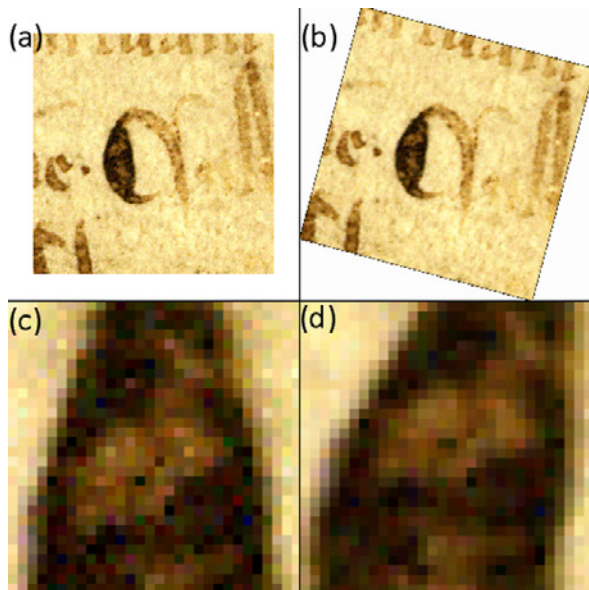


Fig. 3

images in a single window allowing the user to scroll between images and monitor changes in the region of interest. Individual images within a stack are called slices. Cameras can be positioned in areas to collect photographs which can be compared to determine the rate of dust collection or mould growth in a cultural heritage site. Placing images into a stack allows for immediate identification of changes. Multispectral images can be opened as a stack in ImageJ to compare the behaviour of parchment and pigments across the electromagnetic spectrum.

### 8. Artifact Interpretation

**Merging and Splitting Channels:** Pseudocolour images are used to make features such as deterioration artifacts stand-out so that they are easier to interpret. Pseudocolour or false colour images are single channel gray images of 8, 16 or 32-bit pixel depth that have colour assigned to them via a look-up table (LUT). They reflect differences in image intensity rather than differences in the image colour. This type of processing has application for multispectral imaging where three bands revealing different information are chosen and assigned to the colours red, green or blue. These images can be merged to create a pseudocolour image highlighting important features (Fig. 2).

Sometimes image information can be observed more readily in single channel view than in RGB combination. An RGB image can be de-

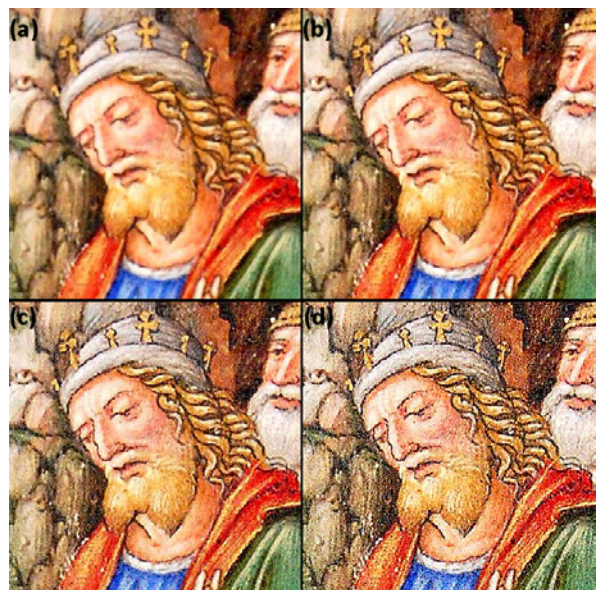


Fig. 4

constructed in ImageJ using the Split Channels tool. The RGB original image separates into three grayscale images, in three different windows representing red, green and blue colour channels.

### 9. Scholarly Understanding and Publication

**Rotation and Transformation:** Captured images are often at an unsuitable orientation for publication. It is also useful to compare writing on one side of a page with that on the reverse to determine if faded text is obscured by ink overleaf. Within the Transform menu are options “Flip Horizontally” (replaces the image or selection with a mirror image of the original), “Flip Vertically” (turns the image or selection upside down), “Flip Z”, “Transform”, and three related to rotation which contains commands that rotate the active image or stack.

Image straightening or image rotation is inadvisable prior to digital restoration unless the image is rotating through 90° or 180° (due to the regular geometry of pixels). Slight rotations are achieved without apparent visible effect on the image, but a rotation results in the rewriting of colour values and slight blurring of boundaries (Fig. 3). For cultural heritage collections, the boundaries of letters and artefacts are crucial to defining context (McFeely 2006).

### 10. Boundary Definition

**Unsharp Mask:** Unsharp Mask is applied to compensate for poor focus during image capture ei-

ther because the user failed to focus the camera tightly enough, or because the camera was too far away from the subject (a possible restriction due to limited gutter opening space for bound collection items). Unsharp mask is a command in the ImageJ Process menu which subtracts a blurred duplicate of the image followed by a rescaling of the image to obtain the same contrast of large low-frequency structures as in the original. The image is sharpened as this process is equivalent to adding a high-pass filtered image to the input image.

Unsharp mask is the final operation which should be applied to an image during processing. It is a destructive process. Images can also be sharpened using Process > Sharpen but the user has no parameter control (blur radius and strength of filtering). Unsharp mask changes colour values and is especially destructive in the fine gradations of colour which form part of the image that is most vital in enhancement processes. Smooth backgrounds become grainy and lose subtle colour definition crucial to restoration, while boundaries become more well-defined (Fig. 4).

## Conclusion

A suite of processing and analysing features in the ImageJ package offers multiple applications to the field of cultural heritage including image file distribution, digital image enhancement, metadata generation, watermark extraction, colour management, provenance determination, degradation monitoring, artifact interpretation, scholarly understanding and publication, and boundary definition. The increase in digitisation projects generates large volumes of image files that can be processed to enhance understanding of our collections, without physically handling fragile material.

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## Figure Captions

Fig. 1: Brightness and Contrast. (a): original image, (b): brightness and contrast adjusted image. The image is processed using the automatic brightness and contrast command which optimises the settings based on the image's histogram. (Image: Cotton MS Nero D.IV Folio 89v).

Fig. 2: Merging and Splitting Channels. (a): multispectral image at 420 nm, (b) multispectral image at 720 nm, (c): multispectral image at 1,000 nm, (d): pseudocolour image which is the sum of (a), (b) and (c) where colours are assigned as (a) = red, (b) = green and (c) = blue. (Image: Add. Ms. 45722, Leaf from Sforza Hours).

Fig. 3: Rotation and Transformation. (a): unrotated original image of the letter a, (b): rotated image of the letter a, (c): unrotated close-up of the letter a showing pixel distribution, (d): rotated close-up of the letter a showing increased pixel blur when compared to (c). (Image: Cotton Augustus ii 106).

Fig. 4: Unsharp Mask: (a): original unsharpened image, (b): image after Unsharp Mask command is applied once, (c): unsharp mask command is applied twice, (d): unsharp mask is applied three times. (Image: Add. Ms. 45722, Leaf from Sforza Hours).

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# Analysing Deterioration Artifacts in Archival Material Using Multispectral Images

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## Introduction

Multispectral imaging is a non-invasive and non-destructive method with applications in remote sensing, astronomy and most recently in the emerging field of cultural heritage. Details of archival material invisible to the naked eye may be revealed by examining them in the infra-red (IR) and ultra-violet (UV) regions of the spectrum. Unlike standard RGB imaging, multispectral imaging captures a dense set of spectral measurements over a wide wavelength range revealing information unobserved in the visible bands. Deteriorating artifacts in archival material can be analysed and documented by processing digital images generated by multispectral instruments, without the risk of damaging the primary source.

Archival degradation is present in all materials due to natural aging and can be accelerated by usage, poor storage conditions, unsuitable humidity, mould and insect infestations, and physical damage such as fires or floods. These conditions lead to typical deterioration artifacts including biological and physical damages, metal gall inks corrosion, ink diffusion and fading, seeping of ink from overleaf (bleed-through effect), blurred or unfocused writings, transparency, parchment gelatinisation, noise, spots, fragmentation of ink, or paper oxidation.

Examining these artifacts in different regions

of the spectrum enables differently-coloured features to be emphasised so that deterioration artifacts may be distinguished and damage may become visible.

**Multispectral Imaging:** The range of all possible frequencies of electromagnetic (EM) radiation is known as the Electromagnetic Spectrum. It extends from low frequency and long-wave radio waves through to high frequency and short gamma waves. The higher the frequency, the more energy a wave contains. These energetic waves can cause serious damage to sensitive material, including skin when exposed to UV radiation from the sun. Radiation either side of the visible region cannot be observed with the human eye, but can be captured visually using multispectral analysis.

Multispectral imaging is a form of computational photography which extracts information from a sequence of digital images. Computational photography is based on the interaction of light with matter. When light falls on an object, energy is absorbed, reflected or transmitted by its surface. The extent to which this energy is absorbed or reflected is dependent upon the chemical nature of the object. Each material will have a characteristic spectral curve dependent on the chemical make-up. Multispectral instruments can provide spatially-resolved analysis and distribution of materials with distinct spectral signatures. Many texts which are illegible to the eye are legible in the infrared. Similarly, deterioration artifacts that cannot be seen in the visible can be observed at other wavelengths.

## Experimental Method

**Hardware:** A number of multispectral imaging systems are available on the market, but each developed for a specific purpose. One of the first systems designed for cultural heritage was developed and used for high resolution digitisation of large easel paintings at the National Gallery under the EU-funded VASARI project (Saunders 1993). Since the VASARI project multiple systems

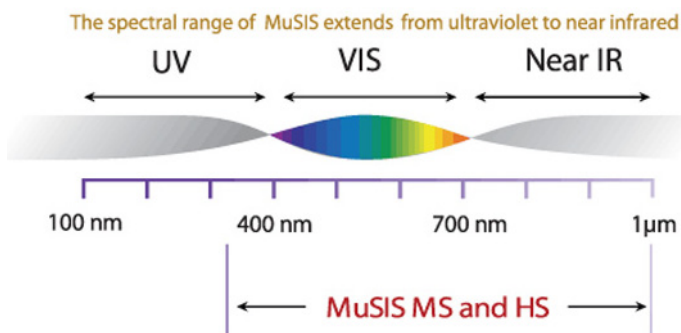


Fig. 1





Fig. 2

have been developed offering the user greater choice in technical specification.

Data in this study was collected using a MuSIS system by Forth Photonics. Pages can be imaged rapidly facilitating real-time examination and a tunable monochromator means that the optimum wavelength for examination can be easily selected. MuSIS contains a sensitive photodetector reducing the amount of illumination required to fall on the object during image capture. Multispectral imaging with a MuSIS system can take photographs at 32 different wavelengths, ranging from the ultra-violet to the near-infrared at 20 nm intervals (420 nm – 1,000 nm) as shown in Fig. 1.

**Software:** Multispectral imaging extracts information from a sequence of digital images. There are several interactive visualisation tools available for handling multispectral imaging. Historically most software that processes multispectral data is specific to astronomical or remote sensing applications. Software ranges from commercial (ENVI from ITT Visual Information Solutions), to freeware (MultiSpec (Biehl, Landgrebe 2002)). These tools were designed to help solve practical problems faced by conservators in libraries, museums, and archives for character segmentation, monitoring of degradation, evaluation of cleaning methods, enhancing manuscript text, visualisation of palimpsests and for pigment identification.

Images collected with the MuSIS system were

analysed using HSI Labs (Joo Kim, Zhuo, Deng, Fu, and Brown 2010). HSI Labs is an imaging software program designed in collaboration with the Nationaal Archief of the Netherlands (NAN) and Art Innovation, a manufacturer of hyperspectral imaging hardware. The software is specifically designed for use on vulnerable historical documents where visualisation and analysis methods are required to determine the state of the collection item. Features available with HSI manipulation include interactive spectral selection, spectral similarity analysis, time-varying data analysis and visualisation and selective band fusion (Seon Joo Kim et al., 2010).

## Results

**Pigment Identification and Monitoring:** Each of the 32 spectral images produced by the MuSIS system is displayed as a monochromatic image representing the percentage of spectral reflectance at each pixel for this band. The change in the value of the pixel's spectral reflectance across the 32 bands can be plotted, and this corresponding plot is characteristic of the material analysed. This information allows the user to differentiate between various pigments which may be unknown and compared to those which are known.

Fig. 2 displays three panels showing different representations of the Renaissance illuminated manuscript Add. Ms. 45722: Leaf from Sforza Hours. To the left is the original colour image. Using HSI Labs spectral data is used to generate



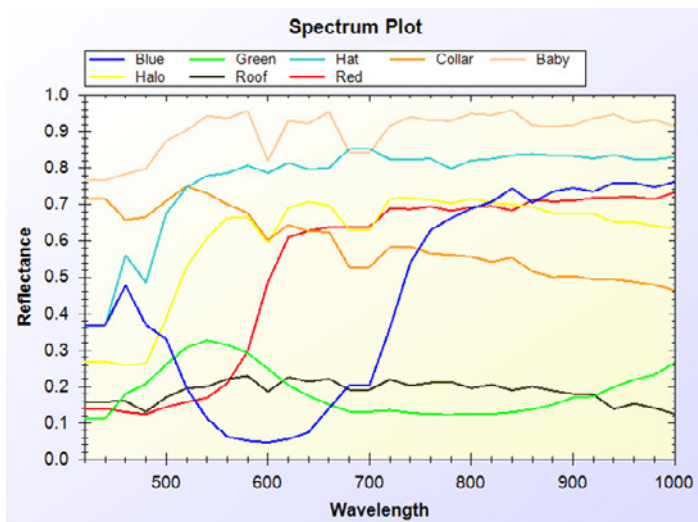


Fig. 3

similarity maps. Similarity maps between the mean of the spectrum of the marked area and the other points in the data are computed by using the entire spectral bands, visible bands and selected bands in the near-IR. The central and right images in Fig. 2 show similarity maps in greyscale and jet colour respectively.

Fig. 3 shows the spectral plot of the points marked 1-8 in the colour image of Fig. 2. The points were chosen based on colour differences observed visually, and were intended to capture a wide range of pigments used in the illumination. A plot of this data allows the user to compare spectra of different image points to determine their similarity (or dissimilarity). This has applications for measuring the corrosion or ink-bleed severity and separating foreground artifacts from the background of the image or document under analysis.

**Photographic Degradation:** Historical photographs form an important part of cultural heritage collections as their examination allows for the improved understanding of most subjects of interest. They capture moments in time and allow observers to connect with characters and places in the past. Photographs are damaged by direct sunlight, insects, degrading adhesives, nearby sulphur compounds and high humidity which encourages mould growth.

Multispectral analysis has been used recently on daguerreotypes (Goltz, Hill 2012). Degradation of daguerreotypes results in the formation of tarnish on the highly polished silver surface which

can obscure the graphic content of the image. It was found that the light absorption properties of a photograph with tarnished and untarnished areas had significant differences. These differences allowed for the near-IR camera to image through dirt and heavily tarnished areas. Multispectral analysis can therefore be used as a means of visually showing the conservator how much and which parts of the photograph have the potential to be recovered. Spectral analysis could be utilised as a means of monitoring changes to tarnish and other photographic artifacts allowing preventative measures to intervene immediately.

Fig. 4 shows a 20<sup>th</sup> century photograph of a girl making her Holy Communion. A written inscription in ink along the top records the date and event. Three bands (420 nm, 620 nm, 1,000 nm) of the 32 which are produced from the MuSIS instrument highlight the differences observed at different parts of the spectrum. Dirt and impurities visible at 420 nm can be eliminated at 1,000 nm. The ink inscription along the top, which is faded to observers in daylight, appears enhanced and more legible at 620 nm.

From Fig. 4 it is evident that each waveband produced by the multispectral instrument contains different information. While it is sometimes useful to isolate these bands it is also advantageous to combine bands with and provide contextual details in the entire data volume in a process known as fusion analysis. This technique aids in enhancing the legibility of the data. The fusion technique is also useful in that it can remove artifacts on the document such as ink-bleed, ink corrosion, and foxing for research purposes.

## Conclusion

Multispectral images are useful for analysing deterioration artifacts in archival material and where possible should be considered as part of the standard condition assessment process. Multispectral data can be used to analyse the effects of environmental aging. It is known that the effects of changes in humidity and temperature and exposure to light induce damage to documents over time. These changes can be systematically monitored with visualisation tools such as HSI Labs to track the exact process of aging. Parchment reflectance can be monitored to detect degradation before it is visually observed.

Image processing is as important as image capture. Processing and analysing digital images



Fig. 4

offers a non-invasive approach to study and disseminate historical documents without the risk of damaging the primary source.

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#### Figure Captions

Fig. 1: The spectral range of the MuSIS system extends from ultraviolet to near infrared including the visible part of the Electromagnetic Spectrum. From <http://musis.forth-photonics.com/>

Fig. 2: HSI Labs multispectral image processing of the Renaissance illuminated manuscript Add. Ms. 45722, Leaf from Sforza Hours. Similarity maps are a measure between the mean spectrum of the marked area and the other points in the data are computed by using the entire spectral bands, visible bands and selected bands in the NIR. Left: Original RGB image showing a variety of pigments used across the illumination. The numbers represent spectral plots shown in Fig. 3. Centre: Grey colour similarity map of the Leaf from Sforza Hours, Right: Jet colour similarity plots of the Leaf from Sforza Hours. Multispectral data was captured with the MuSIS system.

Fig. 3: Spectrum plot of the Renaissance illuminated manuscript Add. Ms. 45722, Leaf from Sforza Hours showing the use of multispectral images in pigment identification. 1 = blue clothing, 2 = green clothing, 3 = yellow hat, 4 = grey collar, 5 = baby skin, 6 = gold halo, 7 = brown roof, 8 = red clothing.

Fig. 4: Three bands of the 32 generated by the MuSIS multispectral instrument are shown. Left: At 420 nm the photograph appears dirty and the ink inscription along the top is faded. Centre: At 620 nm the impurities on the surface have been reduced and the ink inscription is enhanced. Right: At 1,000 nm the impurities have been removed and the image is no longer obscured. The ink, however, is not visible at this band. A combination of the 620 nm and 1,000 nm band would provide the optimum fusion.

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## Strategy in the Case of a Wrecked Papyrus: Is an Intervention Appropriate?

EVE MENEI AND LAURENCE CAYLUX  
*Independent conservators, Paris, France*

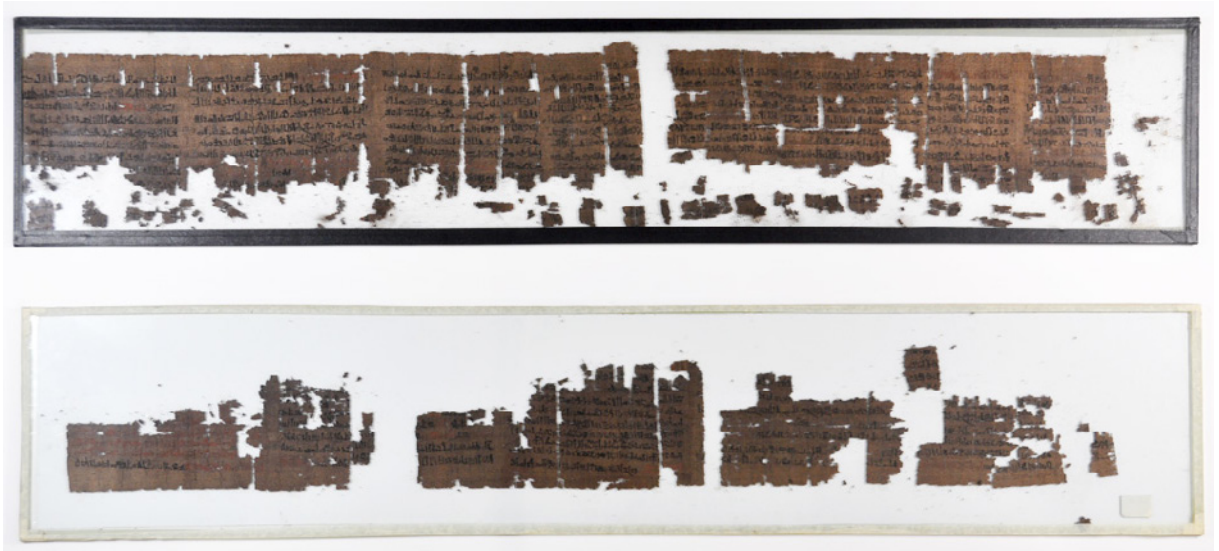


Fig. 1: Overall view of mounts 1 and 7 (Menei & Caylux©).

Some works may be historically significant but in disastrous condition. At each stage of evaluation of the artifact, the conservator finds himself or herself confronted with the very question of whether to intervene.

In 2010, the Department of Egyptian Antiquities of the Louvre asked us to undertake research on the physical condition and possibilities for intervention on a large (estimated length of the scroll: seven metres) and exceptional papyrus, recently acquired by the Museum (inv.E 32 847) (Fig. 1).

### Historical background

The document inscribed recto-verso, dated to the New Kingdom of Egypt (1550-1050 BC) displays a medical treaty on each side. The recto bears descriptions of diseases together with remedies to treat them, for which some parallels are known from other papyri. The verso shows longer and more numerous descriptions together with magical spells unknown from other documents. The first text was written during the reigns of Thutmose III or Amenhotep II (1479-1404 BC) and the second one 150 years later at the beginning of the Ramesside period as an updated version

of the preceding text. The manuscript is written in hieratic script, with cursive hieroglyphs, in carbon black ink and some sections are inscribed in red ink. The papyrus was acquired in 1953 by a private individual. It has remained the property of various private owners until its purchase in 2007 by the Department of Egyptian Antiquities of the Louvre thanks to the contribution of the Ipsen Group. Its general condition was however so preoccupying that the Museum hesitated in concluding its purchase which was finally justified by the scientific importance of the document.

### The production of papyri

The oldest known papyrus is an unwritten scroll found in a tomb and dated to 3100 BC. It shows evidence of a perfectly developed production process.

A sheet of papyrus is made from strips cut vertically from the stem of the *Cyperus papyrus*; two layers of strips would be laid down one upon the other at right angles and then pressed. Like all organic materials, papyri eventually suffer deterioration through ageing, but stored under good conditions, they can still be very light in





Fig. 2: Detail: dust, white halo and piece displaced



Fig. 3: Detail: crumbly fragment and adhesive tape

colour, comparatively flexible, with a good consistency of fibres, even after 5000 years.

### Present condition

The dark brown colour and the fragile and crumbly material of the document are indicative of an unusual and advanced state of deterioration. The scroll was probably in bad condition when it was discovered.

It is separated into two parts (top and bottom) by a horizontal fracture running over its entire length. When the papyrus was unrolled, fragments were placed into nine mounts without the corresponding top and bottom parts being joined. Fragments were attached with strips of self-adhesive plastic tape between two sheets of glass bound with opaque self-adhesive tape. The glass of the mounts is very soiled by the dust of papyrus and some of them show white stains due to previous exposure to water. The papyrus comprises many vertical fractures, lacunae and broken fragments, many of them being detached and now loose. White haloes are today the only traces of pieces either displaced or lost (Fig. 2). Some fragments have become so crumbly that it is no longer possible to distinguish the fibre structure of the papyrus (Fig. 3).

### Intervention

After a preliminary thorough assessment of the condition and the constituents of the document, sponsors were sought to support research into the practical feasibility of a repair intervention. Once this research is completed, will it be possible to open the mounts, handle the fragments and replace them in the right order and store

them in a satisfactory way?

A very progressive approach was decided consisting of several steps (0 to 5, steps 0 to 4 being completed) in order to evaluate the practical possibilities.

#### Step 0

Initially, an overall H-D photographic study was carried out to document all pieces, recto and verso. This then makes it possible for an epigraphist to work simultaneously on the texts with the competent curator in order to find the former position of the fragments misplaced.

We adopted the principle of a chronological journal in order to record every single operation (meetings, tests, orders, conversations, recommendations).

We also got in touch with colleagues specialized in the conservation of papyri and exchanged our views on our problem: Bridget Leach from the British Museum in London and Florence Dalbre from the Bodmer Foundation in Geneva. These contacts have been very valuable to compare the conservation materials used as well as to help us choose the methods to be applied.

#### Step 1

##### Opening the mounts

After this preliminary evaluation, we were conscious of the extreme fragility of the document and our first intention was to limit our intervention to a maximum by only replacing the fragments and changing the glass of the mounts. We began by opening a first mount but we quickly noticed that despite all our precautions, the papyrus was too brittle to be lifted out and handled



without preliminary consolidation.

Our next objective was to select an appropriate consolidant (by nature irreversible) to restore the consistency of the material.

## Step 2

### Consolidant

On the basis of our practical experience in the conservation of papyri ( Menei 2010) and that of our foreign colleagues (Darbre 2008), it was agreed to select funori (an adhesive paste made from Japanese seaweeds of the Gloiopeltis family). This is well known for its great smoothness. Its low surface tension allows for better penetration inside the layers of fibres of papyri which are not refined and not felted like paper. Used well, it does not cause brightness nor darkening of the papyrus.

Several methods for preparing funori exist in Japan: it can be soaked for varying durations, heated or unheated and can be used in various concentrations. To reduce the surface tension, we thought to add a few drops of ethanol. Then a method of preparation and concentrations meeting our requirements of penetration inside our brittle papyrus had to be chosen. We carried out a number of tests to determine the best preparation and concentration of funori.

Two types of funori can be found on the market: an artisanal product sold as dried seaweeds and a product resulting from laboratory extraction (JunFunori®) sold as a white powder. We are currently hesitating between these two products: the first one benefits from already being tried and tested and the second from a laboratory production guarantee although it may be of variable quality. We must carry out quality tests after maturing of the later product (Dauchez 2012, Michel 2011). For the moment we have decided to use traditional Japanese funori sold as dried seaweeds.

Based on our experience and on conservation

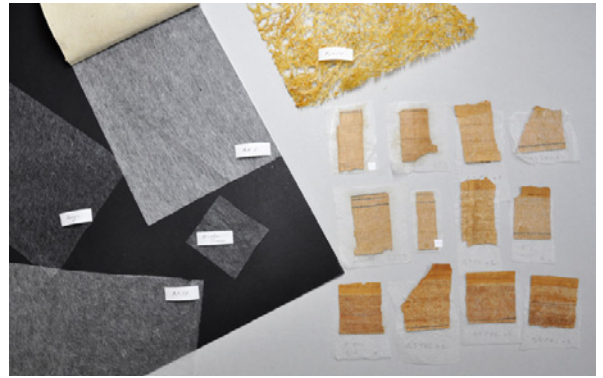


Fig. 4: Products samples and tests. Photos © Menei & Caylux

literature, the safest method for applying funori consists in brushing it over the surface through an intermediary film. The surface is too fragile to support direct friction of the brush and vaporization does not permit overseeing easily the funori impregnation uniformly. After a test, it appeared absolutely indispensable to supplement consolidation by adding a lining paper.

## Step 3

### Facing

Our selection criteria for the lining paper were a great transparency so that the written side being covered should remain readable, a good solidity and a good penetrating ability to allow the transfer of consolidant.

A number of the thinnest Japanese papers were tested:

Paper Nao ref RK 00 3,5g/m<sup>2</sup>

Paper Nao ref RK 01 8g/m<sup>2</sup>

Berlin tissue 2g/m<sup>2</sup>

Tengu 3,5g/m<sup>2</sup> and 2g/m<sup>2</sup>

The first mentioned paper, although very thin, is so coated that it does not let the consolidant get through easily. Best results are obtained with 2g/m<sup>2</sup> papers.

Objective	Final choice
Determine the best method of preparation: various durations for soaking and heating	24 hours soaking + 15 minutes heating
Define the concentration-ratio dry seaweed / water: 0,25%, 0,50%,1%	0,50%
Assess the effect of adding ethanol	None ( water penetrates more rapidly, but the long molecules of consolidant remain on the surface)

## Scope of our tests:

Objective	Final choice
Assess the number of layers of consolidant necessary	Two layers
Appraise the quantity of consolidant on the brush	The brush should be very lightly impregnated in order to avoid overflowing on the sides and wetting the papyrus too much
Determine if pre-pasting the paper increases transparency	Not necessary with two layers of consolidant
Evaluate the need for pre-humidification of the papyrus	Essential to facilitate penetration

## Step 4

### Consolidation/ facing protocol

The putting into place of this procedure has a big influence on all parameters (dispersion, transparency, brightness, pasting quality).

We carried out tests on pieces of paper toned brown using watercolour paint and on pieces of unwritten papyri provided by the Department (Fig. 4).

As for the method of application, we chose to lay the consolidant over the surface through Japanese paper with a flexible flat brush. It appears to us to be the fastest and the most precise method.

### Ongoing step

At this stage, our reflection and the preparation of the protocol must be confronted with the current condition of the document. We must now carry out our first tests on small original fragments. With the assistance of the curator, we will select them and choose the side to be covered with the facing.

After opening the mounts, the strips of adhesive bands will be cut right on the edge of the fragments. Considering the extreme state of brittleness of the papyrus, it is impossible at the present time to eliminate them. After consolidation and lining, we hope that it will be possible. This is why, we would be more favourable to lining the side without adhesive bands.

We are also developing a method for removing fragments from their mount using a sandwich of nonwoven fabric with the aim of implementing the protocol for each separate fragment.

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Bridget Leach, conservator of papyri in the British Museum in London.

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## Fiber Optic Reflectance Spectroscopy (FORS): A Useful Technique for the Analysis of an Early 20<sup>th</sup> Century Livre d'Artiste

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In paper conservation the analysis of materials is often quite difficult due to the fact that in delicate art work paint layers are usually very thin and small in size. The use of in situ non-invasive techniques is recommended as the most appropriate analytical tool.

The analysis provided by Fiber Optic Reflectance Spectroscopy (FORS) is useful in these cases. The proposed in situ non-invasive technique operates in the ultraviolet (UV), visible (Vis) and near-infrared (NIR) regions (350–2200 nm). It allows scientists and conservators to identify different compounds, especially pigments and dyes, to evaluate colour and colour changes and to detect alteration products. Proper instrument configuration may promote the achievement of these goals with just a single measurement. This methodology is based on the measurement of the diffuse radiation from the surface when compared with a standard of calibration, such as Spectralon<sup>®</sup> or barium sulphate plates.

This case study presents a livre d'Artiste by Amadeo de Souza-Cardoso (1887-1918), the most important Portuguese artist of the Avant Guard movements from the beginning of the twentieth century in Western Europe. The book entitled *La Légende de Saint Julien L'Hospitalier* (1912) was copied and illustrated by the artist from the tale of Gustave Flaubert, resulting in a piece of artwork. The decorative elements, illustrations, and text link each other gracefully, the result of which is a modern reinterpretation of a medieval codex. This beautiful and unique piece is now at Centro de Arte Moderna – Fundação Calouste Gulbenkian's collection in Lisbon (Portugal).

The poster illustrates the effective use of FORS

in the analysis of this book. On analysis of the book's production, FORS technique confirmed the use of parchment in the bookbinding. FORS also offered interesting information about the watercolour's molecular palette, rich in coloured and stable pigments, which corroborates previous studies, with the exception of the blue colours. Gold and silver were also identified as well as alterations in silver. However, not all pigments can be identified in the 350–2200 nm range by FORS, because some materials have similar reflectance spectra: for instance, cadmium red and vermilion. The black pigments were not easily identified because they show a strong absorption that masks almost all of their spectral features.

When necessary, analyses were complemented with micro-X-ray fluorescence spectroscopy and micro-Raman spectroscopy.

The application of FORS proved to be useful to paper conservation, providing in situ non-invasive analysis. The advantages of FORS include among others, the portability of the instrument (which allows analysis on site) and the ability to analyse the acquired spectra in real time.

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## Imaging Characteristics of Graphic Materials with the Minidome (RICH)

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### The RICH project

RICH (Reflectance Imaging for Cultural Heritage, KU Leuven, 2012-2015) is creating a digital imaging tool for researching, studying, and exploring material characteristics of library materials. In 2005, the first generation of the module was created for reading cuneiform tablets in the department of Assyriology of the University of Leuven (KU Leuven). With the second generation of the imaging device, developed in 2013, the visualization of paper and parchment artifacts, paper and wax seals, illumination and bookbinding stamps (gold- and blind tooled, on the back and on the boards of bindings) is in development. The imaging tool can create a sharp and exact image of the surface in 2D+ and proves to be an accurate documentation tool for monitoring surface characteristics of graphic materials.

### Infrastructure

The digital imaging device, IMROD (Imaging Module for Multi-spectral, Reflectance or 2D+), is digitizing with omnimulti-directional lighting and exports the result to 2D+ (Fig. 1). The technique is based on polynomial texture mapping, also known as Reflectance Transformation Imag-

ing (RTI), a technique of imaging and interactively displaying objects under varying lighting conditions to reveal surface phenomena. The module is a hemi-spherical structure with a single downward looking video camera (28 million pixels). The object to be captured (maximum 180 to 120 mm) lies in the center and is illuminated from computer-controllable lighting directions, through the subsequent activation of multiple white LEDs. The different angles that illuminate the surface of the artifacts are revealing extreme details. Special attention is taken to produce raking light to provide information on the surface topography. For each illumination an image is taken by the overhead camera, in total 264 images for each object. After processing these 264 images, filters in the visualization system like virtual lighting, shading and sketch are incorporated in the software. The application of these filters allows detailed documentation of surface characteristics, irregularities, undulations, flaking, lacunas and the different levels of loss of the pictorial layers of the researched artifact. After capturing the images, fine details can be highlighted by the use of specific digital filters, bringing out structures that would be less visible

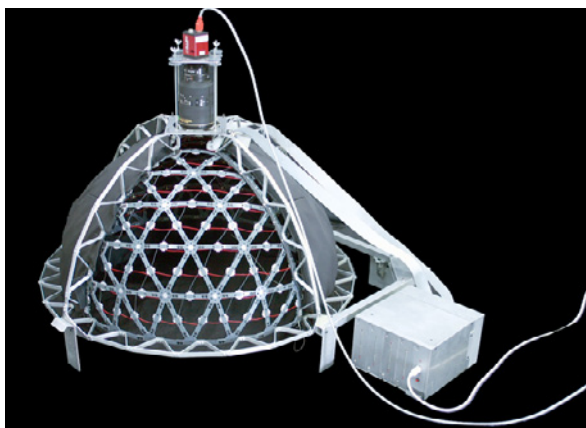


Fig. 1: Dome for digitizing with omnimulti-directional lighting and export the result to 2D+. (© ESAT, KU Leuven)



Fig. 2: Last folio of a severely damaged 19<sup>th</sup> century manuscript on paper, imaged with raking light and adding a shade filter. (© RICH, KU Leuven)





Fig. 3: 18<sup>th</sup> century paper seal, imaged with raking light with IMROD. (© RICH, KU Leuven).

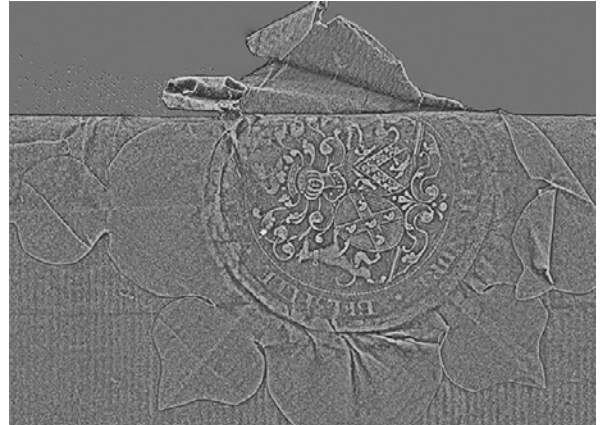


Fig. 4: 18<sup>th</sup> century paper seal, image with raking light and sketch filter (© RICH, KU Leuven).

under single illumination (like shade, contrast, sharpening and sketch filters) (Fig. 2-4). The tool is portable and mobile which makes it possible to examine books and archives in situ.

### Further development

Until 2015 the RICH project will further develop this tool for researching and understanding the material and tactile characteristics of graphic materials. Examination and identification of the production of graphic objects, changes in their structures (the supports) and pictorial layers (paint, inks, drawing- and printing materials, varnish, gilding, retouching, abrasion) could be very accurately documented during the first stage of the project. Complementary, RICH is useful to monitor the conservation and preservation status of an object before and after treatment, transport or exhibition. The results will be managed and disseminated through a portal and an image database (2014 – 2015).

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## The Paper Conservator's Role: The Metropolitan Museum's Renovated Galleries for the Art of the Arab Lands, Turkey, Iran, Central Asia, and Later South Asia

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The Metropolitan Museum of Art houses one of the most important collections of Islamic art outside the Middle East. Within this world-renowned collection is a significant body of works of art on paper and parchment, representing some of the most superlative accomplishments of illuminated and illustrated manuscript production in the Islamic world. The collection safeguards approximately seventy-two fully-bound manuscripts complete with their entire

textblocks, in addition to several thousand detached singular folios, representing a broad span of time, from the tenth to the nineteenth centuries. These works of art on parchment and paper reflect great diversity and range of the cultural traditions of Islam, with works from as far westward as Spain and Morocco and as far eastward as Central Asia and India. Comprising both sacred and secular objects, the collection reveals the interdependency of scholarly and artistic proficiencies within the Islamic world.

In October of 2011, the Metropolitan Museum of Art celebrated the grand reopening of fifteen galleries dedicated to the permanent display of its Islamic collection; following a monumental eight year, \$50 million dollar renovation. This massive project encompassed hundreds of all types of objects housed within the Islamic art department; including objects made of glass, ceramic, wood, metal, carpets and textiles, and jewelry, in addition to works on paper and parchment.

Throughout the course of this eight year enterprise, the responsibilities and demands of the paper conservator were multifaceted: from first time surveys of the extremely rare manuscript collection, participation in exhibition case design, collaborations with curators, to probing scientific inquiries. Moreover, traditional conservation assignments were consistently juxtaposed with surprising and extraordinary challenges. In addition to the practical and ethical considerations that arose alongside the treatment of these complex works on paper and parchment; material investigations with the enlistment of numerous analytical techniques led to a deeper scholarly and technical understanding of objects examined.

The poster illustrates the multifarious professional demands and ever-evolving complex web



Fig. 1



Fig. 2



Fig. 3

of responsibilities requiring appropriate and balanced conservation solutions faced by a paper conservator within a museum environment during a major renovation project. This integral role was one that reached far beyond the microscope and involved a host of collaborations with scientists, designers, engineers, architects, case and lighting designers, mount makers, as well as website designers.

- The project team
- Conceptualizing, envisioning and defining the new galleries
- New galleries exhibition design
- Ensuring the proper testing of all case construction materials
- Checklist: object selections including rotations
- Survey of bound manuscript collection

- Examination and condition assessment
- Prioritization of conservation treatments: straightforward to complex
- Conservation treatment of detached folios
- Conservation treatment of bound manuscripts
- Spearheading scientific inquiries
- Working with museum photographers
- Contributing to new publication of collection catalogue
- Assessing exhibition lighting design
- Rehousing of all artworks for exhibition and long-term preservation
- Display of single folios
- Design custom cradles for display of bound manuscripts
- Object installation phase (Fig. 1-4)
- Facilitate the custom framing and housing of the monumental timurid quran folios
- Technology: create interpretive materials for touch screen monitors in galleries
- Training gallery tour guides on the arts of the book
- Ongoing gallery rotations of detached folios and bound manuscripts
- Ongoing monitoring of environmental conditions
- Sharing and disseminating through online website content
- Presenting gallery talks
- Teaching in curatorial study course
- Participating in an joint conservation exhibition related to the gallery renovation: “making the invisible visible” on view at the metropolitan museum spring 2013



Fig. 4

## Figures

Fig. 1: The Metropolitan Museum of Art, Galleries for the Art of the Arab Lands, Turkey, Iran, Central Asia, and Later South Asia, Gallery 450: The Patti Cadby Birch Gallery: Introductory Gallery, photographed in 2011. Image © The Metropolitan Museum of Art

Fig. 2: The Metropolitan Museum of Art, Galleries for the Art of the Arab Lands, Turkey, Iran, Central Asia, and Later South Asia, Gallery 450: The Patti Cadby Birch Gallery: Introductory Gallery, photographed in 2011. Image © The Metropolitan Museum of Art

Fig. 3: The Metropolitan Museum of Art, Galleries for the Art of the Arab Lands, Turkey, Iran, Central Asia, and Later South Asia, Gallery 455: Iran and Central Asia (13th-16th Centuries), photographed in 2011. Image © The Metropolitan Museum of Art

Fig. 4: The Metropolitan Museum of Art, Galleries for the Art of the Arab Lands, Turkey, Iran, Central Asia, and Later South Asia, Gallery 457: Spain, North Africa, and the Western Mediterranean (8th-19th Centuries), photographed in 2011: Image © The Metropolitan Museum of Art.

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# Characterising the Origin of Carbon Black Inks by ATR FTIR Spectroscopy

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Carbon black inks have been used in Asia for millennia and, therefore, are found in many documents of historic significance. The source of carbon for these inks varies with period and location, and so can provide important information about the origins and nature of such manuscripts.

The work presented here details the use of attenuated total reflectance (ATR) infrared spectroscopy to aid in differentiating these materials. To this end, five inks were prepared using the following carbon sources: ivory, bamboo, coconut and lamp black, made up using traditional techniques, along with a modern high purity carbon black. The inks were applied to rag paper, modern printer paper, pure cellulose paper and parchment. Subtle differences between the spectra recorded from the samples (emphasised by applying spectral subtraction and other enhancement techniques) could be linked to the source of the carbon and arise from incompletely burnt residual material, allowing their origins to be more accurately determined. These differences were not observed with the higher purity modern materials, in which little or no residual material exists. When this method was applied to objects using carbon inks of this kind, in many cases it was possible to determine the likely basis of the ink.

This technique presents a valuable method for investigating the provenance and composition of these historically important inks, and thereby gaining a greater understanding of the objects on which they have been used.

## Introduction

Pigments and inks based on carbon black have a long tradition of use, particularly in Asia, and therefore are found in many documents of historic and cultural significance. The material used to make up these pigments is derived from the soot resulting from the incomplete combustion of a variety of fuels, including plants, ivory, bone, lamp oils and waxes (Eastaugh et al. 2008). Knowing the source of the carbon black can pro-

vide valuable information about the provenance and history of the document in question, as well as giving clues to modifications or alterations. The work presented here details the study of such inks by ATR spectroscopy, with the aim of identifying their source by characterising residual material in the soot.

## Method

Finely ground carbon samples from burnt bamboo, coconut, ivory and lamp oil, as well as a modern carbon black pigment, were made up as inks by combining roughly 0.2 g of the carbon and 0.1 g gum in 5 ml water. A brush was then used to apply these five inks to four different substrates: filter paper (pure cellulose), rag paper, printer paper and parchment.

Once the inks had fully dried, spectra were recorded from these ink specimens and from the substrate itself, using a Perkin-Elmer 'Spectrum 400' spectrometer fitted with an ATR accessory, with 16 accumulations and 4 cm<sup>-1</sup> resolution. In each case, two sets of spectra were recorded, the first using a diamond ATR crystal and the second a germanium crystal, the former over the range 4000-550 cm<sup>-1</sup>, and the latter over 4000-600 cm<sup>-1</sup> (the difference being due to the transmission ranges for the crystals).

For each sample and ATR crystal type, the pure substrate spectrum was subtracted from those of the ink on substrate, giving a spectrum of the residual material in each case.

In order to assess the usability and value of this approach, carbon inks on four documents (labelled as X1 to X4) were assessed in a similar way (subtraction of substrate spectrum from ink-plus-substrate spectrum, followed by interpretation of the result), and the material origin of the ink thereby proposed. This assessment was carried out using the germanium ATR set-up, for reasons discussed below.

## Results and Discussion

The original and subtracted spectra for each of the five types of ink, recorded using the germa-

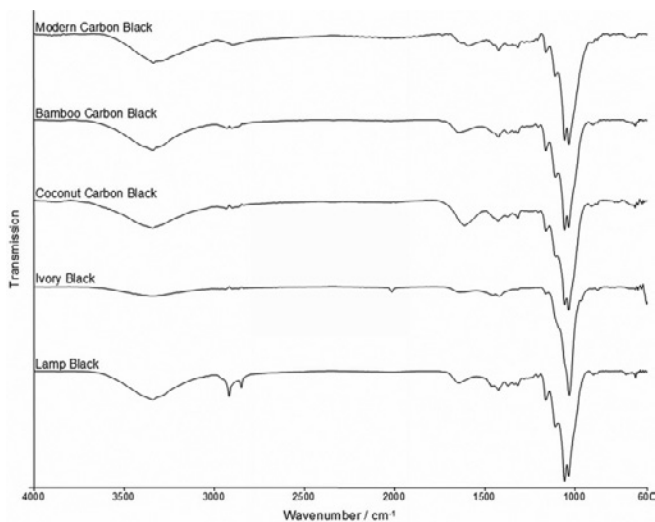


Fig. 1: Germanium ATR FTIR spectra of carbon black inks on modern printer paper.

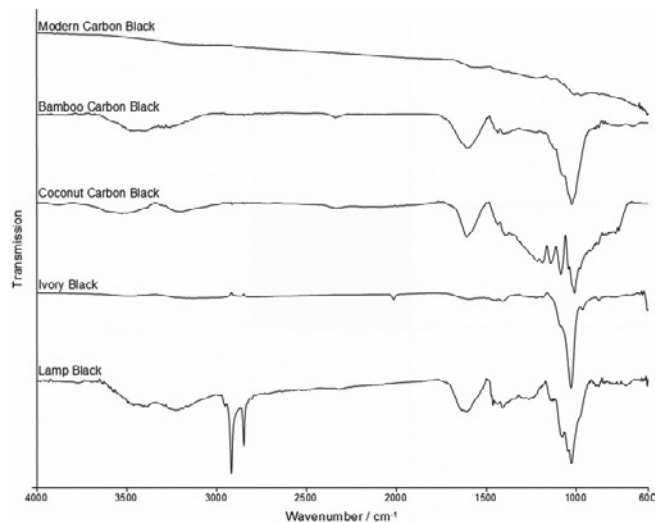


Fig. 2: Results of the subtraction of the paper spectrum from the spectra presented in Fig.1.

germanium ATR crystal are presented (Figs. 1-2); note that only the results for the samples on modern printer paper are given, but those for the other three types of substrate were similar. The results obtained using the diamond ATR crystal were also broadly similar, but the results of the spectral subtraction were less well defined.

If the subtraction spectra are considered, it can be seen that certain characteristic features may be observed, related to the origin of the ink: For the modern carbon black ink, a largely featureless background curve is observed, indicating that the ink spectrum consists almost entirely of a simple carbon black absorption. The two cellulose based inks (coconut and bamboo) yield spectra containing an indication of residual polysaccharide material (highlighted by the typical cluster of peaks in the region  $1100 - 900 \text{ cm}^{-1}$ ); this is poorly defined, as the cellulosic substrate complicates the spectral subtraction, but is sufficiently good for the purposes of identification. For these inks, the results were more clear when the samples using the parchment (proteinaceous) substrate were considered. As may be expected, it was not possible to differentiate the carbon sources for different types of cellulosic material. Ivory black ink gives a characteristic sharp peak centred on  $1050 \text{ cm}^{-1}$ . Lamp black contains residual oils, indicated by the pair of sharp C-H stretch bands in the region  $2800 - 2900 \text{ cm}^{-1}$ .

It is apparent that the results obtained using the germanium ATR crystal are generally superior to those achieved with a diamond crystal.

This may be explained if the difference in ATR sampling depth for the diamond and germanium crystals is considered (Fig. 3), based on the following formula (Coates and Sanders 2000; Coombs 1998; Spectra-Tech 2000):

$$d_p = \frac{\lambda}{2\pi n_c \sqrt{\sin^2 \phi - (n_s/n_c)^2}}$$

Where:

- $d_p$  = Depth of sampling penetration
- $\lambda$  = Wavelength of incident radiation
- $n_c$  = Refractive index of ATR crystal
- $n_s$  = Refractive index of sample
- $\phi$  = Angle of incidence

The ATR accessory employs an angle of incidence,  $\phi$ , of  $45^\circ$ ; over the range that the spectra were recorded, the refractive index of the crystal,  $n_c$ , is approximately 2.4 for diamond and 4.0 for germanium; the refractive index for the sample,  $n_s$ , is taken to be 1.6 for a nominal organic material. This allows the way that the ATR sampling depth varies with incident wavelength and, importantly for this experiment, at any given wavelength is approximately four times greater for diamond than for germanium. This means that if a germanium crystal is used, a greater proportion of any material at the surface (e.g. ink) will be observed in comparison to the bulk substrate, than if a diamond crystal is employed.

When the spectra of the unknown historic ink

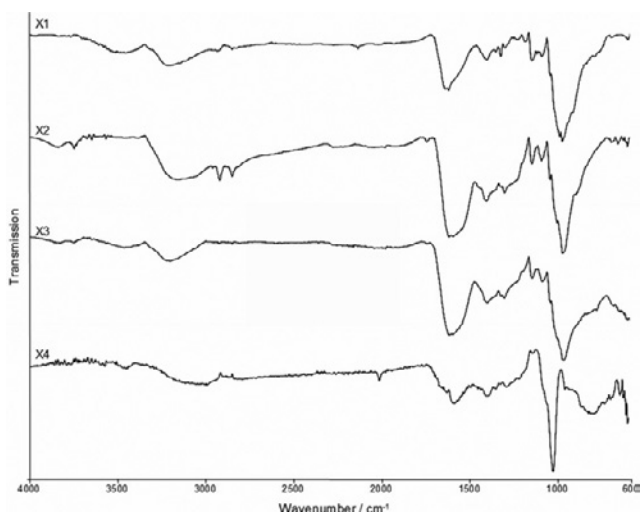


Fig. 3: Sampling depth for ATR spectroscopy, demonstrating the difference between diamond and germanium crystals.

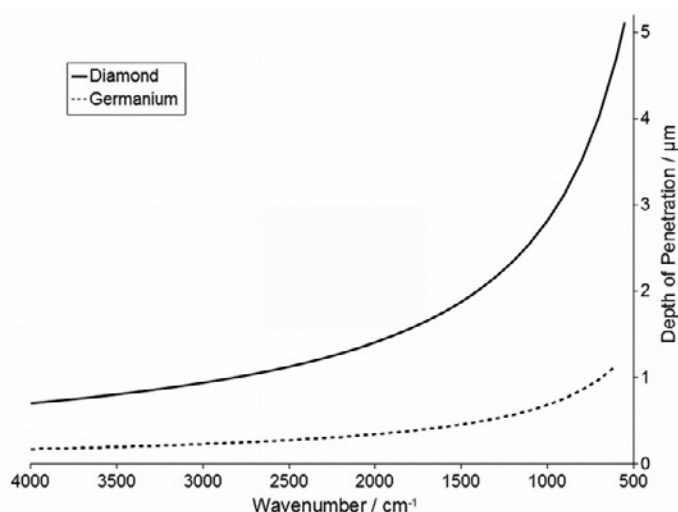


Fig. 4: Subtraction spectra for four unknown carbon black inks.

samples were considered using this information (Fig. 4), it is possible to propose the likely source of the carbon black: for samples X1, X2 and X4 it appears that the ink is derived from cellulosic sources, whilst for X3 it comes from ivory.

### Conclusion

It can be seen that with care, it is possible to identify the general source of carbon used for carbon black inks, providing this source contains residual material. Modern ink of this kind, for which the carbon black has been produced using techniques which effectively ensure the combustion of the original material and thus contain a minimum of other residues, are not amenable to identification in this manner. However, traditional and historic methods of manufacturing carbon black typically allow a small proportion of the material to escape complete combustion, and this residue may then allow the source to be identified.

This technique, therefore, has the potential to reveal important information about the origin of carbon black inks (and provide a method of differentiating different carbon ink found in the same document), thereby providing an insight into the provenance, composition and history of the document.

### Acknowledgements

The authors would like to thank PerkinElmer UK, and particularly Kelly Palmer, for invaluable advice, help and use of equipment whilst carrying out this research; they would like to thank their colleagues at the British Library and the International Islamic University for their help and support, including Barry Knight (Head of Conservation Research, BL), Deborah Novotny (Head of Collection Care, BL).

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## A Technical Study and Conservation Project of Roy Lichtenstein's Screen Print on Plastic, *Sandwich and Soda*, 1964

MARION VERBORG  
Köln, Germany



Fig. 1: Lichtenstein's blue and red ink screen print on clear plastic, *Sandwich and Soda*, 1964

### Introduction

The topic of this technical research is the study of three impressions of the print *Sandwich and Soda*, 1964, by Roy Lichtenstein, owned by the Harvard Art Museums. It is a blue and red ink screen print on clear plastic (Fig. 1). The prints are part of the portfolio X + X (*Ten Works by Ten Painters*), a set of ten works made by ten painters: Stuart Davis, Robert Indiana, Ellsworth Kelly, Roy Lichtenstein, Robert Motherwell, George Ortman, Larry Poons, Ad Reinhardt, Frank Stella and Andy Warhol. It was published by The Wadsworth Atheneum, Hartford, Connecticut; Five hundred portfolios were printed in 1964. The artists were selected by the curator of the Wadsworth Atheneum, Samuel J. Wagstaff, Jr., who states on the back of the title folio: "This portfolio was commissioned and printed in an attempt to extend as much of the visual impact as possible of ten artists to paper and to make these prints available to collectors who might not otherwise have such a vivid slice of the artist."

In this study, the three prints *Sandwich and*

*Soda* owned by the Harvard Art Museums were examined and analyzed to better understand the history, technique and degradation process. There are many screen prints on paper by Roy Lichtenstein but few are ink on clear film. The technique and materials that Lichtenstein used for this work are more linked to commercial practice than the fine arts and many questions arise from this choice: Was *Sandwich and Soda* the first time he made a screen print on plastic and why? Did Lichtenstein keep using plastic as a support for printmaking after *Sandwich and Soda*? What process and materials were used to print *Sandwich and Soda*? What are the problems we can see today?

*Sandwich and Soda* was selected for an in-depth technical study not just because of the unusual support. The prints were also selected because two of the three copies have pressure-sensitive tapes applied to the ink side, presumably as hinges. The tapes are on the ink layers, in this case the verso since the object was meant to be seen through the transparent film, which is the recto. The tapes are different from each other: there is what seems to be two pieces of magic tape<sup>®</sup> on one print and what looks like two pieces of filmoplast<sup>®</sup> tape on the other print (Fig. 2). The carriers are slightly peeled off and the adhesive is accessible on the sides. A previous attempt to test the sensitivity of the ink caused some visible damage, which prompted the need for more information about the materials before coming up with the appropriate conservation techniques.

### Method

In order to understand the materials and technique of the object better and to devise the best conservation treatment options for these prints, analysis was performed in the scientific lab of the Straus Center for Conservation and Technical Studies/Harvard Art Museums. The sampling was challenging since the surface of the object is shiny and very flat.

Micro-samples of each ink (blue in the edge of the printed area and red in the overlapping area)

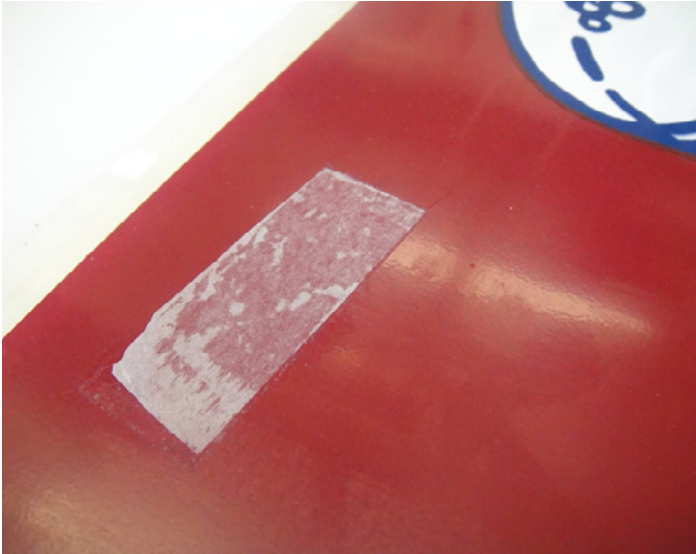


Fig. 2: Filmoplast® tape attached on the ink layer on the verso of one of the prints

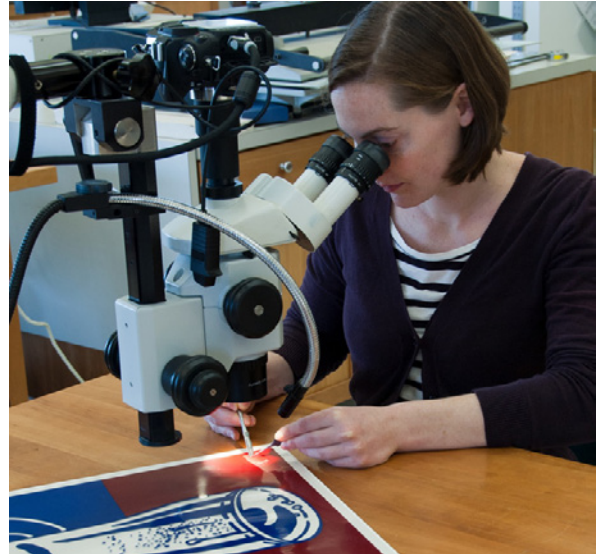


Fig. 3: Sampling under microscope of the tape carrier

were taken under microscope, as was a sample of the clear plastic support, shaved from the very edge of the object. A sample of each type of tape was also taken at the lifting edges (Fig. 3).

FTIR, Raman, GC-MS and LDI-MS (Laser Desorption Ionization-Mass Spectrometry) were used in order to determine the composition of the plastic support, pigments (red and blue) and tapes (carrier and adhesive).

### Results

After GC-MS, the results show that the clear support is not made of acetate as stipulated in all the descriptions, catalogues or even on the invoices the printing company sent to the Wadsworth Athenaeum, but it is polystyrene. It is interesting to note that today it appears that PVC, polyethylene, mylar, and acetate have mostly replaced polystyrene as clear and thin plastic printing surface. Polystyrene is now mostly sold as extruded white foam. LDI suggests that the blue pigment used is PB15 (phthalocyanine blue) which was a pigment commonly used for printing ink. The red ink sample contains chrome red, PR63, and barium sulfate. The binder of the inks, both red and blue, is made of polystyrenes; it is a plastic ink which is specifically for printing on plastic. GC-MS identified the carrier and adhesive components of the Filmoplast-like tape as a cellulosic material as assumed it was; and the office tape as PVA.

These results were interesting as they led us

to develop a conservation procedure. Because the support and the ink binders were both polystyrene and thus probably well bonded, we felt more confident that the bond was strong enough to support gentle mechanical removal of the tape.

### Conservation project

After various tests, the best option was to mechanically remove the tape and tape adhesive. Attempts were carried out using tweezers peeling at an acute angle to remove the tape and various white vinyl eraser pencils of different hardness and shape were used to reduce the adhesive residues. Every step was carried out under microscopic observation to prevent any scratches or physical damage on the surface of the prints.

On one copy, it was possible to remove the Filmoplast-like tape carrier first by applying warm water with a very small brush; this softened the tape carrier, making it removable without affecting the ink. The tape carrier was then removed with tweezers. Then, some cellulose powder<sup>1</sup> was scattered on top of the sticky residual adhesive and the adhesive plus cellulose powder was pushed away with a color shaper tool<sup>2</sup> without scratching the surface or removing ink. It appeared that in this case, instead of using an eraser pencil, a color shaper tool was more successful in reducing the adhesive residues. The results were very satisfying (Fig. 4).

For the acrylic-based office tape on the other



Fig. 4: Removal of the tapes adhesive residues with cellulose powder and a color shaper tool

copy, the same treatment (without the application of warm water on the tape carrier) was carried out with great success as well.

### Conclusion

This object had a ground breaking role in Pop Art and in art history, in terms of materials, techniques and subject matter. *Sandwich and Soda* was one of Lichtenstein's first attempts to use an unusual support, in this case a thin clear plastic. *Sandwich and Soda* was one of many screen prints on unusual supports, he started making in 1964. He kept using plastic as a support, like for *Seascape I* (1964), *Moonscape* (1965), *Landscape 5* (1967) that are screen prints on Rowlux, a multi-lensed effect film that can create Moire-like visual patterns.

Artworks on plastic and their inherent degradation processes is still a very relevant topic for museum's staff. For example, at the MFA, Houston, there was very recently a gallery talk called: Spotlight on "Synthetic Supports: Is Plastic the New Paper?" (December 2011) which shows how this research falls into the trend.

Conservators now have to deal with unusual surfaces and materials, which is challenging and interesting, and requires being very adaptable in our work. This project also served to remind this author that collegiality is the most effective way to understand a complex object and its damages and chose the best option for treatment. It was very helpful to be able to ask questions about

plastics to object conservators and conservation scientists at the Straus Center for Conservation and Technical Studies to better understand the objects and treatment options.

### Endnotes

- 1 alpha-cellulose powder, Sigma Chemical Co., No. c-8002
- 2 Royal Sovereign Ltd UK, Color Sharper, Firm, Taper Point, #2

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## Digitally Printed Paper In-fills for Compensation as Applied to Japanese Fold-Dyed Paper

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### Introduction

In the conservation of Japanese folding screens, the decorative papers on the back can sometimes be replaced with new ones with the same or similar patterns. In the case of the folding screens, *The Deities of the Tanni-sho*, by Munakata Shiko, these decorative papers are typical Folk Art Movement (*Mingei*) style fold-dyed paper. The artist, Munakata Shiko, dedicated these screens to the founder of the *Mingei* movement, Yanagi Soetsu, with an inscription on the labels at the back of the screens. Therefore, the label and the decorative papers should be treated as integral parts of the art work and put back into place on the screens.

However, several large losses to these fold-dyed papers (Fig. 3) were present. For creating in-fills, it is not only a matter of choosing appropriate Japanese paper by evaluating the thickness (slightly less than support) with visually matching chain lines, color and texture, but also reproducing the patterns. Therefore, printing digital photographic images on an appropriate Japanese paper for use as in-fills was considered.

This paper presents the process of assessing the appropriateness of using digital in-fills for

this case, the preparation of these digital in-fills and the materials and equipment that were used.

### Digital techniques for loss compensation

Several papers have been presented about using digital techniques to compensate for losses in textile conservation. Rogerson used digital reconstruction to display the completed image next to a beaded mask after research and discussing with the curator (Rogerson, 2002); this example illustrated how a digitally reconstructed image met the need of conservation and education. In the case in the Victoria and Albert Museum, a digital in-fill was successfully used in compensating large losses on a Thirteenth Century carpet (Hartog, 2009). Since the patterns of carpet are repeated and geometric, the conservator was able to print the image from the surviving pattern on an appropriate substrate. For recognition purposes, the image was printed in a lighter shade than the original, so the visitor could be aware of the digital in-fill at a distance of six inches but would not be distracted by it when viewing at a distance of six feet. In paper conservation, McClintock has mentioned using digital reproduc-



Fig. 1: Printing digital in-fills on the Sekishu paper.



Fig. 2: Tracing the losses before in-filling.

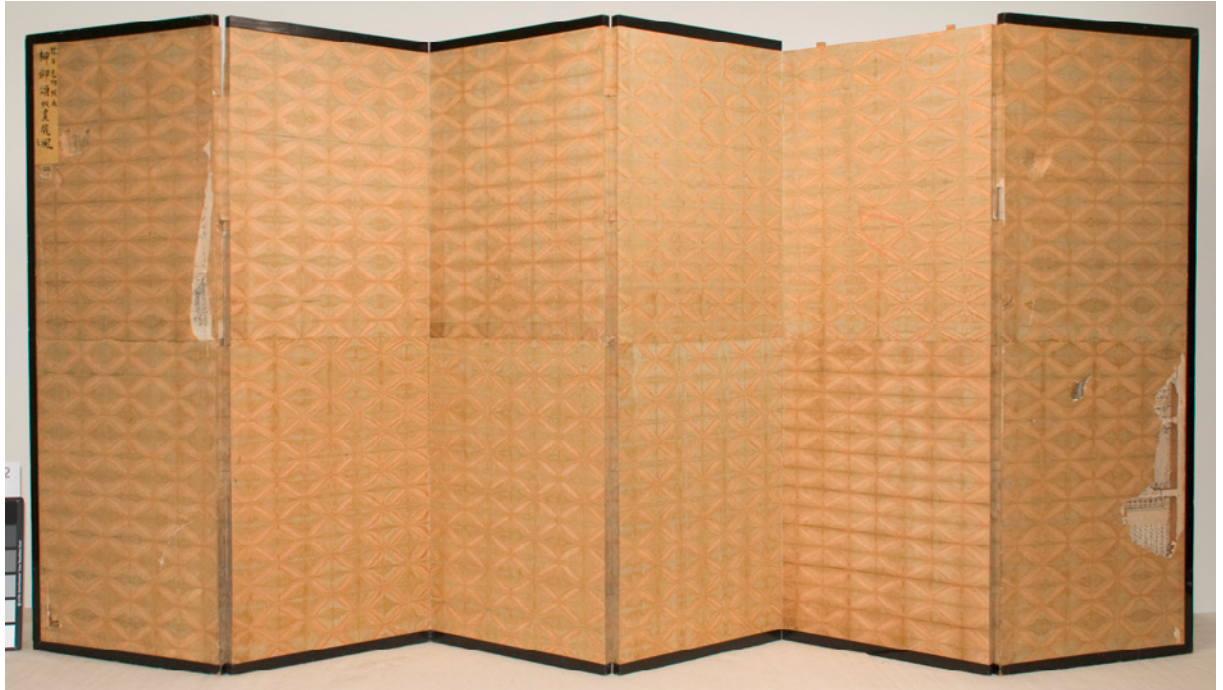


Fig. 3: The reverse of left screen overall before treatment. Large losses and punctures are clearly visible. The hinges were split, with soiling in the lower portions and further damage and tears in the upper portion.

tion for historic wallpapers (McClintock, 2003). In 2012, Melody Chen presented a case of digital in-fills as used for Japanese Prints (Chen, 2012). A digital image of another impression from the Japanese print collection at the Museum of Fine Arts, Boston was printed on the Hahnemuehle Rice Paper ('Digital FineArt', n.d.). This is another successful example of how a digital image was used for in-filling when there exists an authenticated reference.

After reviewing these cases, compelling reasons for compensating losses to the fold-dyed paper of Munakata Shiko's folding screens with digital in-fills were determined. They were:

1. The digital reproduction has enough reference from the original. The image of patterns could be captured from undamaged fold-dyed areas by photography.
2. The losses to the fold-dyed papers are located on the folding screen's reverse. The fold-dyed papers present a style of craft-art but not the fine art created by the artist. Reproducing partial patterns would not change the context and character of these fold-dyed papers.
3. The digital reproduction is less time-consuming and creates a more satisfactory method of creating a visual in-fill than other possibilities, such as using basic toned in-fills, remak-

ing fold-dyed paper using traditional techniques for in-fills or hand painted in-fills.

4. The digital in-fills are printed in a lighter color than the original, so that they would be clearly visible at a close distance. The authenticity of the original would still be distinguishable from the repairs.

### Digital in-filling treatment

After examining and documenting the condition, the folding screens were photographed before and after treatment to document their condition. Wooden trims were removed; each panel was separated and the fold-dyed papers were removed from the panels. The papers attached to the back of the fold-dyed papers were removed using Gore-tex to humidify them; followed by pressing between Reemay, blotting paper and thick Plexiglas.

Of the twelve fold-dyed papers, three had considerable losses and needed large digital in-fills. Since fold-dyed papers were going to be pasted onto the new under-cores, the papers for in-fills had to be similar or slightly thinner in thickness than the fold-dyed papers, so that the in-fills and the original would have similar expansion and shrinkage during mounting. Japanese handmade *Sekishu* paper was chosen for printing the image

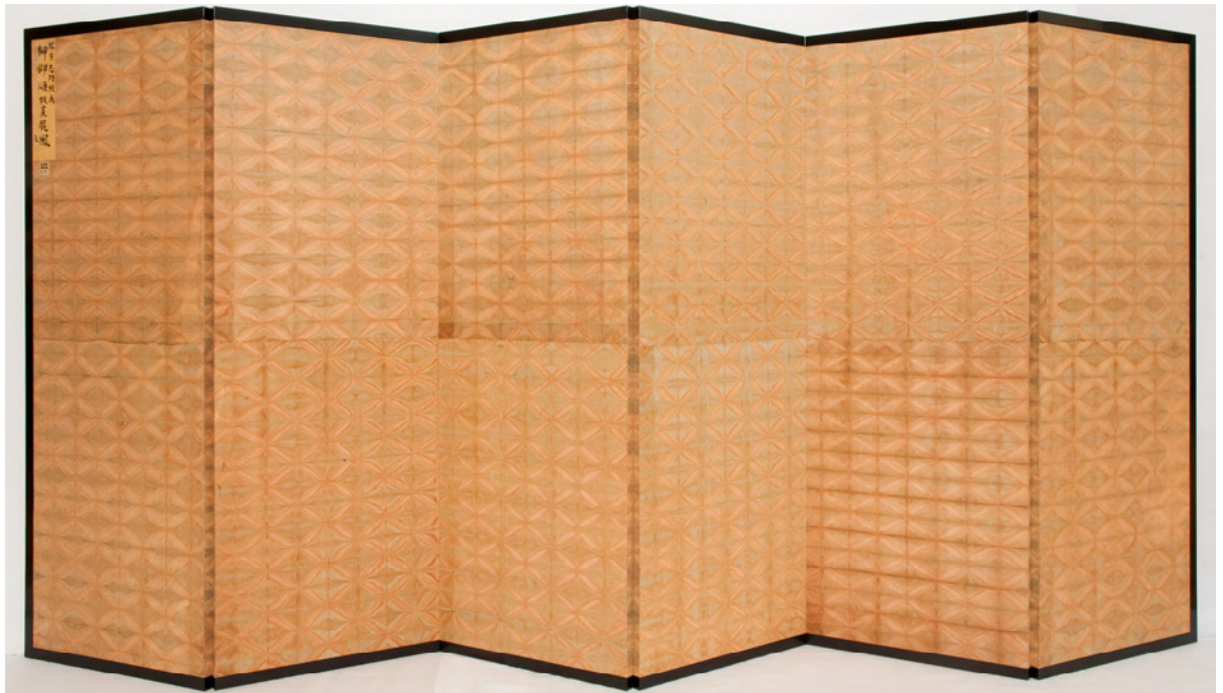


Fig. 4: The reverse of left screen overall after treatment. The large losses located in the first and last panels have been filled with digital in-fills. The hinge covers have been replaced with digital printings also.

onto it for in-filling. The image was taken from another area of fold-dyed paper with fair condition and a clear pattern. Photoshop® was used for adjusting the image by color balance and brightness/contrast functions. Several trials were carried out for comparing the color of the reproduction to the original. An Epson Stylus Pro 4900 printer was used for printing and its ink tested and shown to have great light resistance ('Epson Stylus Pro4900-Print', 2010). Trials showed that there was no migration of ink after the lining treatment. In addition, the trials passed the Oddy test carried out by the preventive conservation specialist at the MFA (Chen, 2012).

Unfortunately, the *Sekishu* paper was not compatible with the printer. After discussing this with the photography/printing expert, we found the irregular surface and the thinness of the *Sekishu* paper might cause the paper to jam in the printer. Therefore, one layer of a temporary lining of Japanese paper and thin wheat starch paste was added to the back of the *Sekishu* paper so it could be properly printed. The lined *Sekishu* paper was accepted by the printer and was able to receive the required image successfully (Fig. 1). A coating was not necessary in this case, because the patterns on the fold-dyed papers are irregular and slightly blurred in character.

After printing out the digital in-fills, sizing was applied on the surface and the temporary lining was removed by humidification then the printed papers air-dried on felts. The sizing application was undertaken for fixing the fibers on the digital in-fills since the printing actually only stayed on the surface and could be lost or diminished if fibers lifted or were to be abraded through handling. Additionally, sizing aided the application of toning washes with Japanese colorant sticks. Digital in-fills were toned in slightly different levels to blend into individual panels. However, they could be easily distinguished at a close-up distance once the losses were filled in. Before in-filling, the digital in-fills were positioned to match the patterns and the losses were traced roughly with pencil marks in transmitted light (Fig. 2). This helped to find the position right away after wetting the fold-dyed papers.

The fold-dyed papers were humidified overall using a sprayer and placed on the top of Rayon paper for protection. Once the fold-dyed papers were moist, they were brushed out from the center to reduce creases and to realign tears. The digital in-fills were set into place with a slight overlap using wheat starch paste. One layer of lining was added and then paper strips were pasted into place for reinforcing tears and sup-



porting the reverse of severe creases. Finally, the fold-dyed papers with their lining were flattened on the drying board to prepare them for placement back onto the folding screens. These in-fills not only even up the fold-dyed papers in structure, but also provide continuous patterns to compensate losses in aesthetic effect (Fig. 4).

Besides compensating the large losses, digital printings were also used in the covers of the hinges. Since those hinge covers appeared dirty and severely damaged (Fig. 3) they were replaced with new ones. The screen after completion of the treatment is shown in Fig. 4.

## Conclusion

In this case, using digital in-fills was successful in compensating losses on the fold-dyed paper with regular patterns. In addition, this case shows the possibility exists to print the image on a thin handmade paper though temporary lining. However, this technique should always be carefully considered and thought through prior to treatment. Before using digital in-fills, conservators should think about the following:

1. The digital image must have a strong reference in order to support the original both aesthetically and historically.
2. Discuss with curator: Where is the digital in-fill going to be and will it change the context of the original?
3. Digital in-fills can be a less time-consuming and more effective technique than other traditional techniques.
4. The digital in-fills will not be confused with the original by the viewer and they are reversible.

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## Material and equipment

*Sekishu* Paper  
Nishida Washi Kobo  
1548 Furuichiba Misumi  
Hamada Shimane  
Japan 699-3225

Epson Stylus Pro 4900 printer  
Epson America, Inc.  
185 Renfrew Drive Markham  
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