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Sắc Phong: A Preliminary Investigation of Vietnamese Imperial Proclamations

INTRODUCTION

In 2022, three paper artifacts from Vietnam were brought to the Garman Art Conservation Department at SUNY Buffalo State University by Bac-Vu Do, a first-year Fulbright graduate fellow, for research. These objects include two Imperial scrolls, known as *sắc phong*, issued by Emperor Khải Định from the Sĩ Mộc collection, and a modern replica purchased from the Zó Project. As part of the Buffalo program's technology project, Bac-Vu Do also attempted to re-create a portion of one of the scrolls to gain a better understanding of the manufacturing process (fig. 1). Given the limited scientific research on the materials and techniques used in creating such manuscripts, a deeper understanding of these materials and their processing is essential for enhancing their longevity through preventive conservation. Over two years at the Garman Art Conservation Department, numerous scientific analyses were conducted by the main author to investigate the materials and manufacturing techniques. It is hoped that this study will serve as a starting point for further research into *sắc phong* and possibly aid in reviving this forgotten art.

BACKGROUND

Sắc phong were composed in Chữ Nôm (Sino-Vietnamese) characters on special yellow handmade paper, adorned with depictions of spiritual animals and imperial symbols. These decrees served as authoritative documents for various purposes, including legal, administrative, and ceremonial matters (Thư Viện Huệ Quang 2024). They embodied imperial authority and conveyed the ruler's commands, carrying significant legal weight in the society of their time. *Sắc phong* played a pivotal role in the governance and administration of Vietnam throughout its history. They were instrumental in conveying orders, codifying laws, acknowledging achievements, and documenting significant events. *Sắc phong* hold a prominent place in Vietnam's cultural heritage, reflecting the nation's historical governance and administrative practices. They are cherished for their artistic and historical significance. These royal edicts reflect the supreme authority of the emperor, who was considered a descendant of heaven sent to the mortal world to govern the people (Thư Viện Huệ Quang 2024). Thus, the emperor

Fig. 1. Bac-Vu Do's attempt to reconstruct a portion of the scroll.

Papers presented during the Book and Paper Group Session, AIC's 52nd Annual Meeting, May 20–24, 2024, Salt Lake City, Utah

Fig. 2. Lại Phú Thạch, one of the last two sắc phong makers of the Lại family (VTV4 2021).

not only ruled over the people in the mundane world but also governed the spiritual world, integrating with religious beliefs and spiritual life (Thư Viện Huệ Quang 2024).

The Lại family in Nghĩa Đô, Hà Nội has been known as the sole family responsible for making this type of paper for more than 600 years (Nguyễn 2024). The technique of making this paper was considered a state secret and has been long lost since the fall of the Nguyễn monarchy in 1945. Lại Phú Thạch and Lại Thu Hà, the 23rd generation of the family, have been working on reviving their ancestor's craft. To make Sắc paper, the maker would order high-quality handmade Dó paper from a reputable papermaker (fig. 2). Each sheet measures about 48 × 20 inches (121 × 50 cm). A sizing made from water buffalo glue was applied. Yellow dye extracted from hoa hòe (*Sophora japonica* sp.) was brushed onto the sized paper to give it the rich golden color, a symbol of the royal family. The paper was then burnished by hammering with a wooden mallet onto a flat, dry stone. The scroll was then decorated with dragons, mythical animals, and sacred symbols using silver or gold pigments. This process was done freehand and required years of training. The technique of making this pigment was considered the Lại family's top secret. The royal family would pay 1.3 ounces of gold for a single sheet of this special paper (Tiểu et al. 2021).

THE OBJECTS

The current study comprises the analysis of two *Sắc phong* imperial edicts and Zó Project modern sắc phong paper, brought from Vietnam to the Garman Art Conservation Department in 2022. The Zó Project is a social enterprise based in Vietnam that focuses on preserving and promoting the traditional craft of handmade paper (Zó Project 2024). Both objects are fragments of original scrolls. Based on visual observation, the scrolls appear to be made of handmade Dó paper, with elaborate gilded designs that include swirling cloud motifs and possibly dragon imagery. The text is written in vertical columns, similar to classical Chinese characters, indicating their historical and cultural significance. The edges of the scrolls are frayed and damaged from improper storage and handling. The decoration along the edge of the scrolls shows evidence of relief printing using a woodblock, whereas the dragon and the cloud seem to be painted freehand.

Scroll #1 (fig. 3) was made from a single thin sheet of paper, whereas Scroll #2 (fig. 4) was made by laminating two

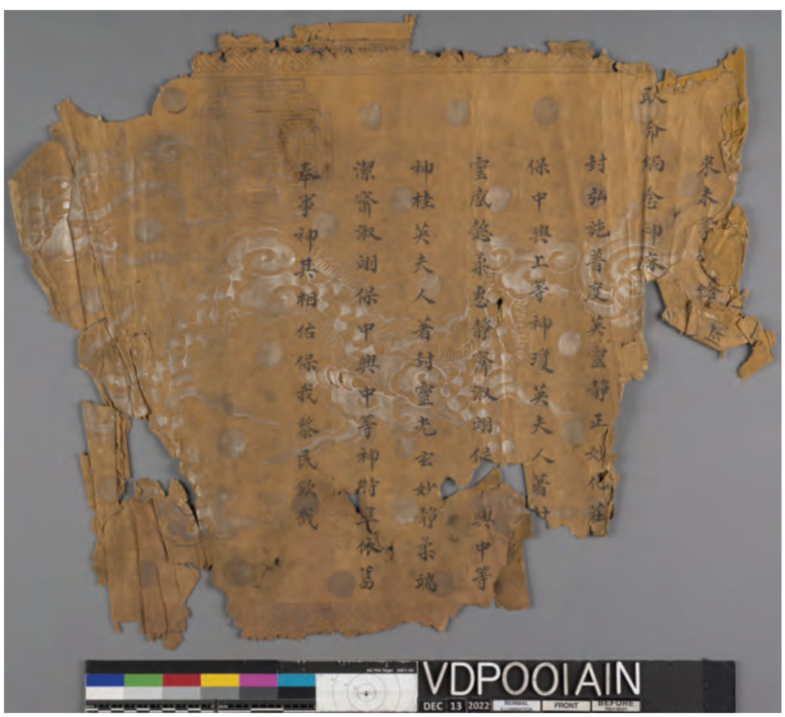

Fig. 3. Scroll #1, Sĩ Mộc collection.

Fig. 4. Scroll #2, Sĩ Mộc collection.

sheets of paper to produce a thicker sheet. The two sheets could have been wet and adhered by pressing them on top of each other, as there is no evidence of adhesive. Scroll #1 has been heavily damaged, with missing characters, making a complete translation impossible. However, these two scrolls were compared with two other scrolls, Or. 14631 and Or. 14632, in the collection of Vietnamese manuscripts at the British Library. Based on visual comparison of the decoration style, these four scrolls seem to have been issued by Emperor Khải Định (figs. 5, 6). A Vietnamese translation by Dr. Phạm Văn Tuấn from the Institute of Hán-Nôm Studies helps date and confirm the origin of Scroll #2.

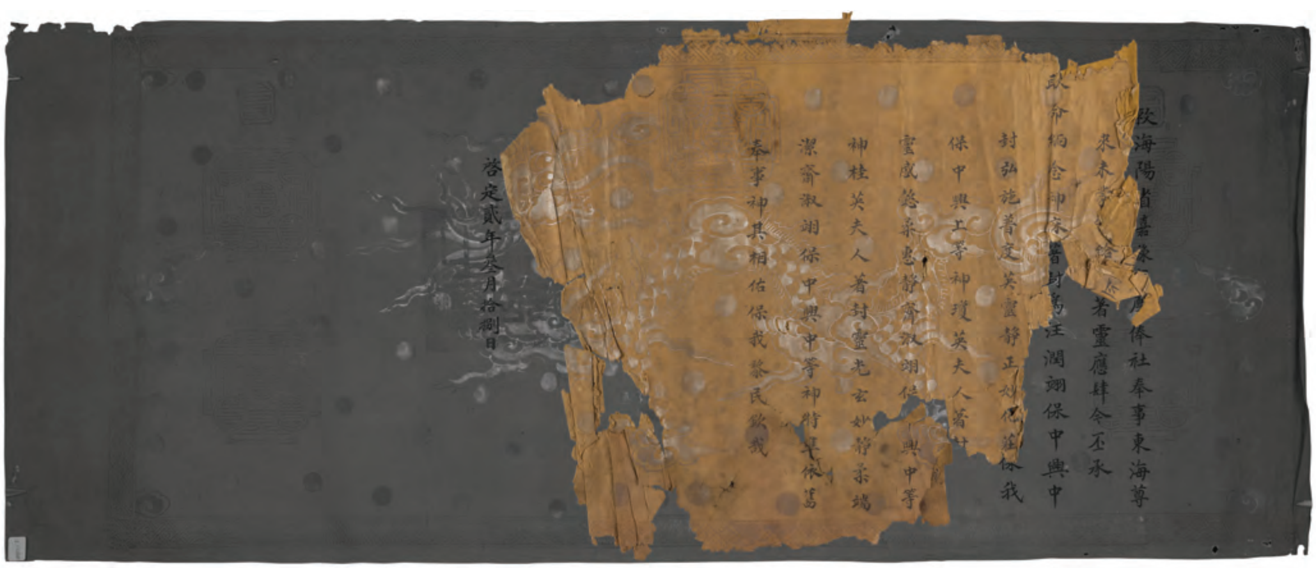

Fig. 5. Digital overlapping between Scroll #1, Sĩ Mộc collection and Or. 14631, British Library.

Fig. 6. Digital overlapping between Scroll #2, Sĩ Mộc collection and Or. 14632, British Library.

English Translation of Scroll #2 Based on the Vietnamese Translation by Dr. Phạm Văn Tuấn

Title: Decree for Mộc Tùng commune in Thanh Liêm district, Hà Nam province, to worship.

Originally awarded the title of "Linh Quang Huyền Diệu Tĩnh Nhu Đoan Khiết Trai Tĩnh Dực Bảo Trung Hưng Quế Anh," the lady protected the nation and sheltered its people, repeatedly manifesting miraculous responses. To this day, she has been granted an official decree for worship. Today coincides with the grand celebration of my forty years birthday, where a precious decree revealing significant grace is bestowed, elevating ceremonial rites. Additionally awarded the title of "Trang Huy Thượng Đẳng Thần." Specifically authorized for worship and recorded on the national holiday in the worship registry.

With deep respect.
July 25, 1924, the 9th year of Khải Định's reign

SCIENTIFIC ANALYSIS

Microscopy

Both scrolls, numbered 1 and 2, were made from Dó fibers, known to be the primary traditional Vietnamese papermaking material. Dó fiber is collected from the inner bark of Dó (*Rhamnoneuron balansae*), a small tree closely related to other popular Asian hand papermaking plants such as Japanese *gampi* and Nepalese *lokta* (Ojascastro 2023a). Kozo is often mistaken for Dó, and the term is used interchangeably in literature translations within the Vietnamese community. Moreover, the Vietnamese papermaking process shows many similarities to the Japanese technique, including fiber processing, sheet formation, and even papermaking tools (Ojascastro 2023b).

In this study, microscopic examinations were conducted to differentiate between the two fibers. A sample of Honmino paper sold by Hiromi was compared with a sample of Dó paper made by Ngô Đức from Dương Ổ, Bắc Ninh. A Leica polarized light microscope equipped with a SPOT Insight CMOS camera was used, and images were processed using SPOT basic imaging software. Both fibers share characteristics of bast fibers, but kozo fibers tend to have more pronounced nodular structures, with the lumen appearing as a fine line (fig. 7). Kozo fibers come in two primary forms: thick fibers with pointed ends, and ribbon-like fibers that are twisted and encased in a thin, transparent cuticle with broad, rounded ends (Smith 2019). Kozo fibers have an average width of 30 µm and a length of 10 mm (Smith 2019). However, not all kozo fibers have the same width; variations may occur depending on the cultivated regions and possibly subspecies (Niwa 2024). For instance, Nasu-Kozo grown in the northern region of Japan may have narrower width compared to kozo grown in Mino (Asano and Sato 2016).

Dó fibers are extremely thin and smooth, resembling silk fibers, with faint nodes and X marks (fig. 8). The width of Dó fibers ranges from 5 to 12 µm. Although both kozo and Dó fibers originate from the bast (phloem) region, the trees belong to different families: Kozo is in the Moraceae family, whereas Dó is in the Thymelaeaceae family, along with mitsumata, gampi, and daphne, despite being from different genera (Mayer 2023). Dó fibers exhibit a "snake that ate a mouse" appearance, characterized by irregular widths with swollen sections, and inherently contain more lignin than kozo fibers

Fig. 7. Kozo fiber, Hon-mino, Hiromi, PPL.

(Mayer 2023). Both kozo and Dó fibers have similar birefringence and extinction angles under cross-polarized light.

Fiber samples were taken from damaged areas on the two scrolls to further investigate the manufacturing technique. Both samples show signs of deterioration with short and broken segments of fiber (figs. 9, 10). Under plain polarized light, the dye appears as small yellow irregular crystals physically bound to the fibers, while the fibers retain their natural yellow-tan color (fig. 11). This confirms that the dye was applied by direct brushing on top of the paper, reacting with the alum sizing and forming these crystals. However, the fiber taken from the Zó Project replica has been dyed completely yellow. This was later confirmed by HPLC analysis as a modern synthetic dye. Together with Dó fibers, which appear to be thin with sharp ends, cotton fibers were found to be present in the Zó Project sample, characterized by wider fiber width, random twisting, and collapsed lumens (figs. 12, 13).

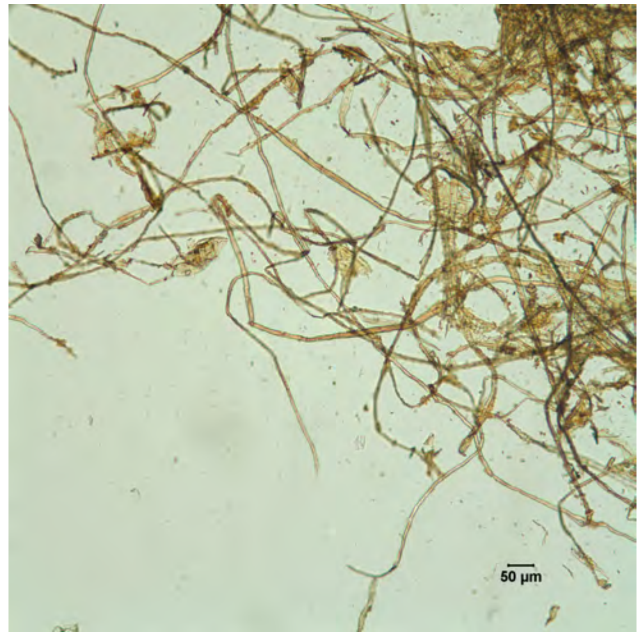

Fig. 9. Fiber sample of Scroll #1, PPL.

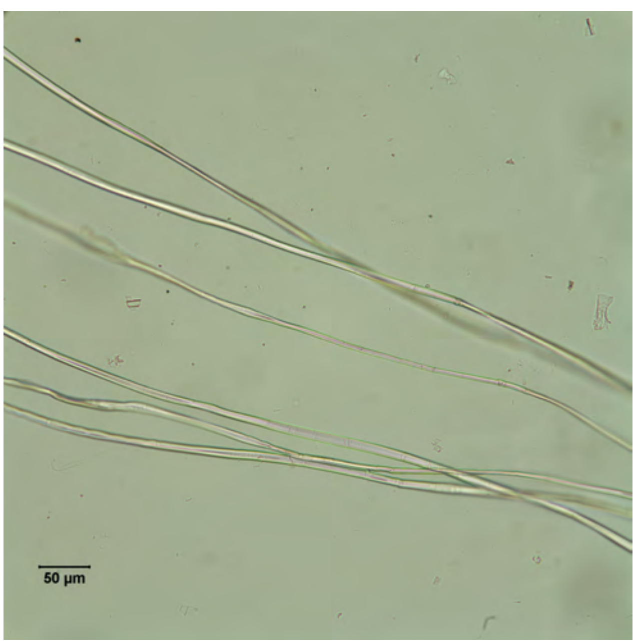

Fig. 8. Dó fiber, Ngô Đức handmade paper, PPL.

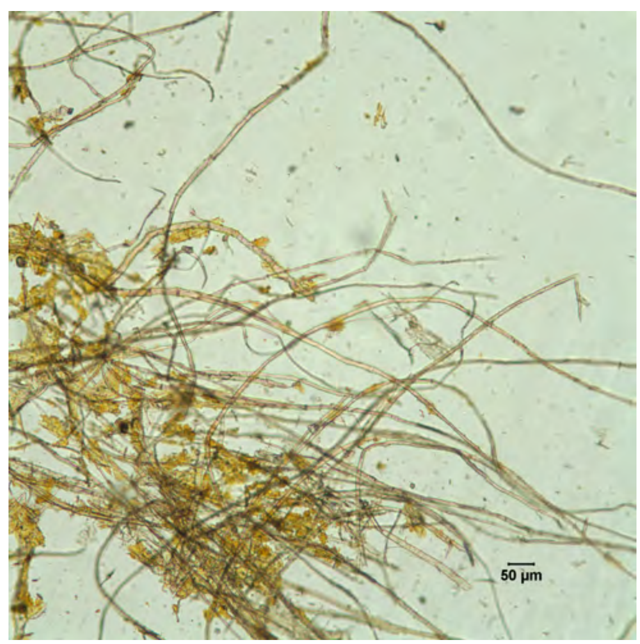

Fig. 10. Fiber sample of Scroll #2, PPL.

Fig. 11. Photomicrograph of Scroll #2, PPL.

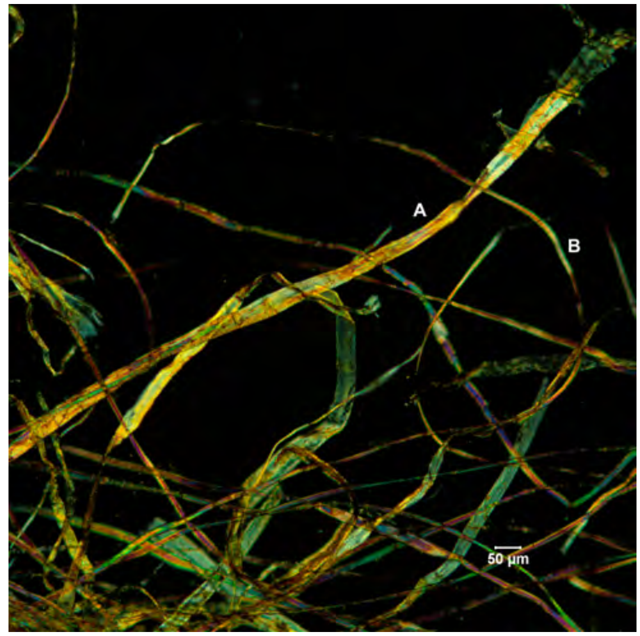

Fig. 13. Zó Project sắc phong paper, XPL, A: cotton fibers, B: Dó fibers.

Multispectral Imaging

The decoration on the back of the two scrolls was heavily abraded, and only traces of the original design can be seen under visible illumination. The Multispectral Imaging System for Historical Artifacts (MISHA) developed at the Rochester Institute of Technology was used to conduct further imaging analysis of the abraded gilding decoration on the back. The system is equipped with 16 LEDs to illuminate objects using different wavelengths ranging from 365 to 940 nm, including two in the ultraviolet spectrum and two in the infrared spectrum. The images were stacked to form a data cube and further processed using the Spectral Analysis App developed by the MISHA team. A false-color image was generated with the results from principal component analysis of the data cube, highlighting the original gilding materials as green, as in figure 14. This area indicates that the gilding was done freehand with precise and elegant brush strokes.

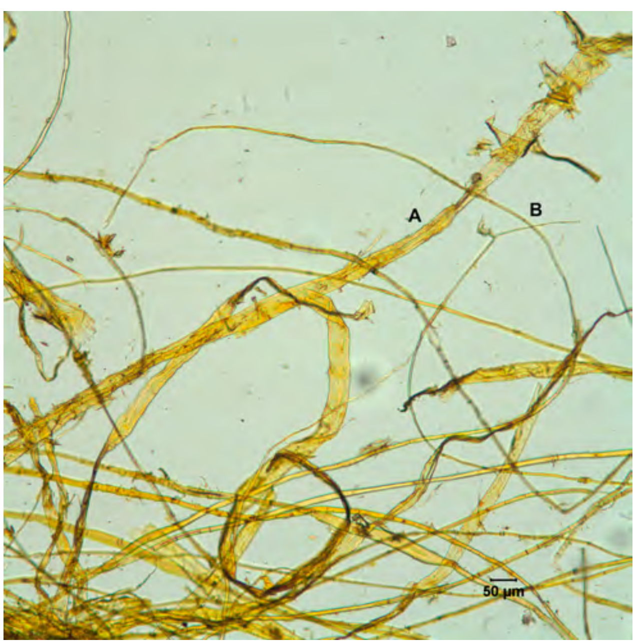

Fig. 12. Zó Project sắc phong paper, PPL, A: cotton fibers, B: Dó fibers.

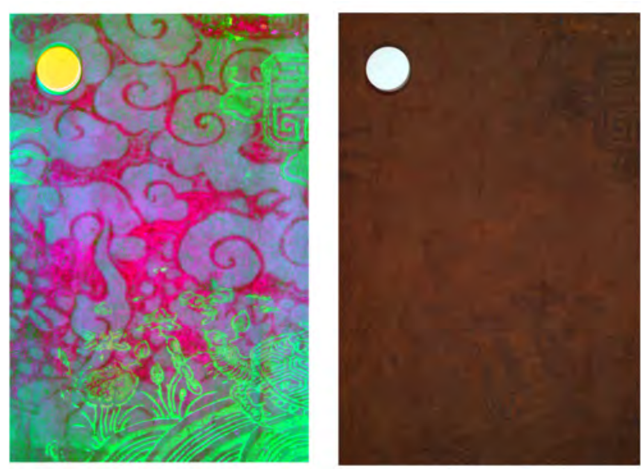

Fig. 14. Detail of the gilding on the verso of Scroll #2. Left: A false color image of principal component analysis results generated with the images acquired through MISHA. Right: Visible light detail of the area shown on the left.

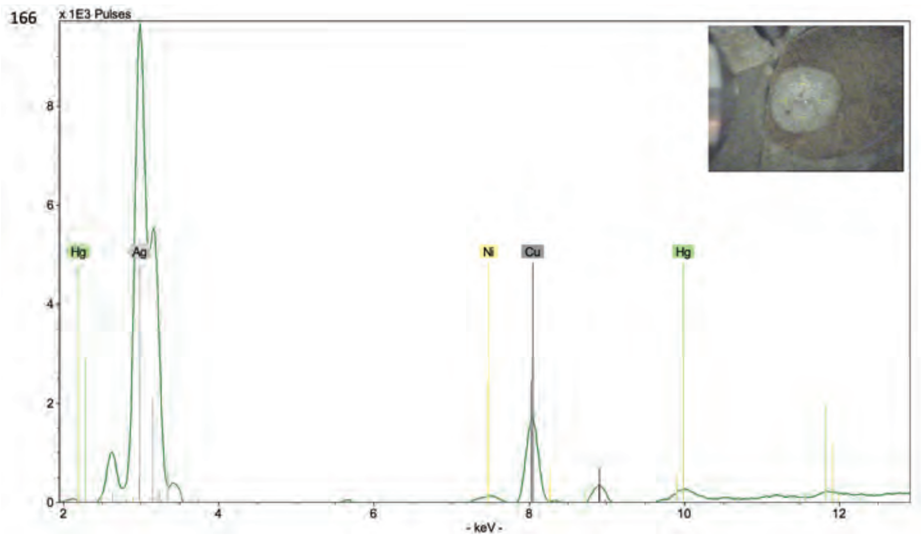

Fig. 15. XRF spectra of the gilding near the dragon's eye on Scroll #1, with background subtraction revealing prominent peaks of silver (Ag) and copper (Cu).

XRF Analysis

X-ray fluorescence spectra were collected using a Bruker Artax 400 energy-dispersive x-ray spectrometer system. The excitation source was a Rhodium (Rh) target x-ray tube with a 0.2 mm thick beryllium (Be) window, operated at 40 kV and 1000 µA current. The x-ray beam was directed at the artifact through a masked aperture of 3 mm in diameter. X-ray signals were detected using a Peltier-cooled XFlash silicon drift detector with a resolution of 146.4 eV. Spectral interpretation was performed using Artax Control software 7.8. Spectra were collected over 30 seconds of live time. No filter was used.

The XRF spectrum with a subtraction of the background of the gilding area near the eyes of the dragon on Scroll #1 reveals the presence of silver and copper, with trace amounts of mercury and nickel (fig. 15). For a long time, silver was known to be the only pigment used in the making of sắc phong. In this case, copper was used as an underlayer to create tonal variations. There are no vermillion or other pigments containing mercury or nickel, which can be interpreted as anomalies adhering to the surface due to direct contact with other works or poor storage conditions. However, the XRF spectra of the gilding area on Scroll #2 reveal the presence of a high amount of copper and zinc (fig. 16). Silver was also present but in much lesser amounts. The copper-to-zinc ratio suggests that this was a brass pigment, possibly used to reduce manufacturing costs while still achieving the rich yellow color of gold. This is evidence of the influence of Western materials explored by traditional craftsmen in the early 20th century.

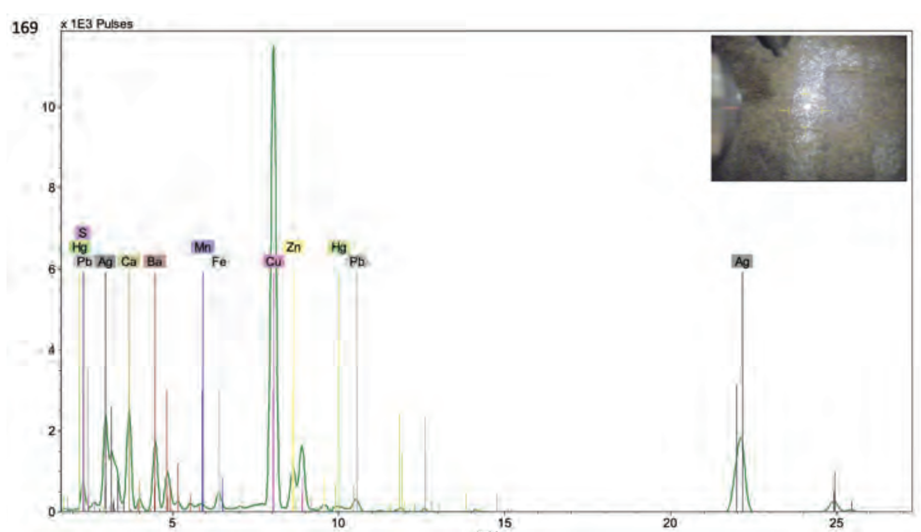

Fig. 16. XRF spectra of the gilding on Scroll #2, showing strong peak of copper (Cu), silver (Ag), calcium (Ca), zinc (Zn), and barium (Ba).

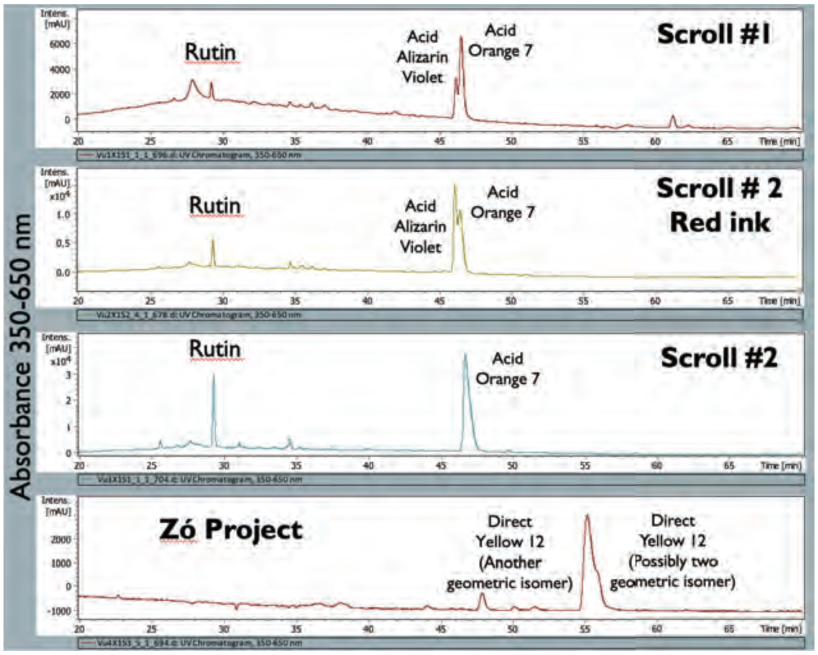

Fig. 17. Absorbance chromatograms of four samples show the presence of rutin, and acid orange 7 in all scroll samples, whereas the Zó Project sample contains only Direct Yellow 12.

The remainder of the elements found are associated with the paper substrate or also due to improper storage conditions. These artifacts were stored directly on top of each other without interleaving layers.

Liquid Chromatograph-Diode Array Detector-Mass Spectrometry

Dye samples were analyzed using Liquid Chromatograph-Diode Array Detector-Mass Spectrometry (LC-DAD-MS). A methanol-water mixture containing oxalic acid was used for all extractions. The paper used per volume of solvent for samples 1 through 4 were 3.7, 6.5, 5.0, and 2.5 mg/mL, respectively (fig. 17). Rutin was found in both scrolls, indicating the use of natural yellow dye extracted from the flower of hoa hòe (Thư Viện Huệ Quang 2024). In Vietnam, there are several native plants that produce similar yellow colorants, such as hoàng đằng (*Fibraurea tinctoria Lour*), hoàng bá (*Phellodendron amurense*), and vàng đắng (*Coscinium fenestratum*) (Do Quyen 2024). Although these plants are popular in traditional cooking and medicine, dyes extracted from them have not been fully studied or compared to *S. japonica*. Surprisingly, synthetic red dyes were found in both scrolls: acid alizarin violet and acid orange 7. In an interview with Lại Phú Bàn, the last sắc phong maker who served the Nguyễn emperors, he mentioned adding a red colorant (*đỏ đơn*) to the Sophora flower's dye to create a warmer yellow tone on paper (Tiểu et al. 2021). Scroll #2 does have a red undertone, which aligns with our findings. Moreover, the layer of red colorant was applied on top of the gilding of Scroll #2 (fig. 18). Dye analysis also shows that the modern replica sắc phong paper from the Zó Project contains Direct Yellow 12, a modern synthetic dye.

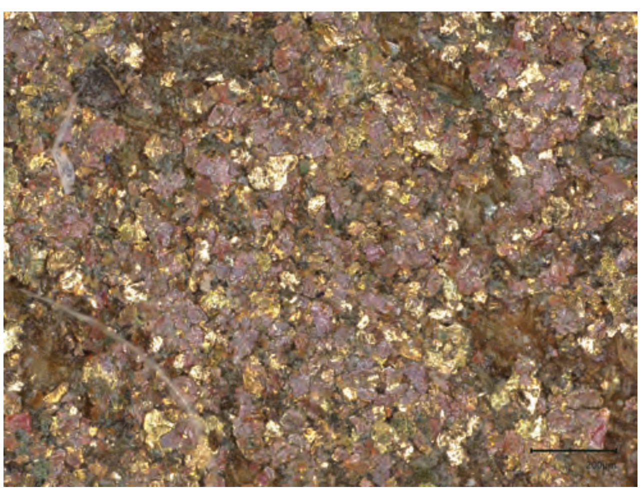

Fig. 18. Detail of Scroll #2 showing that the red colorant was applied on top of the gilding, with a 200 µm scale bar.

Test for Protein Using Amido Black Stain

Many sources have mentioned the use of *keo da trâu* (water buffalo hide glue) as a sizing medium in making sắc phong (Thư Viện Huệ Quang 2024). Amido black stain was used to test for the presence of protein glue in all samples. The samples were observed under a microscope to detect any color changes. Both Scroll #1 and Scroll #2 tested positive, whereas the Zó Project sample showed a negative result. An albumen print was used as a positive control, and tengujo was used as a negative control. Further studies are needed to determine the specific type of glue

Fig. 19. Digital restoration of Scroll #2 based on recent research findings. Courtesy of Xuân Lam and the author.

used. According to Nguyễn Thị Thu Hòa, a Vietnamese folk painting expert, *a giao* (donkey hide glue) imported from China was often used by traditional painters and printmakers in Hanoi.

PREVENTIVE CONSERVATION

One of the advantages of Dó fiber is its natural insect-repellent properties (Ngô 2022); hence, insects were not noted as a significant issue. Controlling temperature and relative humidity can be challenging in Vietnam. Special attention must be paid during seasonal transitions, such as in March and the summer months when temperature and humidity can change drastically over short periods. In periods of higher humidity, there is the risk of mold growth. Since the paper was made using various organic colorants, it can be sensitive to light and needs to be protected from ultraviolet radiation with limited display periods.

Most of these objects are often stored rolled in wooden boxes and occasionally will be presented during religious ceremonial events. Handling may cause creases and damage to the paper support, particularly with thicker sắc phong, which is made from thick paper sheets or by laminating two sheets of paper. A common mistake, although often done with good intentions, is to laminate the scrolls between two sheets of heat-seal plastic or clear packaging tape; these protective measures may cause damage that is often irreversible.

It is best to store the scroll in a box made of acid-free material with silica gel and a reliable relative humidity indicator. Scavenger fabric materials, such as Pacific Silvercloth, are also recommended to shield the object from exposure to air pollutants. The gilding, composed of silver and copper, can tarnish when reacting with airborne sulfur and chlorine-containing compounds. It would be ideal to check the object frequently, such as once a week, to create air circulation and ensure optimal storage conditions.

CONCLUSIONS

Given the limited published scientific research on the materials and techniques used in the creation of this type of manuscript, gaining a deeper understanding of these materials and their processing is crucial for enhancing their longevity through preventive conservation. Our findings indicate that the scroll was produced using a combination of woodblock printing and freehand drawing. While Dó paper is unique, it shares bast fiber characteristics with kozo fiber. Several natural and synthetic dyes, including rutin extracted from the dried flower buds of the Sophora tree, were identified as key components for paper dyeing. XRF analysis revealed significant levels of copper and zinc, suggesting the use of brass pigment and possible Western influence. The Zó Project replica of sắc phong paper, although advertised as authentic, was not made using traditional methods and materials. This study aimed to provide a foundation for further research into sắc phong and potentially aid in reviving this forgotten art (fig. 19).

ACKNOWLEDGMENTS

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SOURCES OF MATERIALS

Hon-mino paper
Hiromi Paper Inc.
9469 Jefferson Blvd. #117
Culver City, CA 90232
310-998-0098
https://hiromipaper.com

Pacific Silvercloth
SilverGuard
321 Kissing Oak Dr.
Austin, TX 78748
512-326-9777
https://silverguard.com

Sắc phong paper
Zó Project
189 Trích Sài
Bưởi, Tây Hồ, Hà Nội 100000
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HEATHER HENDRY

A Medley of Map Treatments

INTRODUCTION

The Conservation Center for Art and Historic Artifacts (CCAHA) is a regional laboratory that provides conservation and preservation services to a wide range of clients. We do not have our own collection, which leads to a wide variety of objects coming into the laboratory, as well as a range of client needs and storage considerations. The objects that our clients send for treatment may be based on our recommendations through collection surveys but more often come from the clients' judgment of their most vulnerable and important objects. There is often some plan for display after treatment, although clients' goals may also include digitization or general collections stewardship.

Our clients frequently select maps for treatment both because of their importance and their precarious condition. For many local historical museums or archives, a historical map of the area is an important grounding framework to understand the rest of their collection. Private clients often feel a great connection to a historic map because of their connection to the area. At the same time, these maps can be extremely fragile due to their history of use. Maps may be made with a wide range of sizes, media, and supports. This article describes treatment solutions for three very different types of problems that occurred during treatments of historic maps but could also apply to other works on paper.

BACKING REMOVAL AND LINING OF A WATER-SOLUBLE HAND-DRAWN MAP

The Map of Essex County, belonging to the Millburn Short-Hills Historical Society Museum, is a hand-drawn map from 1872 (fig. 1). It is drawn in red, brown, black, and blue inks, with additional annotations in red, blue, and graphite pencils. The paper is lined overall on cloth. When it was received at CCAHA, the paper of the map was heavily fragmented and the cloth no longer provided a secure physical support. The adhesive was so weakened that it could be released mechanically, which risked the loss of more fragments. Additionally, there were many tight wrinkles in the paper where it appeared the paper had expanded while the cloth had not; these areas were vulnerable to further physical damage. Overall, the paper was discolored and brittle, with strong liquid stains along the right side.

Fig. 1. Map of Essex County, Millburn Short-Hills Historical Society Museum collection. Courtesy of Andrew Pinkham, CCAHA.

A standard conservation treatment at CCAHA would be to remove the cloth lining with moisture, keeping the pieces aligned by surface tension on a non-woven polyester web such as Hollytex or Bondina, wash the map in calcium-enriched deionized water, and reline it onto a mulberry paper with wheat starch paste. However, the solubility of the inks would not allow standard washing or drop lining techniques. Careful testing determined that the inks could tolerate humidification or a brief suction wash, but not the full saturation of a blotter or Tek-Wipe wash, any immersion bath, or

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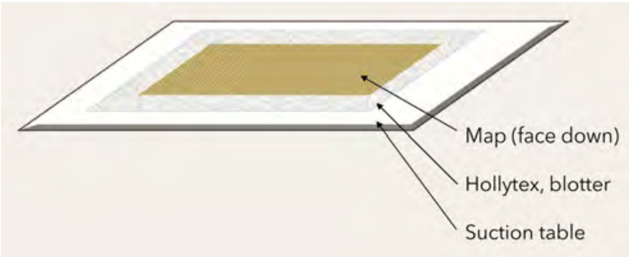

Fig. 2. Diagram of the map laid on the suction table.

the contact involved in either drop lining or being placed face down while wet.

Because of the solubility concerns, the cloth lining was removed and a new mulberry paper lining was applied almost completely dry, using the suction table. First, the map was placed face down on the suction table (fig. 2). The suction held the map in place, with no loss or displacement of fragments, while the lining was mechanically detached in strips (fig. 3). Once the cloth lining was removed, a new lining of Hiromi Self-Adhesive Tengucho was laid on the back of the map. This relatively newer product is a 5 gsm mulberry tissue that has been precoated with jin shofu wheat starch paste—it behaves similarly to remoistenable tissues that conservators prepare by hand but has a much thinner adhesive layer. The

Fig. 3. Detaching the lining mechanically while the map is held with suction. Courtesy of Jilliann Wilcox, CCAHA.

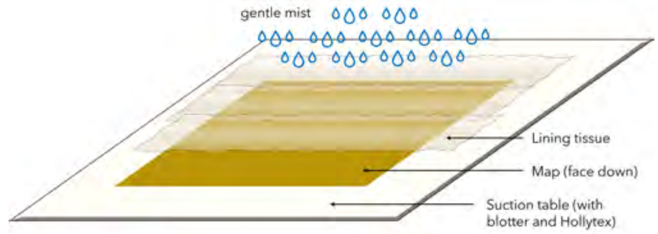

Fig. 4. Diagram of the lining activation process.

lining was activated by gently misting with water while the map was still under suction (fig. 4). In this case, using a new technique, the lining was applied in several 6 inch wide strips for greater control, but an overall single lining may also be possible.

Once the lining was applied with minimal moisture, the map could be removed from suction. The very thin lining was not strong enough to support it permanently but allowed safe handling with no fragment loss throughout the rest of the treatment. The lining tissue was also thin enough that hard creases could be humidified and eased out, even with the lining attached. The map was then washed face up on the suction table, allowing conservators to monitor the soluble media throughout the washing process. During suction washing, the remoistenable lining stayed securely adhered. The map was then lined again overall on a heavier, toned mulberry paper that provided stronger support and bridged the losses visually (fig. 5).

Overall, using the suction table in combination with the remoistenable lining allowed us to prevent any displacement

Fig. 5. Map of Essex County, after treatment. Courtesy of Andrew Pinkham, CCAHA.

or loss of fragments while replacing the unstable cloth lining with minimal moisture. In this example, the media solubility allowed some suction washing after relining, but the suction table, mechanical backing removal, and remoistenable lining could be successful even on media that was too soluble for any amount of washing.

RESOLVING HARD TENTS IN OVERSIZED CLOTH-LINED MAPS

The Schillner maps are a series of 71 hand-drawn maps of the Erie, Oswego, and Champlain canals. They were drawn between 1896 and 1908 based on careful surveying from the winter of 1896, and are colloquially named after George L. Schillner, New York State civil engineer and mapmaker. Each map is approximately 6 × 8 feet and is drawn on a single large sheet of heavy wove paper. The maps are mounted on white fabric supports and have been stored rolled. Currently in the collection of the New York State Archives (NYSA), they will continue to be stored rolled on sturdy alkaline-buffered tubes due to their size.

The paper of the maps remains somewhat flexible, so each map can be rolled and unrolled; however, it retains such a strong memory of rolling that it will not lie flat without restraint. Additionally, there are strong horizontal creases or "tenting" where the ingrained curvature of the paper has resulted in a peak, cracking the paper along the peak (fig. 6). The fabric backing was mostly intact, sturdy, and well adhered but did not pull the paper flat enough to prevent the tenting. Most of the 20 maps examined at CCAHA had three to five major tents across most or all of the width of the map. There were also tented areas that were shorter or less severe, but were expected to develop into larger and more dramatic tents over time. The tenting made the maps unsafe to view or handle, and would also distort the appearance during digital imaging, which was an important goal for the NYSA.

Fig. 6. Tenting on the Schillner maps, NYSA collection.

In determining the treatment plan for this group of maps, CCAHA conservators considered several options, including removing the fabric backings and relining, overall flattening prior to mending, and local flattening and mending. Although the fabric backing could be removed fairly easily either mechanically or with moisture, this did not seem practical because the hand-drawn media was too soluble for washing and lining, and also the size and number of these maps limited the time that could be spent on each. Overall flattening without removing the cloth backing seemed questionable due to the large size of the maps and the strength of both the paper and the cloth, which would create tension when humidified. Additionally, the size of the maps necessitated rolled storage after treatment, so it made more sense to keep them in a rolled format. This left local mending and flattening, which seemed possible but would require fairly strong reinforcement to counter the strong curl of the paper while avoiding creating distortions in the surrounding areas.

Once the client agreed to pursue local flattening and mending of the tented areas, several variations were explored. Local consolidation with methylcellulose was tested but was not strong enough on this heavy paper support. We also tested local humidification, introducing moisture gently through Gore-Tex strips, nano-mist, and humidified blotters, but any method that relaxed the paper enough to lie flat caused radiating distortions, and the weakened crack along the tent meant that the tent would recur as soon as the map was rerolled once.

Because local moisture was a concern, we also tested several nonaqueous adhesives, including films of Lascaux 360 and 498 in various dilutions, activated with either heat or solvents, and Klucel G in ethanol. In combination with testing a nonaqueous adhesive, we compared three mending supports: Hollytex 3257, Bondina, and mulberry paper. We also tested the location of the mending support, whether it could be placed on the verso of the intact cloth or on non-image areas of the recto of the map, or inserted between the paper and cloth backing.

After thoroughly testing mending options, we concluded that applying mending supports to the verso of the cloth could not provide adequate support. Mends with any degree of flexibility applied to the cloth would allow the tent to recur as the fabric bent and the separated edges of the paper split at the peak. Mending the paper on the recto would detract from both the aesthetic and informational value. The only suitable option was to locally peel up the cloth backing to mend the paper on its verso. Once this was decided, we also felt it was necessary to reattach the cloth afterward to avoid having some areas left without cloth backing, which would lead to local tensions and vulnerability.

Based on the adhesive testing, the only adhesive that adhered strongly enough to the tented paper yet remained reversible was wheat starch paste. However, pure wheat starch paste had a tendency to detach from the cloth, which appeared to have a mildly water-repellent finish. To counteract

Fig. 7. Working on the verso by rolling the map onto its storage tube.

this tendency, we used a 2:1 mixture of wheat starch paste and Klucel G (hydroxypropyl cellulose) when adhering to the cloth (note 1). Although the Klucel G was still prepared in water, it is a slightly less polar molecule than starch and was predicted to have a better affinity for the nonpolar finish on the cloth. As expected, the 2:1 wheat starch paste to Klucel G mixture did not peel off the cloth the way the pure wheat starch paste did.

The final hurdle in this treatment was the large size of the maps, which were even more difficult to handle safely with their pronounced curl and fragile tents. To minimize handling, a group of benches slightly larger than the map dimensions was dedicated to this project, with one map undergoing treatment at a time. As each map was unrolled for treatment, the before-treatment photography was completed in that location. A team of five paper conservators would sign up for times on the map workspace so that no single conservator was overwhelmed by the size of the project. When complete, the treated map would be checked and photographed in situ before rerolling. Most significantly, the maps were never placed face down throughout treatment. All verso treatments (surface cleaning, mends, and fills) were completed by rolling the map onto its storage tube to access the verso in sections (fig. 7).

The following treatment steps were used to mend the deep tents:

- The map was rolled onto its tube up to the horizontal tent, with a Hollytex interlayer under the treatment area. When rolled snugly, the tents lie flat.

Fig. 8. Separating the fabric lining and securing the crack with small bridging mends.

- The fabric backing was scored with a scalpel about an inch above or below the tent.
- The cloth was detached mechanically to expose the primary support on either side of the tent crack. As the fabric was removed, small mulberry paper mends were used to hold paper edges in place as needed (fig. 8).
- Any losses along the tent crack were bridged with toned mulberry paper.
- The primary support was mended with 1 1/2 inch wide strips of 30 gsm mulberry paper and wheat starch paste (fig. 9). These mends were dried under small pieces of blotter and weights for a minimum of 1 hour. Because the weights were balanced on the top of the roll, a “crash pad” of acid-free, buffered corrugated cardboard was placed over the exposed map to prevent damage if a weight slipped off the tube.
- The lifted cloth flaps were re-adhered to the map with 2:1 wheat starch paste to Klucel G in water.
- The verso of the cloth was immediately mended with a wider strip of 30 gsm mulberry paper and the 2:1 wheat starch paste to Klucel G mixture (fig. 10).
- The map was unrolled, and the mended area was dried under weights overnight.
- Non-image areas on the recto were given an almost invisible reinforcement with remoistenable tissue (fig. 11). The

Fig. 9. Mending the primary support.

Fig. 10. Reinforcing the secondary support.

Fig. 11. Applying remoistenable tissue to non-image areas of the recto.

remoistenable tissue was prepared in advance by coating 3.5 gsm mulberry tissue with a 1:1 mixture of wheat starch paste and methylcellulose and reactivated with moisture (note 2).

Although an unusual approach to a map treatment, this technique stabilized the vulnerable tents while minimizing handling. Minimizing handling was more important than usual because of the maps' large size and the potential for physical damage from their tenting and curl. The mended tented areas became slightly stiffer, but they could lie flat for digital imaging or roll tightly for storage, as well as being stable to handle either rolled or open. Due to budget constraints, CCAHA conservators completed treatment on 10 of the 71 maps. The rest of the maps will be mended by NYSA conservators as staff time allows, following the protocol developed at CCAHA.

CONDUCTING LARGE-SCALE SOLVENT TREATMENTS

This final treatment described in this article is not specific to one object, but is a solution frequently used at CCAHA when an object requiring an overall solvent treatment exceeds the size of the fume hood. This most commonly occurs with varnish removal from wall maps but can also be applied to any other situation that requires solvents. CCAHA is fortunate to have a large fume hood, but the depth is limited to a natural arm's reach. As paper objects can easily exceed these dimensions, a solution for larger objects was needed.

Several variations of the following design have been used for decades at CCAHA, and the description has been generally approved by an industrial hygienist. However, the specific configuration of any paper conservation laboratory and fume hood may vary. As with any treatment involving solvents, there is some risk of exposure. In our experience, this system

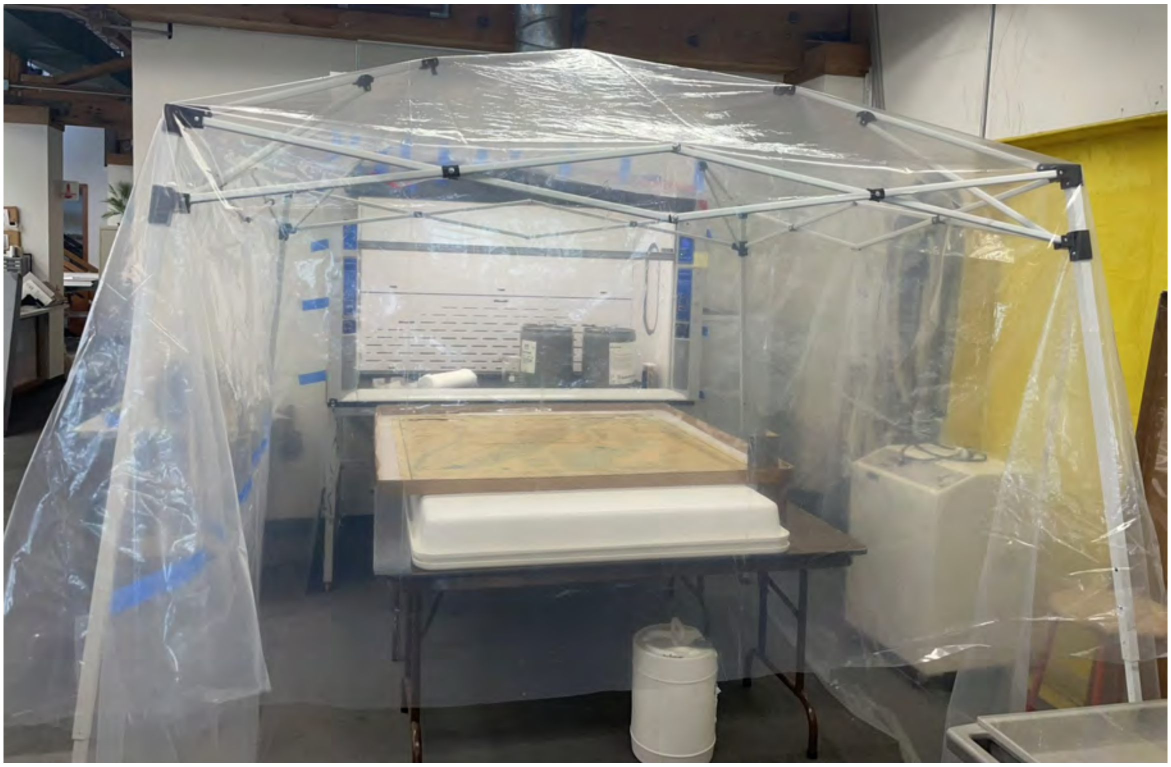

Fig. 12. The temporary tent fume-extraction room.

prevents noticeable solvent odor from escaping into the laboratory, but we have not tested the face velocity of the external opening, nor performed air sampling for solvents in the rest of the laboratory. Please use caution and common sense to minimize exposure with any solvent treatment.

A negative pressure room is constructed outside the fume hood by erecting the frame of an 8 foot pop-up shade tent. The tent's original canopy is not used. The sash of the fume hood is opened fully. The frame is then draped with a large sheet of polyethylene, secured to the fume hood opening with low-tack tape. The plastic sheet should hang low on each side, leaving about a 1 foot gap opposite the fume hood for air intake. When the fume hood is turned on, there will be a steady airflow from outside the plastic tent and up the fume hood exhaust (fig. 12).

Conservators inside the tent wear fit-tested respirators with appropriate filters while using solvents. If staff working outside the tent notice a solvent odor, the setup should be adjusted to reduce leakage. Following treatment, the object will be left inside the tent while the solvent evaporates. The tent has been used successfully with a variety of solvents including ethanol, acetone, and xylene. Because these large solvent treatments are relatively rare, this temporary solution allows the use of a solvent exhaust room when needed without having a permanent dedicated solvent space.

CONCLUSIONS

The three treatment solutions presented in this article were developed to respond to specific problems that were outside of the bounds of everyday paper conservation. This type of problem solving happens naturally in a co-operative laboratory like CCAHA, with many talented conservators working together to tackle new challenges. After delivering this work at the Book and Paper Group session in Salt Lake City in 2024, many other conservators approached me with similar but slightly different scenarios that some aspect of my presentation could contribute to solving. This collaborative creativity is one of the most rewarding aspects of the paper conservation field, and it is my hope that the ideas shared here can be taken and adapted by other conservators to solve future problems.

ACKNOWLEDGMENTS

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NOTES

1. For this project, the initial concentrations used were 1:3 wheat starch to water by volume, strained, before mixing with 5% (w/v) Klucel G. After combining, the adhesive was thinned to a workable consistency with water.
2. There are many recipes for remoistenable tissue in paper conservation literature. CCAHA uses wheat starch paste that is prepared in a 3:1 v:v, water to starch ratio and 5% w/v methylcellulose in water. The paste is strained and mixed with an equal amount of methylcellulose, then the adhesive mixture is thinned with water to a workable consistency.

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Will the Circle Be Unbroken?: A Case Study in Addressing Acceptable Loss, Historic Conservation Techniques, and Project Burnout on a 1732–1796 South Carolinian Church Register

INTRODUCTION

On occasion, there are challenging conservation projects in which treatment seems inadvisable despite the potential reward of improving the objects in a substantial way. In cases such as these, the line between safe, ethical treatment and potential, unmitigated disaster is not an easy one to walk and requires a clear definition of what is considered acceptable loss for the object. In undertaking the treatment of an 18th century church register, the conservators at Northeast Document Conservation Center (NEDCC) were faced with such a challenge.

The register details the early days of the Circular Congregational Church, the earliest congregation of English Dissenters (Protestants) in South Carolina. It was founded in 1681 and was attended by both African American and White members until 1867, when the African American members left to form the Plymouth Congregational Church in Charleston, South Carolina. While some documents from the early days of the church do still exist, many were lost to various disasters including hurricanes, earthquakes, fires, war, and vandalism (Circular Church 2024). The register, with records from 1732 to 1796, is one of the earliest remaining pieces of church history, as the previous volume, according to a memorandum in the register, was lost in the Great Hurricane of 1713. Beyond notes on church matters, the volume also contains vital records from 1732 to 1738, including baptisms, deaths, burials, and marriages for both African American and White members. This makes the volume especially important because, at this time, these types of records were held only by houses of worship. This book therefore has information about the congregants that is not otherwise recorded and is of particular interest given the mixed nature of the congregation.

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The volume was not an unusual object considering its structure, materials, and historical significance; it was, however, so brittle and extensively damaged as to be inaccessible in any tangible manner, despite previous conservation efforts (fig. 1). During the initial examination of the object, it was clear that the conservation treatment would be both challenging and time consuming, and that some loss of the text was likely to occur during treatment. Before moving forward with developing a treatment plan, further discussion with the client was required. This allowed a full understanding of the client's goals, how they planned to use the manuscript, and its future storage conditions. The potential risks and benefits of treatment were also clearly communicated to the client at this time. Following this conversation, more detailed examination and testing of the object was conducted to develop the best possible treatment plan. Once a treatment plan was established and approved, conservators worked together to establish treatment parameters for the object and divide the work into manageable sections. This would allow treatment to proceed in a manner that was of the most benefit to the object, while also ensuring the physical, mental, and emotional health of the treating conservators throughout this daunting and occasionally disheartening project.

THE CIRCULAR CHURCH REGISTER, 1732–1796

Condition and Concerns

The text block consisted of 252 leaves of laid paper with entries written in iron gall ink on both sides. The paper was extremely discolored and brittle, and the iron gall ink was severely degraded with extensive fracturing and drop-out on many leaves. The opening of the volume was restricted by the heavy application of adhesive on the spine and the extreme brittleness of the paper, so access to the leaves in the various text block sections ranged from the manageable to the almost impossible (fig. 2). The challenge of handling and accessing the volume had clearly been a known concern by

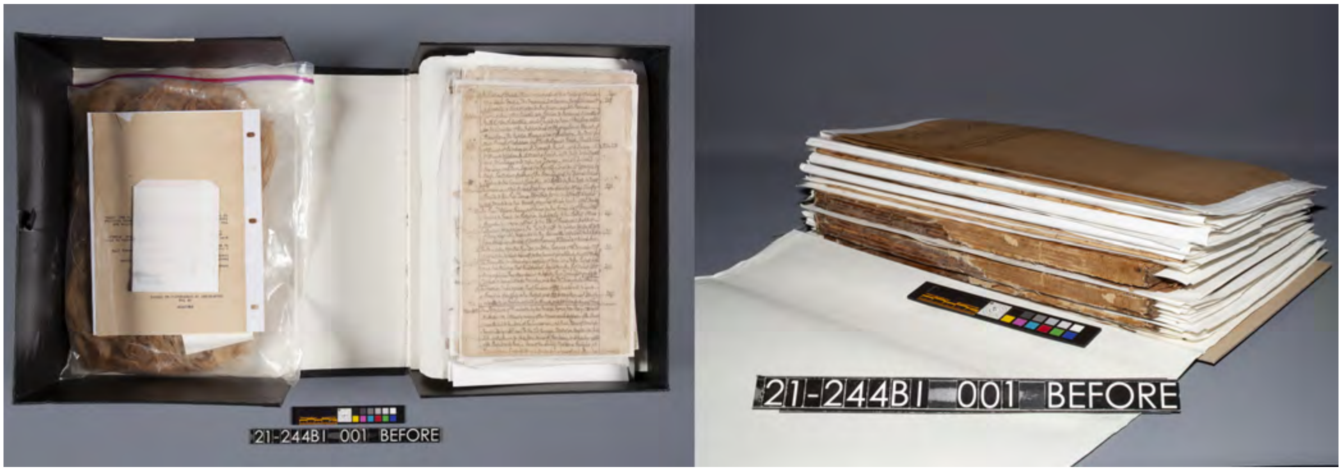

Fig. 1. The Circular Church Register before treatment.

the institution. A note placed near the front of the volume by a previous archivist read, “These pages [are in] extremely bad condition. Handle with great care.” In this condition, safe handling of the volume was not possible. Simply trying to turn the pages would cause leaves to snap out and loose fragments to dislodge.

One of the client’s main goals was to fully digitize the volume to enable greater access to the object and reduce the need to handle the original. However, it was understood that conservation was required to facilitate safe handling during digital imaging. With the improved stability, conservation would enable physical access and exhibition of the volume—neither of which were possible in its pretreatment state. While improving access and facilitating long-term preservation are generally considered a standard function of conservation treatment, the best approach to achieve this goal was debated in the initial stages of examination.

Complicating the condition issues, the register had undergone at least three treatments in the past. The oldest extant repairs, which happened prior to 1936, consisted of strips and patches of translucent paper adhered with water-soluble adhesive over major fractures (fig. 3). It was unclear if the repairs had degraded extensively or not, but upon assessment of volume, the paper patches were dark, brittle, and barely translucent.

Fig. 2. Examples showcasing range of damage in the volume.

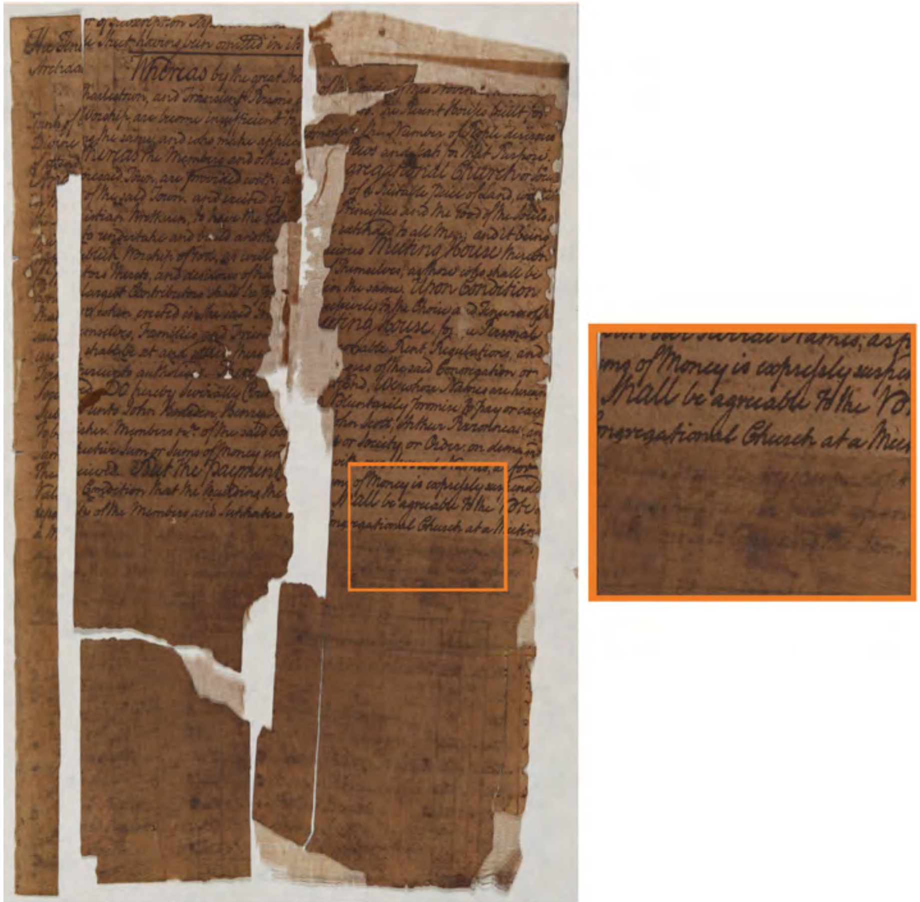

Fig. 3. Example of a large paper patch obstructing text with detail inset.

The second and most comprehensive treatment happened in 1936 when, according to a note included with the volume, the register was treated by the Works Progress Administration (WPA), likely as a part of the Historical Records Survey. As part of this work, three typed copies of the volume were created but have since been lost. During this treatment, the volume was disbound into single sheets and each leaf was lined on recto and verso with silk "chiffon" using a water-soluble adhesive. Silk lining ("silking") was a common manuscript conservation technique at the time and utilized as part of the Library of Congress workflow on fragile documents as early as 1899 (Smith 2016, 253). Its long use at the federal level likely influenced the WPA's choice and methodology for the treatment of this volume. Additionally, the silk chiffon ("crepeline") was noted by many in the archives community to hold iron gall ink and small tears in place more firmly than other linings while being "easily executed by every binder with a little intelligence and skill" [Vatican Prefect Franz Ehrle] (Smith 2016, 254–56).

Areas of iron gall ink fracturing and voids where there was silk lining but no paper suggested that the leaves were already in dire condition when the silking was undertaken. This type of damage was likely what made the register a good candidate for this treatment approach by the WPA. In the subsequent years, the silk had discolored and become brittle and powdery—deterioration commonly seen on silk lined objects—and many of the lined leaves had shattered further, leaving numerous lined fragments loose within the volume and box.

This combination of darkened paper repairs and degraded silk lining rendered some areas of the text completely illegible. Furthermore, given the methods used for silking and the current improved understanding of the physical chemistry of iron gall ink, it is possible that the silking process exacerbated the damage to the media, increasing the overall fragility and embrittlement of the object.

The third and most recent round of treatment was attempted by a conservator in private practice in 2009. This involved partially disbinding the volume, washing, removing the silk lining, and relining the leaves with a wet strength tissue (noted as "spider tissue" in the treatment report) and wheat starch paste (fig. 4). Many fragments of text had separated during washing and were either misaligned or adhered to an extended margin. Forty-nine leaves, including all of the

Fig. 4. Example of a tissue-lined bifolio.

vital records pages, were treated this way before the treatment was halted. According to the conservator's treatment report, there was "no way for me to remove the silk chiffon and apply another support without what I consider to be more loss than benefit" (note 1).

This partial treatment had significant consequences for the potential new treatment of the volume. First, it stood as a warning about what damage could occur during treatment and the level of loss that might be expected. Second, the unbound leaves were no longer in the correct order. As some leaves were missing page numbers—and some page numbers occurred twice in the volume—collation would be a critical step in organizing and tracking the treatment. Third, and most importantly, it meant that two different treatment approaches would be required—one for each type of lining. Consideration had to be given as to the best way to remove the wet strength tissue and unevenly applied wheat starch paste which, when combined, were far stronger than the underlying object.

Treatment Parameters and Establishing Acceptable Loss

Given the challenges presented by the condition of the item, how and why would one take on a project that was virtually certain to have a less than perfect outcome? Will pursuing treatment cause more damage to the object? Or will the object's condition continue to dramatically worsen over time?

Whether conservators want to admit it or not, treatment of objects, especially interventive treatment, always results in a change to the piece. Ideally, as much of the original object as possible should be preserved during treatment. However, a treatment that incurs no loss is not possible. Therefore, the goal is to better understand the potential for loss and weigh that against the potential for future damage of the piece if it does *not* undergo treatment.

Ultimately, although some loss was likely to occur during treatment of the Circular Church Register, treatment would provide enhanced access and improved long-term stability, and was therefore considered beneficial. After discussion, the client agreed to having the volume fully digitized twice—once before washing and removal of the silk, and again after washing and mending were complete. Digitization of the object prior to conservation not only protected against the loss of information but also created an important visual reference. Conservators were able to consult the "before" images to help them place loose fragments, and the two sets of images together captured the maximum amount of information.

When preparing for this intensive treatment, NEDCC's book and paper conservators collaborated to create a plan to complete the work. The ratio of projected loss for each leaf was determined using the 20-60-20 rule. This ratio can be helpful in cases where conducting item-by-item estimates is impractical or especially challenging, but still requires some

Fig. 5. Example of a Farmer (left), a Sheep (center), and a Goat (right) before treatment (a) and after treatment (b).

overarching understanding to determine treatment pathways and their associated times and costs. Using this ratio, it was assumed that 20% of the volume was in *good* condition, 60% of the volume was *fair*, and 20% of the volume was in *poor* condition, with the understanding that even the leaves in good condition were challenging to handle and easily damaged (note 2). Differing perspectives in thinking about each leaf at an individual level and holistically as a bound volume helped further define best- and worst-case scenarios for loss. In pieces such as these, collaboration within laboratories and leaning on skills and knowledge from other conservators can be critical in creating projected percentage losses for each object (fig. 5).

To determine the overall percentages of potential loss, loss and gain were both defined as the amount of text area in the piece that would be either destroyed or reconstructed by treatment. A gain was further defined as improved handling and legibility. Counter to this, a loss was further defined as the likelihood for disintegration or irreparable fracturing of the paper during treatment.

The condition of the leaves was assessed through transmissive light. For the leaves in good condition, it was believed that there would be no loss, as these leaves had minimal or no tears and media fracturing. The leaves in fair condition were thought to potentially have between 5% and 10% loss, with most being 5% or less loss overall. These leaves included many of the leaves lined in 2009, as well as silked leaves that had moderate to severe fracturing but no major paper losses. Within this group, it was projected that the tissue-lined leaves had the potential for a greater amount of loss. The remaining leaves in poor condition were projected to have between 20% and 30% loss throughout the course of treatment. These were the leaves that were the most damaged and already had 30% to 40% loss to their text or substrate. As a single object, such a level of loss would be considered a catastrophic failure and indicate that treatment was inadvisable.

However, collectively, these potential percentages were projected to equate to somewhere around 5% total object loss, with a maximum of 10% object loss expected in a worst-case scenario. Counter to this, the gain in accessibility was projected to be between 90% and 100% when factoring in the potential to place loose fragments, remove obscuring linings and mends, increase paper and media stability, and improve physical and intellectual control by rebinding the volume. Using these projections, acceptable loss was then informally defined as overall 5% or less loss to the individual leaves, with a grace window of 10% or less for the bottom 20% of materials. As part of the decision to move forward with treatment, the client was informed that if loss went outside these percentages, treatment would be stopped and either modified or reduced depending on what was observed.

The greatest risk of meaningful change would occur during the aqueous treatment step. It was within this treatment step that further guardrails were established to try to maintain the level of acceptable loss. First, the leaves were divided into groups using the somewhat comical but useful shorthand of Farmers, Sheep, and Goats. Originating from an off-hand comment about having to “separate the sheep from the goats,” these terms forced a break in each conservator’s personal bias for what it meant for a piece to be in fair, average, or poor condition. Beyond this, it also provided a bit of levity during an otherwise serious and occasionally overwhelming project. Each leaf was assessed before and after aqueous treatment based on this ranking by both senior conservators simultaneously. Farmers (52 leaves = ~20%) were deemed to be able to take care of themselves–that is, they were in good enough condition to be washed in groups with little damage occurring or much mending needed after aqueous treatment. Sheep (156 leaves = ~62%) needed more attention but in most cases were within the bounds of what was considered standard damage for this volume. This was the broadest category in terms of condition issues. After aqueous treatment, some leaves were marked as “Sheepish Goats” because it was apparent that these leaves would need more extensive mending than initially predicted. The Goats (44 leaves = ~18%) were expected to be nothing but trouble; would require individual, undivided attention during aqueous treatment; and would likely need to be lined rather than mended afterward.

Once divided into groups, the following treatment guidelines were established:

1. Each stage of treatment would be fully completed before the next stage was begun to assess the change evenly and equally across the entire project.
2. The leaves were to be treated so that within each step, the Farmers were treated first, then the Sheep, and then the Goats to refine the treatment process and minimize the potential loss.
3. The aqueous treatment would be completed by two senior conservators working simultaneously in the laboratory’s two fume hoods. This would allow the conservators to share their expertise and experience and compare notes as they went along.
4. To prevent burnout, aqueous treatment was never to be done more than two days in a row and never more than three days in a week.
5. Leaves were lined by the same conservator who washed that leaf, as they tended to have a better memory of how it broke and where fragments needed to be placed. Due to a scheduling conflict, this was later revised so that most of the lining was completed by the senior paper conservator and then most of the loose fragment placement was done by the senior book conservator.
6. Mending would be completed with the help of a third conservator.

These parameters not only allowed for tight monitoring of change to the leaves, including any loss or fragmentation that might occur, but also encouraged staff to pace themselves and consult with each other if something was especially challenging, weird, or just overwhelming. This collaborative approach facilitated sharing of differing techniques on the same treatment, led to a deeper appreciation for the work being conducted, helped minimize project burnout, and provided a space in which to reevaluate treatment biases that may be present.

TREATMENT OF THE REGISTER

After photo-documentation, disbinding and collation were done simultaneously. The leaves had been paginated, but the volume was written from both directions—meaning it had

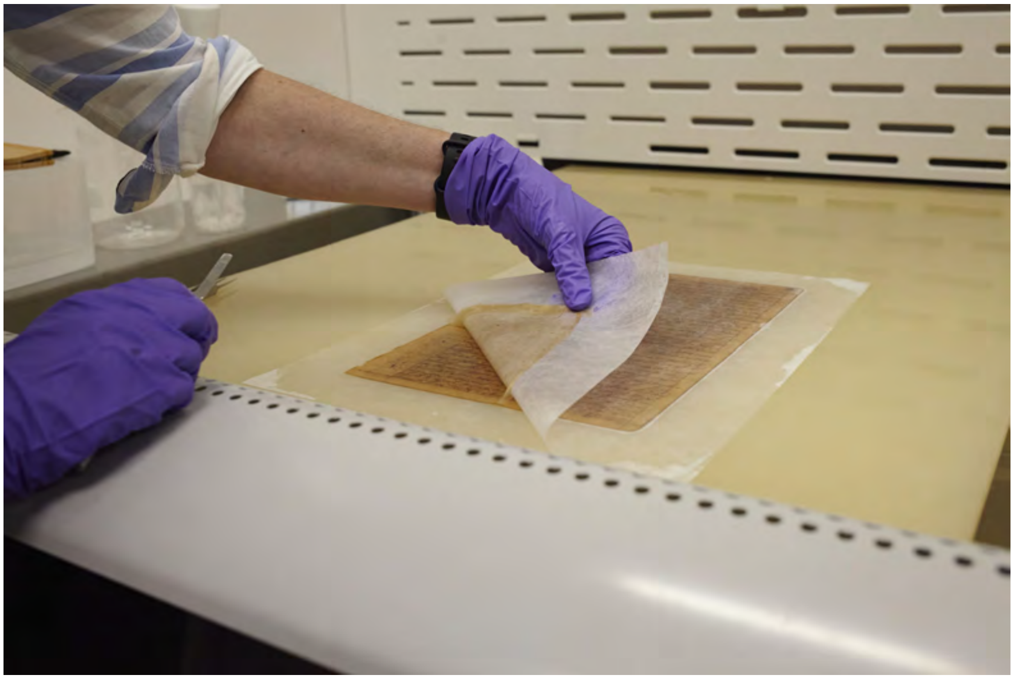

Fig. 6. Removing the silk lining from a leaf.

two front covers and no back cover. Furthermore, it was out of order when it arrived due to the 2009 treatment. Many leaves were snapped off near the gutter margin, leaving only the stubs still bound due to the ruling line. During collation, the stubs were separated and matched with leaves, fragments were matched with corresponding leaves as possible, and each leaf was placed in a numbered folder. During this process, the first word or phrase on recto and verso of each leaf was recorded in a spreadsheet so that the leaf could be recognized even if the page numbers were missing. This spreadsheet was critical throughout the treatment to ensure that nothing was misplaced or lost while moving through the steps.

Each leaf and all fragments, whether associated with a leaf or not, were then photographed both recto and verso, cross-referencing the spreadsheet that was created during collation. The high-resolution digitization was done using a Phase One 100 megapixel back camera to capture the leaves at 600 ppi and a minimum of FADGI 3 Star quality across all relevant metrics. By doing so, the images allowed true capture of the maximum amount of information remaining in the volume.

After dividing the leaves into their respective categories, aqueous treatment began. Each day's work followed a set of internal protocols that used as a foundation the methods, steps, and solutions detailed by Birgit Reissland, Karin Scheper, and Sabine Fleischer on the Iron Gall Ink website (Reissland, Scheper, and Fleischer 2007). These protocols included rough time slots in which steps needed to be completed and were established to ensure that treatment of iron gall ink material was complete within the 8-hour workday. This led to the conservators working on a strict schedule on the days that aqueous treatment was conducted and was one factor in limiting the number of days in a row that this part of the treatment was undertaken. The only modification to the usual washing and phytate protocol was that removal of the linings was factored into the schedule.

It was believed that the silked Farmer leaves would be the easiest and most predictable leaves to begin the treatment. More intensive solubility testing was conducted to confirm that the observed preliminary media stability was accurate before overall aqueous work was done. Once confirmed, the leaves were sprayed out with ethanol to help with equal paper and media expansion before brushing a 50:50 ethanol and filtered water solution through a nonwoven polyester (Hollytex) support to fully saturate paper and silk and solubilize lining and mending adhesives. The silk lining and paper mends were removed from the leaves mechanically. The silk removal process primarily relied on water surface tension between the silk and Hollytex with brushes and tweezers only used for the most degraded sections (fig. 6). The WPA had applied the silk in a format that had not been seen before by the treating conservators. Rather than separate pieces of silk on each side of the document, the silk had been wrapped around the fore edge. This required flipping the piece mid-removal, as the silk could not be cut without pulling fractured media and paper away. With the silk removed, paper mends could then be removed by lifting fragments with a spatula.

Fig. 7. Tissue paper lined leaf (left) that had a section (right) that could not be fully removed from the wet strength tissue used in 2009.

For the 2009 tissue linings, a similar methodology was used with one small adjustment. When the pieces were treated in 2009, the wheat starch paste that was used to adhere the lining to the object was not well sieved, leading to an uneven application of the paste. It was determined that after brushing with a 50:50 ethanol and filtered water solution, the leaves needed to be placed in a 30:70 ethanol and warm filtered water bath for 5 to 15 minutes. The longer, warmer bath helped soften and dilute the adhesive so that mechanical removal of the tissue was possible. Overall, removal of these linings was both slower and more difficult, especially after one side had been fully removed. In a few cases, the paste had become bound with the iron gall ink, leaving a ghost image of the text on the tissue, although there was not a noticeable decrease in legibility on the leaf. Excess chunks of paste had to be mechanically removed from the surface once the tissue had been released before treatment could continue.

It was toward the end of treatment of these leaves that a leaf fell outside of what both conservators considered an acceptable loss. There was an irregularly shaped 4 × 3 inch section where the lining could not be removed on one side despite all efforts (fig. 7). The paper appeared to have weakened internally from prior treatment and sheared laterally during the removal of the much stronger lining tissue and adhesive despite adjustments to the treatment process. In this case, it became clear that more time or alternative local removal methods were needed. As there was a clear area of breakage from prior damage, both conservators agreed that separating as much as possible and then washing the tissue-lined piece along with the rest of the leaf was the safest option to salvage the section. While removal with local moisture and methylcellulose poultices was later attempted, the fragment could not be removed from the lining and was unable to be rejoined with the rest of its leaf. It was later encapsulated on a separate page in the correct location so that the text could be read. The damage to this leaf resulted in a temporary pause to the work while conservators assessed what had happened and what remained to be done. As this had been one of the very last lined leaves to be treated and no similar issues were expected to arise with the remaining leaves, aqueous treatment was continued.

After the linings were removed, the leaves were then transferred to the first of three wash baths, each decreasing the ethanol ratio from 30:70 to 10:90, until they were placed in pure filtered water. The leaves were stacked no more than five to a tray, and two trays were usually done simultaneously by each conservator. The number of leaves treated in a day eventually decreased to one leaf per tray and two trays per conservator once reaching the Goats. When washing was deemed complete, the leaves were transferred to the calcium phytate solution, evaluated with bathophenanthroline paper to confirm media stabilization, and moved to the calcium bicarbonate bath. Predrying and sizing with a 1% gelatin solution were then completed with conservators partially reconstructing the leaves by placing as many fragments in the correct location as possible.

Overall, after drying, there was significant improvement in color and legibility, the leaves were no longer shedding silk dust every time they were touched, and the degradation processes affecting the ink and paper had been slowed. In total, the aqueous treatment stage required 268 contact hours completed over a course of two and a half months.

The partial reconstruction of the leaves prior to sizing was helpful to check if there were any significant losses and render judgment about how the treatment was going overall. It also helped when it came to mending and lining the leaves, as fragments were usually already close to their final locations, speeding up the accuracy and mending process overall. For the leaves that were mended, a lightweight (7 gsm) machine-made Japanese tissue paper with a pale brown tone was used. The paper was prepared as a solvent set tissue using 5% Klucel G in ethanol and reactivated with the same solvent when they were applied. As the leaves would be encapsulated, strategic bridge mends were used to stabilize the breaks, tears, and losses rather than fully mending every break. Some of the trickiest mending was done in areas where previous repairs had been removed prior to lining with silk, likely by the WPA workers. The previous removal of old repairs had left networks of small fractures and losses surrounding some straight-line fractures (fig. 8). While the original straight-line fractures were easy to deal with, there were often new small losses or minor enlargement of the existing losses once the silk was removed from these sections. Many fussy little bridge mends were required to stabilize these areas.

After several of the Sheep and Sheepish Goats were mended, all three conservators discussed the need to line the Goats. While originally it was hoped that this could be avoided or kept to a minimum, the extensive fracturing of the Goats made bridge mends impractical. Due to the beneficial properties of gelatin on iron gall ink corrosion (Gimat et al. 2021) and the observed effects of the previous paste linings, the choice was made to use gelatin as a lining adhesive rather than wheat starch paste. The leaves were lightly remoistened overall and placed on a lightbox for chain line alignment and to have the fragments placed, a process that could take several hours to complete. The high-resolution before-treatment images were referenced during this process to best reconstruct text and ensure that the correlating sides of the fragment and leaf were chosen, as there were some “islands” of fragments connected to the rest of the leaf by a small bridge of text that could easily go awry. The leaves were then lined on the versos only with a 5 gsm machine-made Japanese tissue paper that allowed for the text to still be legible. An unexpected downside of this lining and adhesive choice was not discovered until the final digitization of the volume. The specular reflectance from the gelatin resulted in more obstruction of text in the digital images than was observed in person or, when later rebound, through the polyester film of the postbinding encapsulations.

After the mending and lining were complete, a daunting number of fragments remained—including many bits that had been loose in the volume’s enclosure and could therefore have come from anywhere within the volume. The fragments were spread out in trays and were compared against all leaves that still had areas of loss. In most cases, this final matchup produced more complete leaves than were observed at the start, but for some of the Goats the gains of reconstructed text were offset by new losses (fig. 9). Any fragments that remained after this process, most which had little or no text on them, were grouped based on the believed approximate location, placed in polyethylene bags, and boxed in a 5-minute phase box made from gray archival corrugated board for return to the client.

After the second round of high-resolution digital capture, all that remained was to encapsulate, postbind, and box the volume. Due to the number of leaves and the added weight of polyester film, it was agreed that the register would be divided into two volumes. The division within the register was chosen to be between pages 200 and 201, as this is one of the few places where an entry ends on a verso and the next begins on a recto. While not the exact center, dividing the text at a round number made intuitive sense and avoided splitting an entry between the two volumes. A 4 mil Melinex 516 polyester film was used for the ultrasonic encapsulation, and the leaves were returned to their original order and orientation during the process.

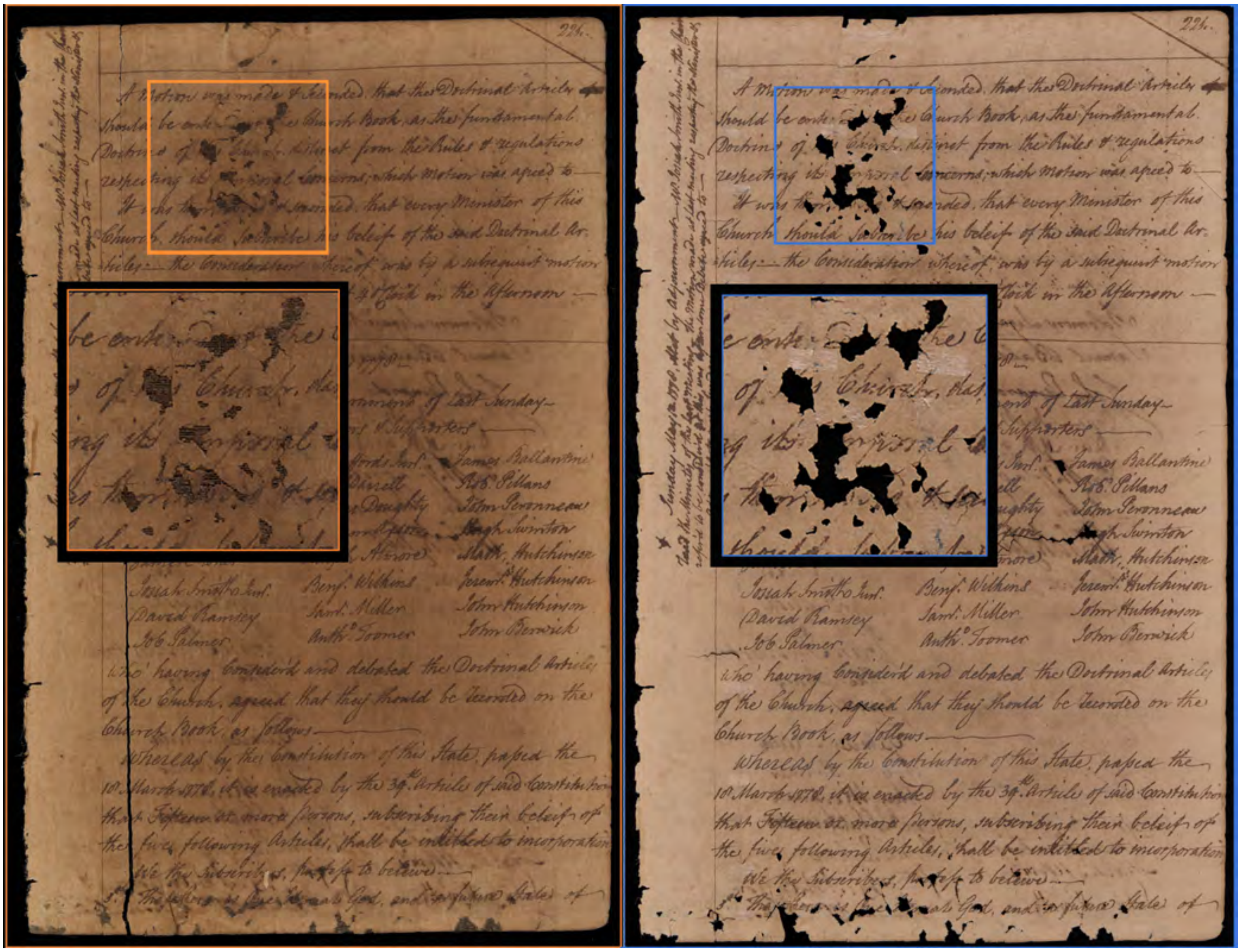

Fig. 8. Damage showing where a previously applied paper patch was removed by the WPA (left) and the complications it caused during the mending process (right) after aqueous treatment.

This meant that the vitals and tabbed index were encapsulated "upside down" as originally written. The volumes were then housed in two drop-spine boxes—one with a space for the corrugated box that contained the unplaced fragments and the other with space for the previous binding (fig. 10).

CONCLUSIONS

Overall, most of the leaves, as well as the volume as a whole, stayed within or under the acceptable loss parameters established at the beginning of the project. For the intact and mostly intact leaves, the gains in legibility and stability were obvious. For many of the severely fractured leaves or fragmentary leaves, the gains were also obvious. Piles of fragments were now organized into leaves, and paper patches were no longer obscuring text; however, in a few cases, these gains were offset by new losses. Despite these losses, the result was one that met the goals of capturing the information in the register, allowing for safe use of the original, and safeguarding the volume for the future.

The success of this challenging project can be attributed to the systematic, coordinated efforts by the conservation and digitization teams. While organizing and planning treatment is second nature to many conservators, it is easy to become entrenched in treatment biases when working solo. By approaching the methodology in a way that establishes clear treatment protocols, pathways of communication are open that allow for honesty in the work, both from a treatment and mental health standpoint. Conservators were able to communicate observations or concerns in an honest manner throughout the project and check in with each other to figure out if the issue was with the piece, with the approach, or with the conservator that day. This way of working, along with the ability to consult the original high-resolution captures as a

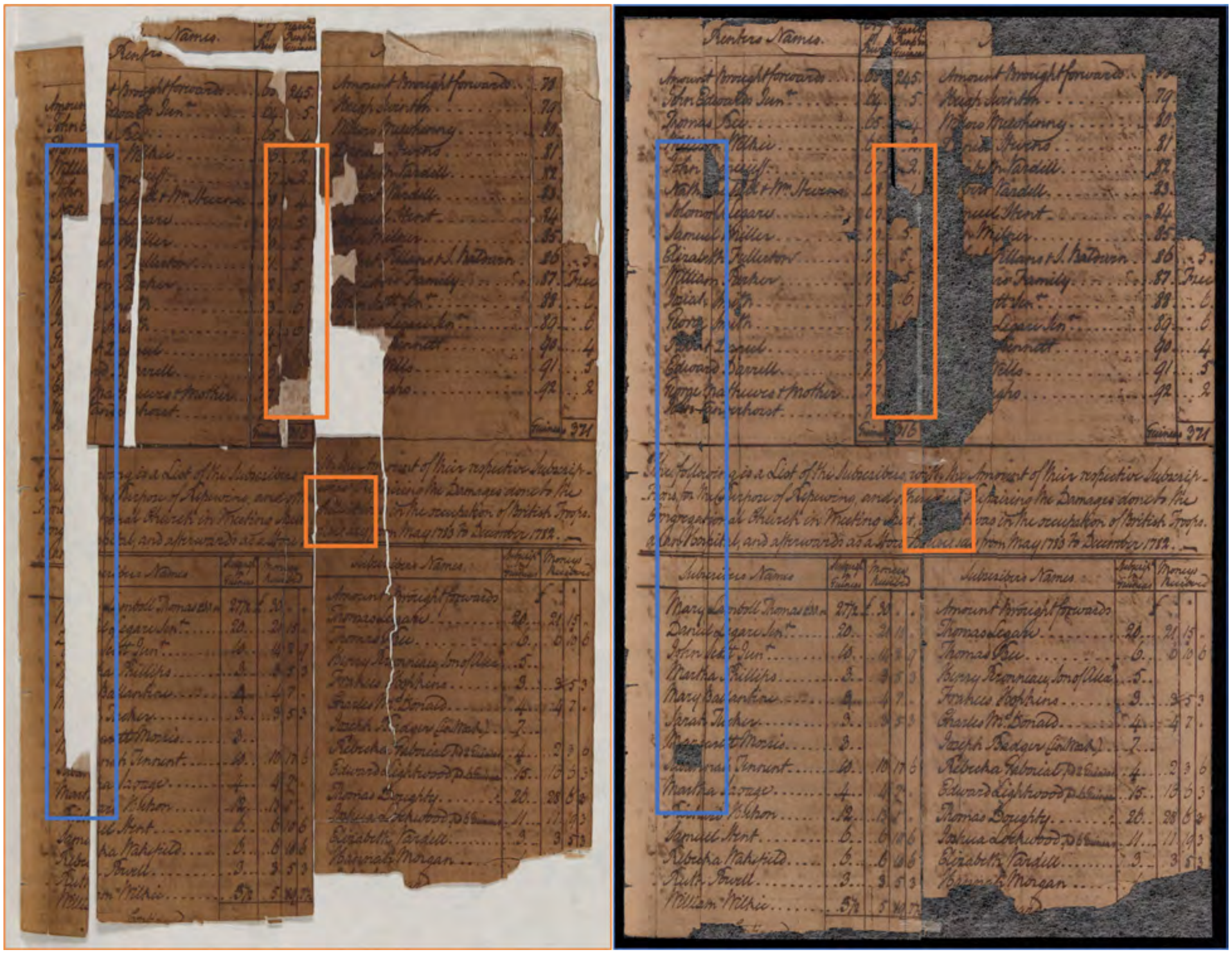

Fig. 9. Examples of gain (circled in blue) and loss (circled in orange) on a Goat.

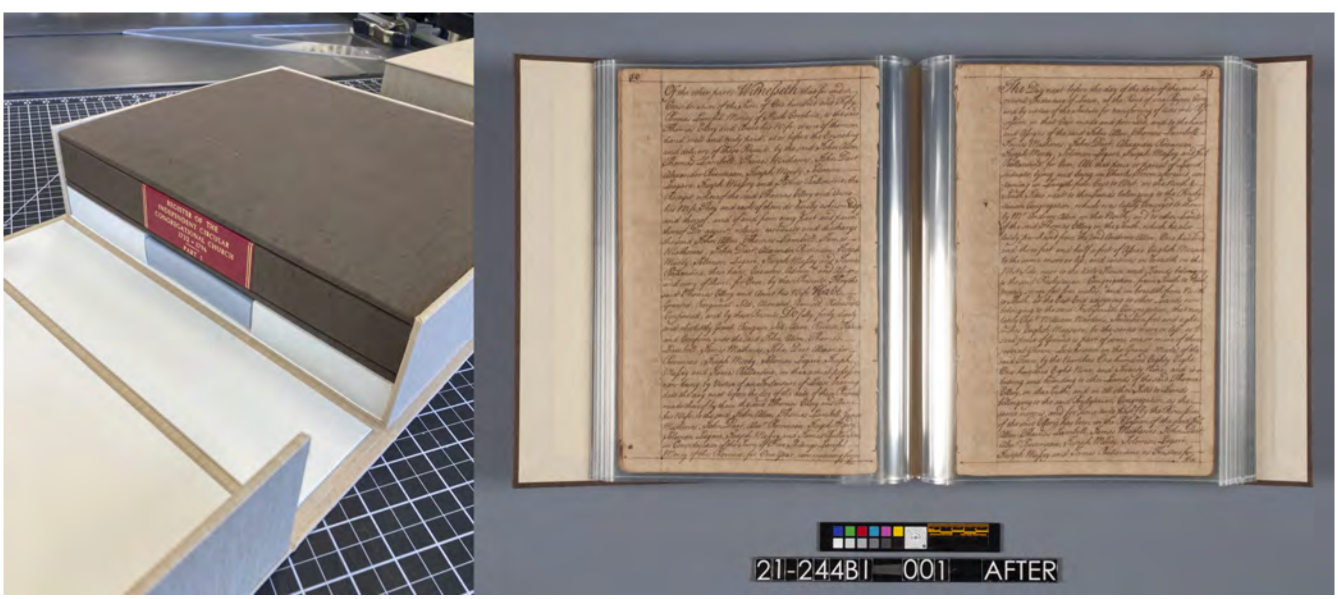

Fig. 10. Part of the Circular Church Register after treatment.

point of reference, led to careful consideration at all stages, allowed for realistic assessment of the inevitable changes to the object, and ensured that treatment remained as safe and ethical as possible for this complex project.

ACKNOWLEDGMENTS

The authors would like to thank Virginia Ellison, archivist, and the South Carolina Historical Society for the opportunity to both work on and present the treatment completed. Additional thanks go to the others involved on the project behind the scenes: Associate Collections Photographer Harrison Walker, NEDCC; Collections Documentation Specialist Meredith Moore, Peabody Museum of Archaeology & Ethnology (formerly associate collections photographer at NEDCC); Director of Book Conservation Bexx Caswell-Olson, NEDCC.

NOTES

1. The authors acknowledge that this cannot have been an easy decision to make or an easy treatment report to write, and commend the conservator for being honest about the state of the project and realizing that they could not continue with the treatment. In doing so, they offered valuable insight into the process when making decisions about the levels of acceptable loss.
2. The 20-60-20 rule ended up being close to accurate. The 52 Farmers (good) made up 20.6% of the volume, the 156 Sheep (average) made up 61.9%, and the 44 Goats (poor) made up 17.5%.

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Plotting a Treatment: Delaminating and Bathing an 18 Foot Manuscript Map

INTRODUCTION

Oversize materials can be intimidating, and an 18 foot laminated manuscript map from San Juan National Historic Site was no exception. The size increased the handling risks during treatment, and required planning and logistics not typically needed for paper conservation. While the treatment steps for this project will be familiar to most paper conservators, their application to a map of this size represented a unique challenge.

The treatment plan evolved from careful testing and from prior observations made when treating two smaller, similarly laminated maps. The overall treatment was successful, with both planning and luck contributing to the final outcome. The goal of this article is to share what was effective and what could be done differently to make the process even smoother in the future.

San Juan National Historic Site

This map, along with 27 other documents and maps in similar condition, came to Harpers Ferry Center (HFC) after being identified as a high priority for treatment during a 2016 collections condition survey at San Juan National Historic Site. This park preserves and interprets the colonial era forts and walls that surround old San Juan in Puerto Rico. The history and collections of the park cover more than 500 years, including the Spanish-American War at the end of the 19th century.

The items conserved, which include letters, telegrams, maps, and covert messages, document US involvement in Puerto Rico and the transfer of power from Spain near the end of the war. They were all given a high priority for treatment during the survey due to an extensive cellulose acetate lamination campaign carried out at some point in the past. Some of the documents incorporated thin layers of tissue with the acetate lamination, whereas others were mounted overall to folder stock, or cloth with multiple layers of cellulose acetate.

LeHardy Map

The 18 foot map (fig. 1) was drawn in 1898 under the direction of George Washington Goethals, chief engineer of 1st Army Corps. Goethals is best known as the chief engineer for the Panama Canal. Paul LeHardy, the topographer, also has a tie to the National Park Service, as he was a member of the Jones expedition in 1873 to map the Yellowstone River. A cascading rapid in Yellowstone National Park was named for him after his party capsized there. The map will be referred to as the LeHardy map throughout this article.

Smaller Maps

The treatment of two smaller maps in the collection contributed significantly to understanding the potential pitfalls for the LeHardy map. The first, *Sketch Map, City of San Juan*, is hand drawn with black and red inks, blue washes, and graphite notations on architectural starched linen. It measures 12 × 24 inches. The second, a drawing in graphite and black media on extremely thin, poor-quality paper, depicts the whole island of Puerto Rico. The solubility and appearance of the black media (discussed in section 4) suggests Conte crayon or something similar. This map is 24 × 36 inches.

DESCRIPTION AND CONDITION

The LeHardy map is one continuous 18 foot sheet of heavyweight, machine-made paper. It is completely hand drawn with a graphite underdrawing and inked lines. The inked areas are opaque, using several colors including black, blue, and brown.

The LeHardy map (fig. 2) and the two smaller maps had been laminated in exactly the same conformation. The paper supports were mounted onto a woven cloth backing and heat- and pressure set with three layers of cellulose acetate film using a hydraulic press (fig. 3): one layer on the recto,

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Fig. 1. During-treatment image of the LeHardy map just prior to humidification and flattening.

one layer between the map and the support, and another layer on the verso of the maps.

Cellulose acetate lamination was established by conservators at the National Archives and Records Administration (NARA) in the 1930s as a standard conservation treatment and was regularly practiced into the 1980s (Page 2003, 55). The idea behind this outdated treatment was to create a rigid and self-sustaining support for fragile documents.

For these three maps, the most dire condition issue was the degradation of the cellulose acetate lamination. This was immediately apparent upon unrolling the LeHardy map, as the map emitted the distinct vinegar odor that is synonymous with cellulose acetate deterioration. Even when kept in optimal storage conditions, cellulose acetate can oxidize and degrade into acetic acid—the same compound found in vinegar.

Cellulose acetate can create a host of condition issues, such as embrittlement, cracking, off-gassing, oxidation, and discoloration, as well as cockling and warping (fig. 4), as the map and support degrade at different rates. In addition, the degradation reaction is autocatalytic and will worsen, more quickly, over time without intervention.

In addition to the cellulose acetate lamination, each of the maps had condition issues typically seen in paper, including discoloration, tears, staining, tide lines, and minor losses.

TREATMENT GOALS

The primary goal of this conservation campaign was to remove degrading cellulose acetate from 28 documents from San Juan National Historic Park. This treatment, along with more typical stabilization treatments like mending and washing, was imperative to slow their deterioration and preserve the objects for long-term access for park visitors and researchers.

Delamination requires solvent baths, which are time and space consuming, often requires the use of hazardous chemicals, and does not always successfully remove the cellulose acetate. Furthermore, even when delamination is successful, total removal of the cellulose acetate is impossible, such as

Fig. 2. Before-treatment images of the LeHardy map.

Fig. 3. A document undergoing lamination treatment at NARA in 1949. Courtesy of the National Archives Catalog.

in this case, where the plastic film was fused with the paper fibers and media during application.

The main challenge of this treatment was determining how to delaminate an 18 foot map. Spatial limitations notwithstanding, establishing and practicing a treatment protocol on smaller objects prior to treating the LeHardy map was crucial in ensuring a successful outcome. Since the other two maps were on a much more manageable scale, treatment was carried out on these first to identify the most successful approach for treating the LeHardy map.

SOLVENT TESTING

To begin, extensive solvent testing was carried out on the media of all three maps. This was the most time-consuming step, taking about three days to identify a solvent that would dissolve the cellulose acetate but would not disrupt the various media found throughout the maps. This step was done with the aid of a microscope and an elephant fume trunk. Solvents were brushed through the layers of cellulose acetate until the paper and media were exposed. It was apparent when the cellulose acetate was dissolved, as the surface turned from

Fig. 4. Laminated and severely warped NARA record.

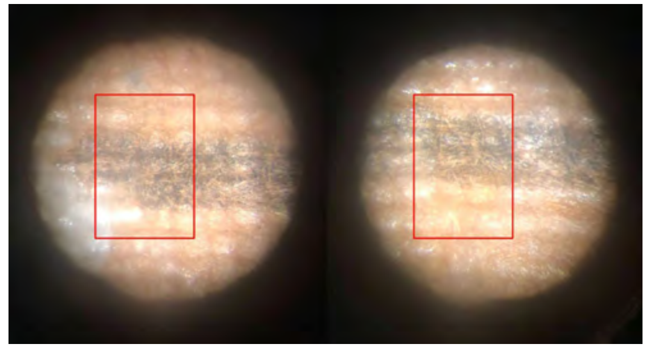

Fig. 5. Left: Microscopic image of a section of the map prior to solvent application; texture is shiny and smooth. Right: Microscopic image of a section of the map after solvent application; texture is matte and fibrous.

shiny and smooth to more matte and fibrous, typical of bare paper (fig. 5).

It is standard to begin this testing with acetone and ethyl acetate, as these solvents are known to dissolve cellulose acetate. While these were both successful in softening the laminate, they disrupted the red media and some of the heavier applications of black media on the two smaller maps. Further research was needed to find a solvent that would dissolve the laminate without damaging the media.

The Teas chart was an invaluable tool when finding a solvent with similar bonding forces as acetone and ethyl acetate. Several solvents were identified using the Teas chart, which were then cross-referenced with the inventory at HFC, including methyl ethyl ketone (MEK). MEK falls close to acetone on the Teas chart (fig. 6), indicating that it has similar solubility characteristics.

Following the same solvent testing procedure, the media of the two smaller maps was tested with MEK and found to be stable. However, the short-term workplace exposure limit for MEK is about 300 parts per million (ppm) (New

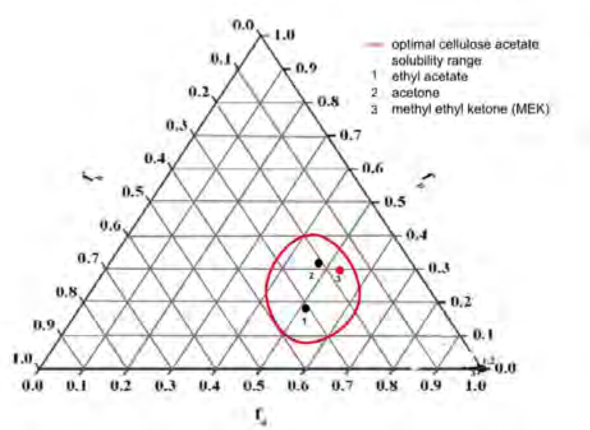

Fig. 6. Teas chart showing the three primary cellulose acetate solvents: ethyl acetate, acetone, and MEK.

Jersey Department of Health and Senior Services 2002), which is significantly lower than that for acetone (750 ppm) (New Jersey Department of Health and Senior Services 2015). To limit unsafe exposure to MEK, a 1:1 mixture of acetone and MEK was tested and had no negative visual impact on the media, and so was chosen to delaminate the smaller maps.

SAFETY

Acetone and MEK are noxious solvents that can cause serious skin and lung irritation in the short term, and reproductive and neurological complications from long-term exposure (New Jersey Department of Health and Senior Services 2002, 2015). To minimize these effects, delamination treatments were carried out in well-ventilated areas and with proper personal protective equipment.

Only the "Sketch Map," the smallest of the San Juan maps, fit inside the fume hood at HFC, so treatment was carried out there using nitrile gloves (fig. 7). For the other small map, the one depicting Puerto Rico, an outdoor treatment area was set up using an industrial fan to encourage further air movement (fig. 8). This treatment was also carried out using just nitrile gloves, but it quickly became apparent from the odor that working directly over a solvent bath, without respiratory protection, even outdoors and with a fan, created the potential for unacceptable solvent exposure on a large scale.

Fig. 7. The smallest map undergoing delamination in a disposable Mylar tray inside a fume hood.

Fig. 8. Delamination setup of the middle-size map.

The LeHardy map was going to require multiple solvent rinses that would take several hours to complete, so all participants in the treatment were medically cleared and fit tested for respirators. Half-mask respirators equipped with organic vapor filters were worn during the delamination of the LeHardy map.

PRACTICE RUNS ON SMALLER MAPS

Both of the smaller maps were successfully delaminated (fig. 9), which suggested that the LeHardy map would also be successful should the same treatment procedure be followed. However, there were some issues that arose during those treatments that required tailoring the approach according to the object's needs.

To begin, peeling the backing material off the smallest map prior to solvent submersion streamlined the treatment immensely. With the middle-sized map, the paper was too fragile and the adhesive had become too cross-linked to safely remove it prior to the solvent bath, so it was necessary

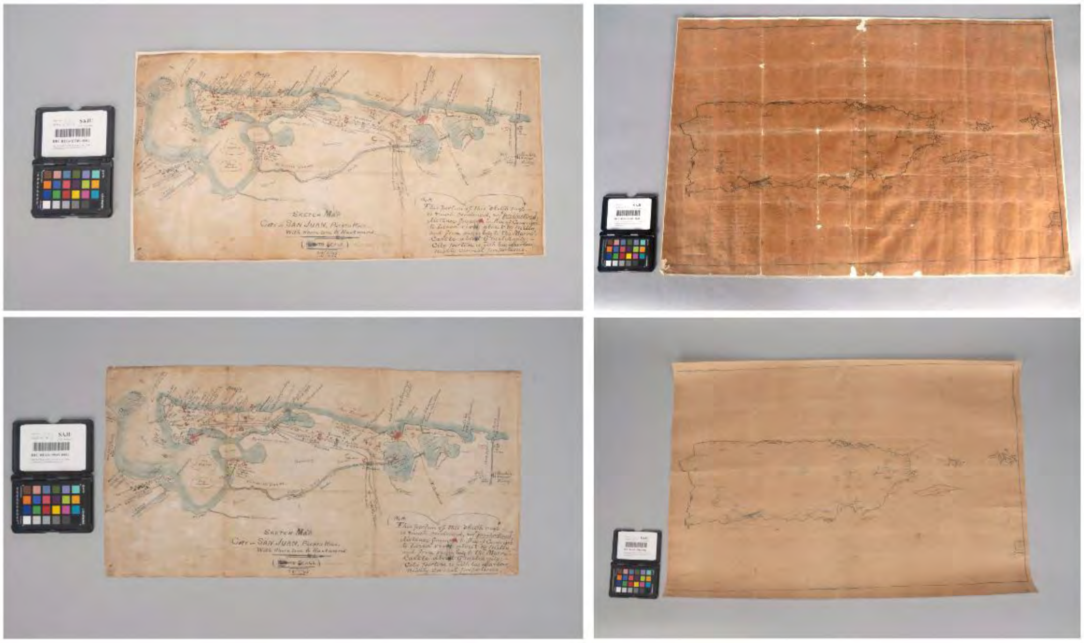

Fig. 9. Top and bottom left: Before- and after-treatment images, respectively, of the smallest map. Top and bottom right. Before- and after-treatment images, respectively, of the middle-size map.

to remove it while the document was submerged, which required additional time and care (fig. 10). Fortunately, the backing material of the LeHardy map peeled off easily before submersion. Furthermore, when stripping the backing material, the middle and bottom layers of the laminate were removed as well, which allowed the delamination treatment to be carried out from just the recto rather than the recto and verso. This saved an enormous amount of time and resources.

Additionally, the container for the solvent bath had to be customized for each map. For the smaller maps, disposable trays were constructed of Mylar (polyester film). The Mylar was cut to 2 inches larger than both the width and length of the map, then stapled at the corners to create walls (see fig. 7). The easy construction and simplicity of the materials allowed multiple trays to be made for each solvent rinse. However, creating multiple 20 foot long Mylar trays to accommodate the full size of the LeHardy map was not going to be feasible or structurally sound. Finding an alternative that would support the weight of the object was necessary. Therefore, the map was delaminated piecemeal, in a smaller, more manageable container with walls able to support the weight of the heavy paper.

Fig. 10. Left: Dry removal of the cloth backing from the smallest San Juan map. Right: Wet removal of the cloth backing from the middle-size San Juan map.

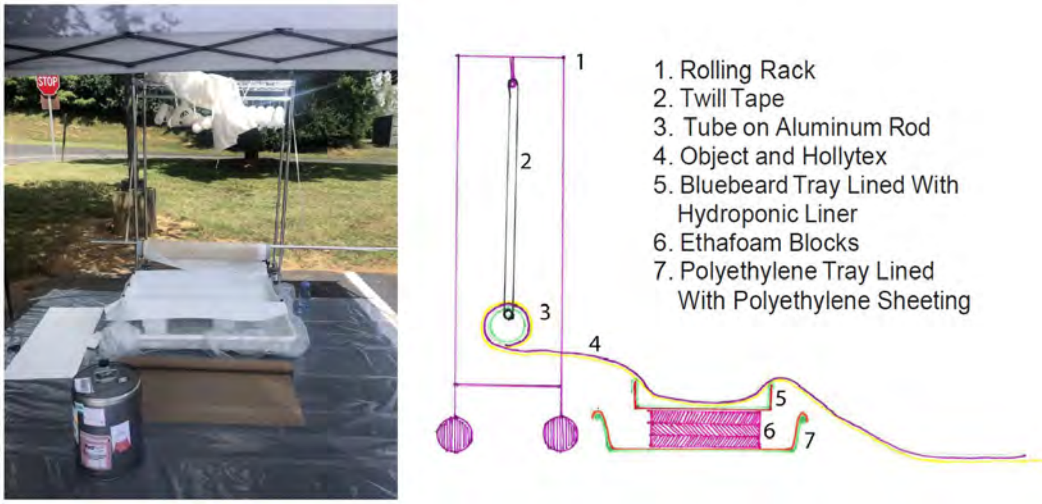

Fig. 11. The delamination setup for the LeHardy map.

THE SETUP

The delamination rig used for this project was assembled using supplies found around the conservation laboratories, such as those presented next (fig. 11).

Rolling Rack. A repurposed storage rack was used to support the map and keep it elevated above the solvent bath.

Tube. A six inch diameter archival tube was used in this case, but any sturdy tube could be substituted. The tube was wrapped with Teflon-coated fiberglass secured with staples to prevent the solvent or cellulose acetate residues from saturating the tube. The tube was then suspended on a pole and hung from the top of the rolling rack with twill tapes. The map was wrapped around the tube on a layer of Hollytex to prevent it from sticking to itself between solvent baths.

Primary Tray. To begin the delamination process, the map was unrolled from the tube, in sections, into the primary tray containing the acetone bath. The tray was constructed using double-walled, blue corrugated cardboard lined with hydroponic liner. The corners of the tray were cut and held together with Velcro tabs (fig. 12). This design allowed the walls to collapse so that used acetone could be drained into a secondary container. The ability to refill the tray with fresh acetone rather than continually adding more acetone to an already dirty bath saved time, resources, and grief. For this object, the dimensions of the tray were 22 × 42 × 4 inches.

Secondary Tray. The primary tray rested on Ethafoam blocks inside a secondary tray, raising it slightly above the lip. This tray served as a drainage basin for spent solvent and dirty blotters used during treatment. A large polyethylene tray was lined with polyethylene sheeting and served as the secondary tray. Such a tray could also easily be constructed from blueboard or any existing corrugated cardboard box.

Polyethylene Sheeting. Polyethylene sheeting was used to line the ground under the entire area used for treatment to keep the setup and object as clean as possible.

Canopy. The treatment took place at the end of August, and shade was essential to getting the treatment done, even on a more temperate day.

DELAMINATION

Although untraditional to delamination practice, the quickest way to delaminate the LeHardy map was to use squares of blotter to manually remove the laminate as it softened (fig. 13). This helped speed the overall process, and helped

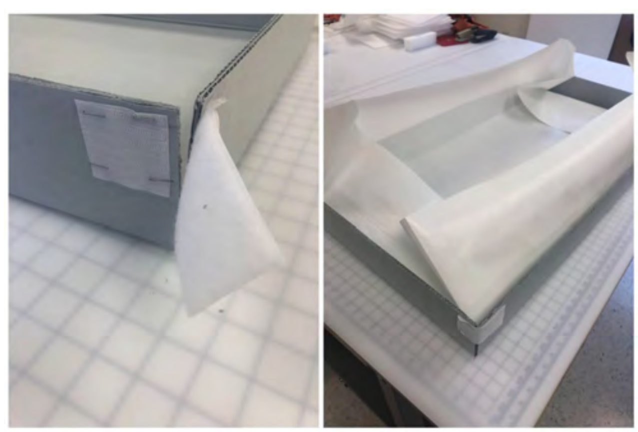

Fig. 12. Construction of the primary tray, highlighting the collapsible Velcro walls.

Fig. 13. Scraps of blotter used to manually remove softened laminate from the submerged object.

the solvent last longer in the tray without becoming thick with dissolved cellulose acetate. The procedure was to have two people on each side of the object: one person scraping the submerged portion of the object and removing the softened laminate, and another person to scrape the previously submerged portion for excess laminate and to help blend the drying front to prevent tide lines (fig. 14). When the time came to move on to the next section, two people would unroll the object from the tube while the other two slid the delaminated portion down.

Acetone was added to the bath, as needed, during each round of delamination. Between each round, two people would roll the object back onto the tube while the other two drained the primary bath into the secondary tray and refilled it with fresh acetone. The first two rounds required more frequent refreshes of acetone, but this slowed down with each subsequent round as more laminate was removed from the object. The used blotter scraps were tossed into the secondary tray along with the used acetone from the bath, containing the waste and simplifying cleanup. In the end, two 20 L drums of acetone were used in the delamination of the LeHardy map.

As was expected, cellulose acetate precipitated back onto the surface of the map as it dried between each round. With each round, this was reduced until there was no remaining visual or tactile evidence of cellulose acetate. The delamination process was repeated for a total of four rounds and took approximately 5 hours from setup to cleanup.

BATHING

The next treatment challenge was determining how to bathe the map. Several options were considered, including

Fig. 14. Clockwise from top right: Sara Leonowitz, Megan O'Brien, Maeve O'Shea, and Allison Holcomb delaminating the LeHardy map.

Fig. 15. Bathing setup for the LeHardy map.

outdoors or on the floor, but each of these presented their own problems and were thus discarded. In the end, there was just enough space to line up the two 4 × 8 foot benches and build a tabletop sink spanning the entire width of the paper laboratory (fig. 15). Blueboard was used to compensate for uneven table height, and 1 × 1 inch wooden boards were used to create a shallow wall around the edges. The same hydroponic liner used to line the acetone bath was used to line the sink. The liner was creased with a bone folder to smooth it flat against the walls of the bath, then clamped in place along with the boards. A small extension to the tables was necessary and was built using double-wall blueboard held in place with the 1 × 1 inch boards and clamps.

A homemade squeegee, slightly smaller than the width of the sink and built with double-wall blueboard, a scrap of hydroponic liner, and a staple gun came in very handy. This was key in draining the sink between each bath.

The bathing process and solutions were similar to those that would be used for any smaller bathing treatment. Ammonium hydroxide and calcium hydroxide were used to adjust the pH of the water. Sodium citrate, a mild chelator, was used to help reduce discoloration and tide lines. Buckets of the solutions were used to fill the sink. By using a dilute stock of ammonium hydroxide, the same pH could be easily and quickly produced in each bucket. For the first bath, the sink was filled with 16 gallons of solution. For each successive bath, 8 gallons was enough to fully immerse the map. The bathing procedure was as follows:

- Ethanol spray to wet out
- Ammonium hydroxide at pH 8
- 1% sodium citrate (pH 8)
- Ammonium hydroxide at pH 8 with local sodium citrate (pH 8)
- Rinse with ammonium hydroxide at pH 8
- Final bath with calcium hydroxide at pH 8

Hollytex was used for support, and the map was never moved during the bathing process. An additional piece of Hollytex was used to cover the object between each bath as the sink was drained. The bathing solutions were emptied through a corner drain, and the map was blotted with Tek-Wipe between each bath. The most time-intensive part of this process was filling and draining the sink, making the bathing a full-day process.

The map was dried in the sink, to avoid moving it while wet, with polyester felts underneath and on top to slow the process.

HUMIDIFICATION AND FLATTENING

The map dried with noticeable distortions, so after mending the small tears and filling the losses, a round of overall humidification was needed. To avoid moving the map, it was humidified and dried in the same place. First, three layers of 100 pt blotter were laid out on the counter, with the seams of each layer staggered. These were covered with a layer of Dartek Nylon film that could be removed after humidification. The map, with a layer of Hollytex on each side, was laid down over the Dartek and covered with dampened Gore-Tex. The Dartek–map–Gore-Tex stack was sealed with Mylar. To simplify the process, the map was only humidified from the top, which lengthened the time necessary but eliminated the handling risk. Once humidification was complete, the plastic was removed, the Gore-Tex was rolled up, and another three layers of 100 pt blotter were layered over top, along with plates of glass and weights.

STORAGE

With treatment complete, the map was returned to the park on a lignin-free, buffered, 6 inch diameter tube rolled with Permalife interleaving paper. The exterior was wrapped with Mylar to protect against dust, pollutants, and water.

DISCUSSION

Overall, the treatment was successful and yielded a map that is still in good condition with enough strength to be handled for research purposes or displayed for short-term exhibits (figs. 16, 17). Treatment increased the map's legibility, revealing subtle graphite details not apparent before. Throughout the treatment process, there were elements that helped and hindered the progress, both through luck and planning.

Successes

Cloth Backing. The cloth backing was easy to remove mechanically, taking the middle layer of cellulose acetate with it. This was most likely due to the thickness of both the paper and the cloth, which prevented proper adhesion of the middle

Fig. 16. After-treatment image of the LeHardy map, on the floor of the photography studio at HFC in West Virginia.

layer of cellulose acetate during the original lamination. With a thinner paper, or a lamination without a cloth backing, it is unlikely that mechanical removal would have been as successful. In turn, this meant that the map could be face up and easily monitored for the entirety of treatment, decreasing the overall time necessary for delamination.

Collapsible Tray Wall. The collapsible tray wall functioned as anticipated and streamlined the process of changing out the solvent with minimal fuss.

Hydroponic Liner. The use of hydroponic liner was suggested by HFC's textile conservator based on a paper presented by Jennifer Cruise at the AIC Annual Conference in 2019. The liner is made from polyethylene and can be treated in the same way as a polyethylene tray used for solvent and aqueous treatments. It is fairly rigid and offers more structural stability than polyester or polyethylene film, but can be folded and creased, which allows for more flexibility in size and shape than traditional trays.

Blotter Scraps. Using blotter scraps to help remove the softened cellulose acetate in the solvent bath greatly reduced the overall time needed for this part of the process and, perhaps more meaningfully, reduced the amount of solvent needed. This was in part possible due to the resilience of the media and the overall texture of the paper. This would not have been possible given friable media or a rougher and more fibrous paper.

Adjustments

Instrumental Analysis. While testing is always a necessary step, it is possible that media analysis prior to treatment could have narrowed the solvent selection prior to treatment. X-ray fluorescence spectroscopy could have given an indication of the presence of specific media, such as iron gall ink, or helped to distinguish between dye and pigment-based inks.

Tide Lines. When wetting out the map at the start of the aqueous bathing process, tide lines not visible when the object was dry became very apparent. The spacing of these lines indicated that they were likely caused during the delamination process despite efforts to feather the wet/dry interface while the object was drying (fig. 18). These tide lines were all but completely reduced during the bathing process, but ideally this could have been mitigated during the delamination through a few different means:

- Polyester film could have been used to cover the paper and slow the solvent evaporation as it was pulled from the acetone bath.
- An additional final run through the acetone bath with the goal of evenly saturating the paper without the stop and start necessary during the earlier baths could also have helped disperse the tide lines.

Solvent Tray. The solvent tray worked very well overall. Tweaks could be made to simplify its use and protect the object:

- The tray was deeper than it needed to be. A 2 inch tray would have been enough to contain the small amount of solvent in the bottom of the tray while allowing the paper to lay with less stress over the edges of the tray.
- The edges of the tray could be rounded with Ethafoam underneath the hydroponic liner, again with the goal of mitigating stress on the object.

Fig. 17. After-treatment images of the LeHardy map.

Fig. 18. Residual laminate re-formed during the delamination process corresponded with tide lines seen during the early parts of the bathing process.

Additional Hands. While there was the perfect amount of human support for the delamination portion of the treatment, with more people on standby, additional hands for the bathing portion of the treatment would have substantially streamlined the overall process.

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SOURCES OF MATERIALS

Hydroponic liner: Ultra Scrim FGC
Global Plastic Sheeting
1548 Jayken Way, Units C & D
Chula Vista, CA 91911
866-597-9298
https://www.globalplasticsheeting.com

PrecisionFab Teflon-coated fiberglass PC-3 standard
Precision Coating
51 Parmenter Rd.
Hudson, MA 01749
978-562-7561
https://www.precisioncoating.com

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ASHLEIGH FERGUSON SCHIESZER

Merging of Techniques to Unite Historical Integrity with Function: Treatment of the Hebrew Union College 1526 Prague Haggadah

INTRODUCTION

Over a series of years, treatment was performed at the Preservation Lab on one of the earliest printed Haggadot in history, a text central to the celebration of Passover. The book, printed in Prague in 1526, is owned by Hebrew Union College (HUC), located in Cincinnati, Ohio. The object was in need of treatment to reverse poorly aging prior repairs so the item could be better interpreted. A custom treatment was designed to restore the functionality of failing reformatted book pages—pages that had been previously trimmed to varying dimensions and shapes.

The goal of treatment was to reunite pages of differing dimensions within historical leather covers while keeping to the original sewn book structure. The solution was unique and unexpected. To conquer the challenge of rebinding different page dimensions, both encapsulated pages and paper leaves were united and sewn together onto raised supports to preserve the historical covers and the binding structure. This solution proved surprisingly successful in facilitating the reuse of the historic leather cover and recombining the existing pages.

The Prague Haggadah is also interesting to consider in the evolution of printed Haggadot and how this fully illustrated edition influenced future printed text. Historical achievements of Haggadah imagery through time are presented in relation to two other Haggadot treatments performed at the Preservation Lab. Showcasing these additional Haggadah examples paves the way for the merging of history and conservation solutions that led to the Prague Haggadah treatment.

Hebrew Union College

HUC is an international institution with campuses in Cincinnati, Jerusalem, Los Angeles, and New York. Cincinnati is known as the birthplace of American Reform Judaism, beginning in 1875 with Rabbi Isaac Mayer Wise, who paved the way for shifting gender roles and progressive Jewish education within the reform movement. As a result, the Cincinnati campus houses internationally renowned special collections at the Klau Library, Jacob Rader Marcus Center of the American Jewish Archives, and the Skirball Museum.

HUC (Cincinnati campus) is located less than a mile from the Preservation Lab where treatment was performed. The Preservation Lab, located on the University of Cincinnati Campus, is a collaborative hybrid laboratory where we perform limited third-party institutional work. This multifaceted book treatment utilized a wide set of paper and book conservation techniques and was heavily influenced by two other Haggadah treatments previously performed by the Preservation Lab. In total since 2015, the laboratory has treated three leatherbound HUC Haggadot, ranging from the 16th to the 18th century, whose history and conservation relate to each other and build upon prior treatment strategies.

HISTORICAL BACKGROUND

The Haggadah is central to the Passover celebration. It is written in Hebrew script and read right to left. The Haggadah is read during the Seder ritual meal, which consists of symbolic food and storytelling and outlines an order of activities. Because these books are heavily used around the dinner table, it is not unusual for Haggadah pages to be dirty and food smeared. This evidence of use is an important part of the history of a Haggadah and is preserved during treatment.

The Seder meal traditionally ends in song. These songs are often included in a Haggadah; however, songs were not printed in the Prague text until 1590. Because of this, at some point in the 1526 binding's history, a group of handwritten songs—including the popular song "Chad Gadya," also known as "One Little Goat"—were sewn into the back of the printed text.

1526 Prague Haggadah History

The Prague text from 1526 is significant because it is the earliest fully illustrated printed Haggadah. It was published

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Fig. 1. Woodblock printed leaves from the 1526 Prague Haggadah.

in Prague by the brothers Gershom Cohen and Gronom Katz. There are more than 60 woodblock prints throughout that are attributed to artist Hayyim Schwarz. Other features include printed type of varying styles and sizes, decorative initials, and short interpretations printed in the pages' margins. The woodcut imagery served as the model for future printed Haggadot and had an enormous influence on the history of Haggadah illustration going forward (fig. 1).

1695 Amsterdam Haggadah History and Treatment

The Amsterdam text dates to 1695 and is significant as it contains influences of Christian imagery, such as those found in the Protestant Merian Bible, and it was the first time in the history of the Jewish Book that copper engravings were used instead of woodblock prints. On the title page, you can see hand-colored engravings by Abraham ben Jacob containing the figures Moses and Aaron, which are modeled after the print by the Swiss artist Mattheus Merian. The Amsterdam Haggadah was revolutionary in its kind and still has influence on the layout and illustrations of modern Haggadot (fig. 2).

The 17th century printed text is bound in what are likely its original covers and sewing structure. It was printed in Amsterdam and is the fourth copy owned by the college; however, it is the only copy at HUC that contains hand-colored illumination. As a result, the binding is used frequently in the reading room as a teaching tool and needed treatment to prevent parts from becoming further damaged.

To treat, the text was fully disbound and repaired. It was rebound with a historically sympathetic structure, adding endbands to recreate lost parts of the original binding and rebacked with a new vegetable-tanned goatskin that was dyed

Fig. 2. Hand-colored engraving by Abraham ben Jacob from the 1695 Amsterdam Haggadah.

Fig. 3. View of the 1695 Amsterdam Haggadah spine before and after treatment.

to match the historic leather (fig. 3). This treatment was a great introduction for the laboratory to learn about the history of Haggadot and to become familiar with their historical format.

1716 Van Geldern Haggadah History and Treatment

The next Haggadah treated by the laboratory was a 1716 Haggadah manuscript, which is a companion to the Van Geldern Haggadah from 1723. It is also known as the *Second Cincinnati Haggadah*. Both were produced by Moses Loebben Wolf, who is well known for his Jewish manuscript art. The miniatures are in oil on parchment and are based on the engravings found in the printed Amsterdam Haggadah but also contain influences of the Prague text, especially when comparing title pages (fig. 4).

The treatment was similar to the prior conservation project with a few key differences. The text block was parchment, and its original sewing had been fully replaced with heavy-handed 20th century repairs. These page repairs needed to be

Fig. 4. Miniature oil paintings painted on parchment by Moses Loebben Wolf. Imagery and layout contain influences of both the Prague and Amsterdam Haggadot.

Fig. 5. The 1715 Haggadah is stored near the original slipcase within a new cloth-covered clamshell.

carefully removed and the pages rebound with as little moisture as possible to preserve the flexibility of the animal skin leaves, a treatment step that would help inform linings in the Prague treatment.

As an interesting side note, the Haggadah was stored next to its original slipcase in a new cloth-covered clamshell. That way, the Haggadah could remain in context with the original enclosure but would not suffer any abrasion from being pulled in and out of the original case (fig. 5).

TREATMENT OF THE 1526 HAGGADAH

Having treated two prior Haggadot (see figs. 2–5) of varying conditions and materials, the laboratory was prepared to pursue treatment on the earliest printed Haggadah.

Condition

The 16th century Haggadah suffered from degraded leather, cockled pages, and broken sewing. It was clear that at multiple points in this object's history, it had been reformatted since the pages consisted of differing dimensions. In addition, sewing holes and leather impressions showed that the text block was originally sewn with six raised sewing supports, despite it currently being sewn onto 20th century flat sewing tapes.

In its current state, the printed text had been trimmed and mounted within larger paper frames. These paper frames helped extend the sheet dimensions to fit within the dimensions of the leather covers. Over time, the mounting tape had yellowed and darkened. The paper frames were cockled due to differing expansion and contraction rates to the printed leaves, and the 20th century sewing was broken (fig. 6). Manuscript leaves with iron gall ink at the ultimate section of the text were showing signs of early corrosion with ink bleeding through the paper.

Since the leather binding could have been contemporaneous with the manuscript, treatment consisted of conserving all components and rebinding them into the existing covers.

Testing a Unique Treatment Solution

Before treatment began, a model was created to test a unique rebinding solution to recombine the different-sized pages (fig. 7). As an alternative to inlaying treated pages back into new paper frames, polyester encapsulated pages were constructed to be sewn through the fold next to the manuscript leaves, similar to how they were previously bound. This was done in a structure sympathetic to the historical one to reuse the original leather covers. The advantage of this format is that it allows the printed leaves to be removable for handling and display and shows a clear delineation between new materials introduced during treatment and the original leaves.

Other options considered were to secure the leaves in a traditional screw-post encapsulation binding with new cloth covers or to hinge the pages along the gutter, leaving the rough edges exposed. Due to the irregular nature of the trimmed pages, impressions in the paper over time would likely have become an issue when a shorter page was hinged next to a larger one. The margins of the pages also did not line up, causing challenges in deciding how high or low to orient leaves within a gathering, even further increasing the possibility for impressions of page edges to be imparted against adjacent leaves.

Creating the model proved successful in proposing an encapsulation solution to HUC's special collection librarians and troubleshooting the encapsulation form. Lessons learned included how to map out the welding process for creating nested gatherings with paper hinges, and an effective amount of stubbing near the gutter was added to compensate for the added thickness of the polyester film to prevent the book from becoming wedge shaped. There were structural binding considerations tested as well, such as creating a natural hollow

Fig. 6. Prague 1526 Haggadah condition before treatment.

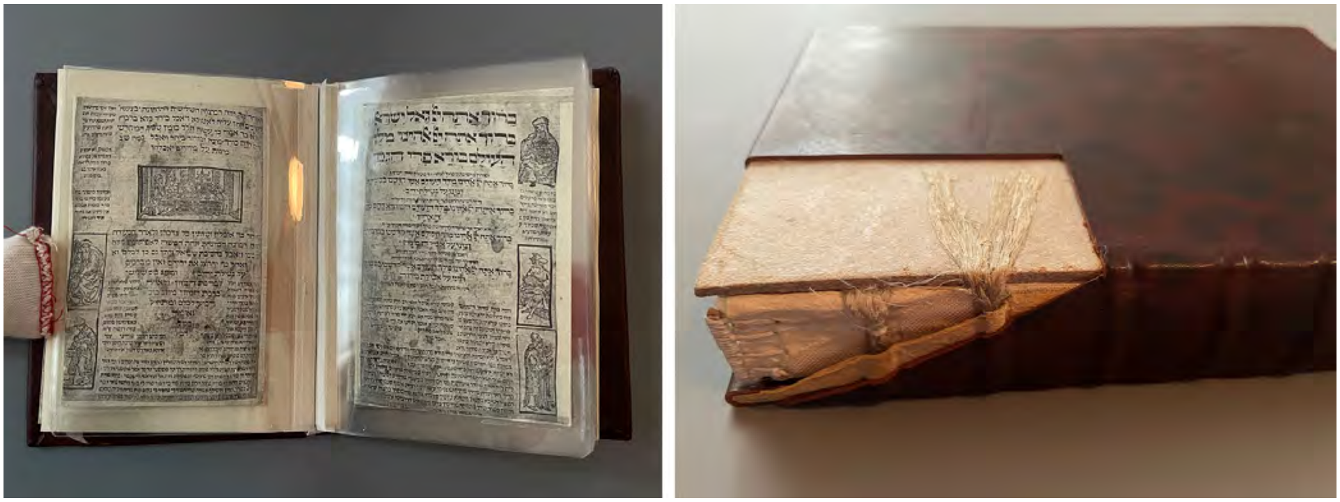

Fig. 7. A cut-away model was constructed to test a sewn encapsulation solution to recombine differing-sized pages. The cut-away reveals board attachment and spine lining tests.

leather spine that gives the appearance of a tight back binding while providing enhanced flexibility. In this case, the tight back form also protected the paper hinges of the encapsulated leaves from cockling from excess moisture when rebacked.

Paper Treatments

Pages contained both printed and handwritten leaves that required disparate wet treatments. Early printed leaves were treated to remove prior poorly aged taped and cockled repairs in a traditional wet bath, whereas handwritten songs added in the back of the binding required a specialized calcium phytate treatment to preserve handwritten iron gall ink. After wet work was completed, lost dirt found beneath previous repairs was inpainted to preserve the prior evidence of use.

Printed Leaf Treatment

Treatment began with printed leaves. Printed leaves were treated in five major stages: They were immersion washed to remove tape, they were inpainted to compensate for visual loss of surface dirt, tears were repaired, and then both the obvious and inconspicuous paper losses were filled before final encapsulation.

Immersion Washing. All leaves were washed until the bath water ran clear; however, some leaves required more than one immersion to remove multiple layers of tape. A handful of leaves contained additional areas of prior repairs that did not readily lift during the initial baths. Baths successfully reactivated two types of adhesive; the printed leaves were both adhered to the paper frames with a water-soluble adhesive and taped on the opposite side with a yellowed paper tape. During frame removal, paper losses along the edges of leaves and areas of dirt loss were further revealed that were once masked by the paper frames (fig. 8).

Inpainting. Leaves were not surface cleaned prior to washing for two reasons: to prevent a shift in paper tone between the taped and untaped areas, and to preserve the evidence of use. However, after removal of the yellowed tape, areas

Fig. 8. A printed leaf immersed to remove tape and framing. Imagery and paper loss are revealed under overlapping paper frames.

Fig. 9. A printed leaf in need of compensation for dirt loss along the left edge, before and after inpainting.

of dirt loss became more pronounced after the removal of the paper frames. While it was possible some dirt was lifted when the tape was removed, it was apparent that dirt had been previously lost prior to the laboratory's treatment, further indicating that the pages had been reformatted multiple times. To compensate for the dirt loss, these brighter beige areas were inpainted with watercolors and pastels (fig. 9).

Paper Repair. Paper losses along edges were primarily filled with laminated layers of acrylic toned kozo tissue (fig. 10). A large rectangular cut out in the front title page required a

Fig. 10. Before- and after-treatment images show paper losses filled with an acrylic-toned kozo tissue.

Fig. 11. Before- and after-treatment images show a large cut-out requiring additional structural support with a handmade Western paper.

stronger paper fill support and was filled with a handmade Western paper that was specially toned to match the darkened edges and the lighter tone in the center of the paper (fig. 11).

Encapsulation. Once repaired, the printed leaves were encapsulated with wide margins to match the larger size of the manuscript leaves. To create sewn gatherings, 38 encapsulated pages were ultrasonically welded with Sekishu paper hinges to create folios. Encapsulated folios were then nested into groups of four to create one gathering. When creating the gatherings, to accommodate the increase in folio size as it wraps around the previous inner folio, Sekishu hinges were stepped out into four different widths, with the smallest hinge on the inside folios and the largest hinge welded to the outermost folio of a gathering (fig. 12).

Encapsulations were partially welded around the edge with an upper corner open to allow the leaves to be removed should someone want to experience the material outside of the protective polyester film. To achieve this, three outer weld lines were placed along the edges. A short 1 cm weld line was added along the top edge near the gutter to protect the paper hinge weld from wear when pages were turned. A 20 cm weld was placed along the bottom edge, spanning the entire length of the printed leaves to support them overall. An 8 cm weld was placed along two-thirds of the fore-edge, spanning from the bottom toward the center. These three welds allowed the printed leaves to be removed along the top of the fore-edge (fig. 13). The bottom fore-edge weld prevents the pages from slipping out along the fore-edge during handling. The book model provided a good testing ground for how best to trim the inner margins to prevent them from catching and rubbing when pages were turned.

The most difficult part of the encapsulation process was realizing that the polyester pages would need to be cut out of square to fit within covers that were also askew. To trim the edges of the sleeves on a board shear, the board shear gauge

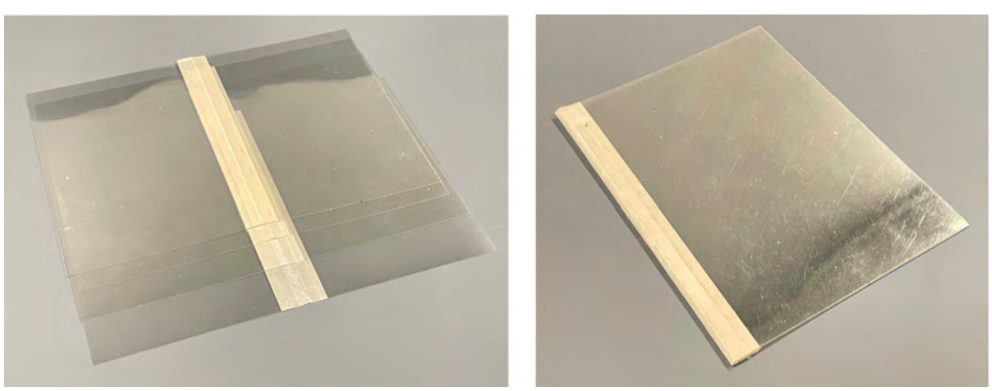

Fig. 12. Paper hinges widen for each nested folio of a gathering so that when closed, all paper and plastic edges align.

Fig. 13. Yellow lines represent outer ultrasonic weld lines.

was removed, and the individual polyester sleeves were placed at an angle identical to the obtuse top corner angle of the manuscript leaves and secured with a weight before chopping.

Manuscript Leaf Treatment

To treat manuscript leaves suffering from iron gall ink corrosion, wet treatment was performed. This consisted of a prewash bath, followed by a bath of phytic acid mixed with calcium carbonate to chelate the unstable FE(II) ions. Documents were rinsed to remove precipitate, then washed with a calcium bicarbonate bath for deacidification. This was achieved by premixing seltzer water with calcium carbonate powder. Last, the pages were sized with gelatin.

Gelatin has been found to have beneficial effects on iron gall ink documents and helps keep the chemical equilibrium favored toward Fe(III) rather than the destructive Fe(II), so this is the preferred material for resizing in conservation treatment (Kolbe 2004). However, when treating Jewish materials, it is recommended to consult with the client to consider kosher food-grade gelatin options or using a plant-based size instead of using traditional conservation gelatins that may not be kosher.

While examining a treated iron gall ink folio overlaid on top of an untreated folio under UVA fluorescence during treatment, it was noted that while the overall tone of the paper shifts from a yellow-green tone to a bluish tone under UVA, the ink was not found to shift or bleed through more than before treatment in either UVA or visible illumination (fig. 14), indicating that treatment was successful.

Fig. 14. A treated manuscript leaf is overlaid on top of an unwashed sheet to compare ink bleed-through before and after treatment.

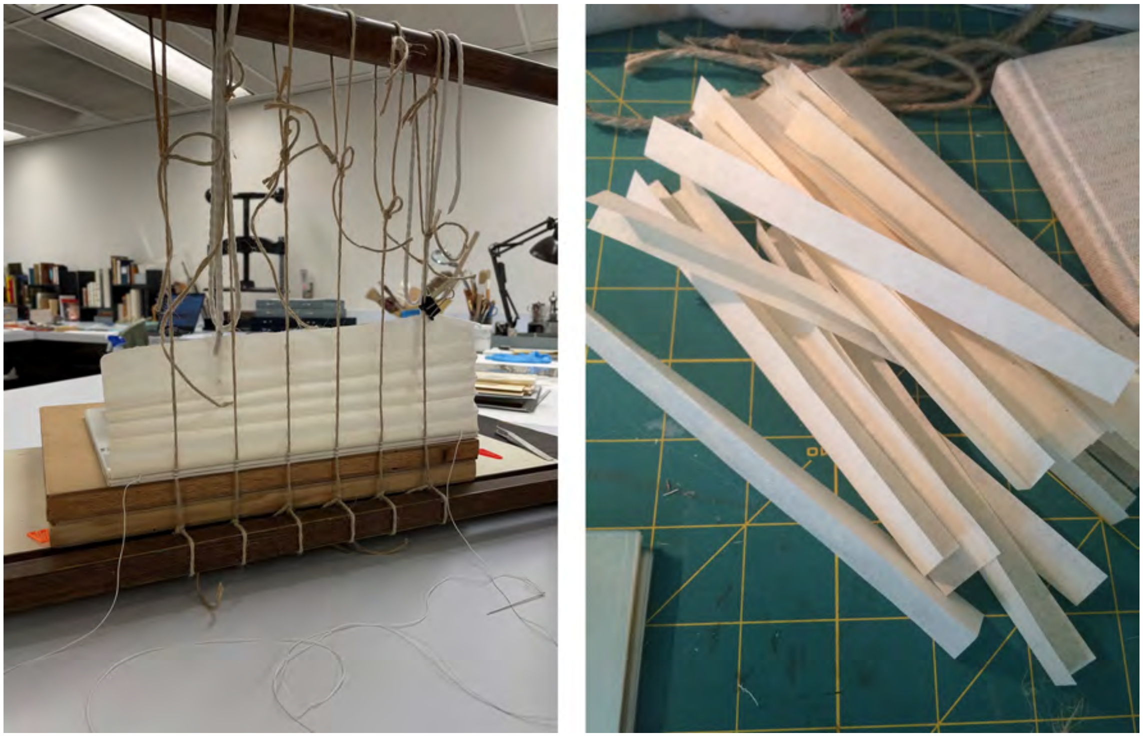

Fig. 15. During sewing, a concertina guard was placed on the outside of the gatherings while loose free guards were added in between each encapsulated folio.

New Endsheets

Next, a new handmade laid Twinrocker paper was custom toned to rest against the manuscript leaves and the original marbled paper endleaves. One challenge when toning Western paper is that sometimes one side of the sheet readily accepts diluted acrylic paints while the other side does not. Fully wetting out the paper before applying pigment helps alleviate this, but as luck would have it, the tones of the text block pages on either side of the endsheet were slightly different shades of beige. Therefore, this treatment challenge could instead be embraced to create a two-tone colored sheet.

Binding Treatment

Text block parts that were treated as separate objects were next bound together. The text consisted of one manuscript gathering, five gatherings of encapsulated pages, original marbled papers, and new endsheets. To protect the manuscript and printed text from possible acidity in the retained marbled papers, new endsheet papers were hinged around the original marbled papers.

Sewing

The next step was to establish sewing stations. Sewing holes were based on holes discovered in the manuscript leaves that were identical to the placement of original sewing supports, as evidenced by impression marks where the spine leather was once tied up around prior sewing supports. As a result, new sewing holes were punched in the welded sleeves prior to rebinding, whereas existing sewing holes were used in the manuscript leaves.

Two types of paper guards were added to the text block during resewing. A concertina guard was created to protect the welded sleeves from spine-lining adhesive, a technique often used for rebinding parchment text blocks. Additionally, four sizes of compensation v-hinges, also known as free guards, were created to rest between folios to compensate for the added thickness of the welded leaves (fig. 15).

The text was sewn unpacked on six cord supports. Prior support fragments found beneath lifted leather along the board measured about 2.5 mm in size. Their size informed the support size used for rebinding. After the spine linings were attached, conservation endbands were sewn onto cores of alum-tawed leather laminated to vellum since there was evidence of prior endbands, but they had become lost.

Spine Linings

Unstrained wheat starch paste was applied to the concertina guard as a size and allowed to fully dry before applying panel spine linings. For the panel linings, paper panels of Sekishu kozo tissue were adhered in between sewing supports with additional coatings of undiluted wheat starch paste. Next, slotted airplane linen was adhered overall, with slots cut for the sewing supports,

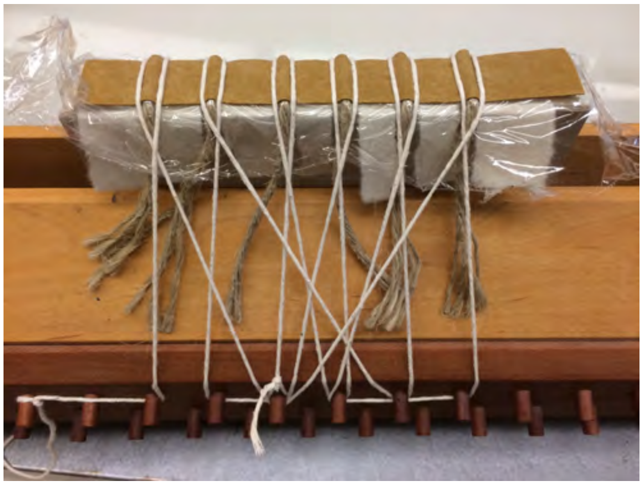

Fig. 16. An example of a molded cave paper spine. Cave paper is dampened and molded over the spine of the text block in a finishing press. Text is protected from moisture with plastic wrap.

adhered in place with paste. Last, Twinrocker handmade laid paper panel linings were adhered with wheat starch paste in between sewing supports on top of the cloth lining.

Molded Spine

A custom-molded spine was created out of cave paper to support a natural hollow leather structure while retaining the appearance of a tight back binding. This molded paper spine also had the added benefit of protecting the spine of the text block from absorbing access moisture during rebacking (fig. 16).

Leather Cover Repair

For cover repair, the board leather was stabilized and consolidated where it was worn and abraded. The leather was first consolidated overall with Zen Shofu wheat starch paste. A thin layer of SC6000 microcrystalline wax was further applied over the worn areas. Deep areas of leather loss and some areas of board loss were filled with pulped blotter combined with a 1:1 mix of Jade 403 PVA and wheat starch paste (fig. 17). Filled areas were further covered with toned kozo tissue and inpainted to improve visual cohesiveness of the leather.

A new calf leather was selected for rebacking that had a surface grain similar to the original. It was dyed with Selladerm leather dyes with a black speckled pattern. The reback leather was shaped and pared in preparation for the final binding steps. It was pared overall with a Shärffix machine and around the edges with paring knives to a flexible thickness suitable for molding over sewing supports.

Board Attachment

To reattach the boards, new supports were frayed and adhered to the outside of the boards beneath the lifted leather. The supports were adhered with a mix of wheat starch paste and

Fig. 17. During treatment, losses in leather and board are filled with pulped blotter before applying toned tissue and inpainting.

Jade 403 PVA. The PVA was incorporated to help prevent the supports from slipping when the new leather was adhered during rebacking. Boards were further attached with spline lining flanges inserted beneath lifted pastedowns. Spine lining flanges consisted of one layer of cloth and two layers of kozo tissue, with one of the flanges spanning from the concertina guard. The prepared leather was then used for rebacking and tied up to dry in a finishing press.

CONCLUSIONS

After treatment, the printed pages were preserved securely and could flexibly function as was once intended next to the handwritten manuscript leaves. Using parchment binding conservation techniques proved successful to sew in encapsulations with paper hinges next to other paper gatherings. The unique encapsulated page format allowed us to retain the original covers and provide the user with a page-turning experience that would not have been otherwise achieved with a traditional screw-post encapsulated binding format (fig. 18).

Some advantages to the unique binding treatment included revealing the versos of a handwritten fragment and the first leaf, which were previously inaccessible due to being adhered overall to an inserted paper support. Being stored in an encapsulated sleeve, rather than a paper frame, exposed additional crossed-out handwriting that was not visible in the prior format. All printed leaves are now able to be experienced either within the binding format or removed from their sleeves for exhibition or digitization. Loose white interleaving sheets were replaced with new custom-toned sewn-in endsheets. Leaves with manuscript writing unexpectedly brightened in tone after acidity was reduced and iron gall ink was stabilized.

For long-term storage, treatment documentation and retained components, including the original leather spine, were stored in a folder within a cloth-covered clamshell. Should a future steward be interested in reversing treatment and testing another format, the binding treatment is easily reversible.

Fig. 18. Condition of the 1526 Prague Haggadah after treatment.

Following treatment, HUC has since used the binding during Passover celebration. Its historical technological advancements have been highlighted from tours to online virtual presentations with the Jewish Federation community, broadening exposure of the religious text history to a wider audience.

ACKNOWLEDGMENTS

Thank you to many colleagues who supported and played a role in the treatment of the 1526 Haggadah. In particular, Jessica Ebert conducted formal treatment photographic documentation, Kasie Janssen assisted in creating sleeves for the creation of the model, and Chris Voynovich constructed the final encapsulated pages used in the Haggadah treatment. Kathy Lechuga was integral in learning the practical process for performing the calcium phytate treatment. She provided mentorship after my attendance at the Iron Gall ink symposium in Champaign, Illinois. Laurel Wolfson and Jordan Finkin at Hebrew Union College guided treatment decisions and provided historical background.

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Calcium carbonate MW 100.086 (100 g)
Fisher Scientific
81 Wyman St.
Waltham, MA 02451
800-766-7000
https://www.fishersci.com

HP-06 Sekishu Tsuru kozo tissue, HP-04 Usu-Gami Thin (formerly Usu-Mino) kozo tissue
Hiromi Paper Inc.
2525 Michigan Ave.
Bergamot Station Unit G-9
Santa Monica, CA 90404
310-998-0098
hiromi@hiromipaper.com

50% phytic acid solution in H20 (250 mL)
Sigma Aldrich (MilliporeSigma)
PO Box 14508
St. Louis, MO 63178
800-325-3010
https://www.sigmaaldrich.com

Zen (Jin) Shofu Japanese wheat paste, 3 mil Mylar film roll, Hewit leather
TALAS
330 Morgan Ave.
Brooklyn, NY 11211
212-219-0770
https://www.talasonline.com

Bone laid handmade cotton rag paper
Twinrocker Handmade Paper
100 E. 3rd St.
Brookston, IN 47923
800-757-8946
info@twinrockerhandmadepaper.com

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PING-CHUNG TSENG

Making a Chinese Woodblock Print Easy on the Eye: Merging Chinese Aesthetics With Western Conservation Methods

INTRODUCTION

Inpainting is a widely practiced technique used to address areas of loss in pictorial art, aiming to balance respect for the original elements with the need for distinction between original and restored passages. Historically, traditional Chinese painting conservation was conducted by highly skilled "master mounters," who fulfilled the role of modern conservators. The treatment process included wet cleaning, patching, infilling losses, inpainting, and remounting, with inpainting considered the most critical task. Chinese master mounters sought to conceal losses flawlessly, an approach that may raise ethical concerns by modern conservation standards due to the difficulty in distinguishing between original and inpainted areas. Moreover, unnecessary remounting to correct discoloration or unsatisfactory inpainting may also conflict with modern conservation principles.

This article presents a case study of remounting a rare 18th century Chinese woodblock print, *A Scenic View of Yueyang Tower* (岳陽樓勝景) depicting the Eight Immortals gathering in one of the most famous pavilions in China. The artwork exhibited significant losses and incorrect reattachments, necessitating careful image adjustments and inpainting. Given the artwork's cultural significance and the importance of preserving its aesthetic integrity, it was crucial to devise a treatment plan that honored traditional Chinese practices while adhering to modern conservation ethics. Collaboration with colleagues to develop a balanced approach led to the use of detectable inpainting materials and reversible techniques. The project aimed to provide a solution that was not only theoretical but also practical, serving as a bridge between traditional aesthetics and Western conservation methods in Chinese painting conservation.

Papers presented during the Book and Paper Group Session, AIC's 52nd Annual Meeting, May 20–24, 2024, Salt Lake City, Utah

TRADITIONAL CHINESE MOUNTING AND CONSERVATION

Traditionally, "master mounters" carried out the entire conservation process for Chinese paintings, fulfilling the role of what we now call a *conservator*. An important book, *The Mounting Manual* (裝潢志 Zhuang Huang Zhi), published around 1650 during the late Ming Dynasty by Zhou Jiazhou (周嘉胄), consolidates ancient mounting theories and remains an essential resource for traditional Chinese mounting practices (Xie 1998, 433). This manual is now available in modern editions, including the version translated and annotated by Tian Jun, published in 2003 as *Illustrated Treatise on Mounting*. In this article, citations from Jun's edition are referenced throughout (Zhou 2003, 22, 78), with additional English translation provided by the author.

Zhou wrote, "The mounter is the director of life for calligraphy and painting" (裝潢者, 書畫之司命也) (2003, 9). This statement underscores the mounter's influence over the 'fate' of the artwork, highlighting their responsibility in both the technical and aesthetic aspects of conservation.

The manual includes an introduction and 42 sections detailing various steps such as washing, lining, mending, and other aspects of mounting materials and traditional restoration techniques in China. This comprehensive guide offers insights not only into the techniques but also into the aesthetics of Chinese mounting practices.

The tradition of Chinese mounting has remained consistent for centuries. A section of a handscroll depicts a mounter holding the same brushes and working by a red table, surrounded by several paintings on the drying walls of a mounting shop. This visual continuity emphasizes the lasting significance of traditional Chinese mounting techniques (fig. 1).

THE PHILOSOPHY AND PRACTICE OF INPAINTING IN TRADITIONAL CHINESE MOUNTING

A chapter in *The Mounting Manual* (裝潢志 Zhuang Huang Zhi) discusses the concept of *quan* (全), literally meaning

Fig. 1. A scene of a mounting shop in the 18th century. Wang Hui, *Kangxi Emperor's Southern Inspections Tour, Scroll 7: Wuxi to Suzhou* (detail), 1691–98. Handscroll; ink and color on silk. China, Qing dynasty (1644–1911). University of Alberta Museum. Courtesy of University of Alberta Museum.

"inpainting." The term *quan-se* (全色) refers to "completing the colors" and encompasses the skills of connecting strokes, known as *jiebi* (接筆), and adding colors. This process involves using ink and colors to fill in areas where the ancient painting is damaged or has lost color. In this chapter, Zhou illustrates the importance and intricacy of inpainting through an anecdote:

> *I have a friend named Zheng Qianli, who is a skilled professional in inpainting old paintings and calligraphy. He once restored Zhao Qianli's painting* Fang Lin Chun Xiao Tu *for me. The inpainting was so perfect that even Zhao Qianli himself couldn't identify the restored areas if he were to be resurrected. However, if the wrong person is chosen to inpaint the artwork, it can significantly damage the original piece. (Zhou 2003, 22, 78)*

Zhou also wrote, "If an ancient painting or calligraphy is damaged or has missing parts, it's recommended to use aged ink and to ask a skilled mounting master for restoration. The mounting master should possess the extraordinary talent to restore the artwork to a divine level" (Zhou 2003, 22, 78).

Zhou further emphasizes the use of aged ink because its color and consistency have matured over time, allowing it to blend more seamlessly with the original artwork. Additionally, using old or worn-out brushes can provide more irregular bristle strokes that are less sharp and more blended, closely matching ancient artworks' texture and line quality. This manual reveals that the traditional Chinese mounting practice aims to conceal losses through perfect inpainting, reflecting their philosophy and ultimate goal. Even today, Chinese master mounters regard inpainting as the most critical process in conserving paintings (Zhou 2003, 22, 78).

The Concept of "Si Mian Guang" in Chinese Painting Conservation

To achieve perfection inpainting, it is essential to understand the Chinese phrase *Si Mian Guang* (四面光), which translates to "four-sided light" in English. *Si Mian* (四面) refers to all four directions, whereas *Guang* (光) translates to "light." In this context, it symbolizes uniformity and consistency. When used in traditional Chinese painting conservation, *Si Mian Guang* describes a standard where the restored or repaired section blends seamlessly with the surrounding areas. Essentially, it means that the colors, tones, and textures should match so well that it becomes difficult to distinguish the repaired part from the original work when viewed from any direction. This standard ensures that the conservation work maintains the integrity and aesthetics of the original artwork, reflecting the high level of skill and attention to detail required in traditional Chinese mounting practices.

Ethical Concerns in Imitative Inpainting

However, the pursuit of flawless, imitative inpainting raises significant ethical concerns:

1. *Risk of unnecessary remounting*: Over time, discoloration or inappropriate repairs may necessitate reversing the inpainting, often requiring full remounting. Remounting typically involves introducing water, presenting a risk to the original paint. Unnecessary remounting can conflict with modern

Fig. 2. Before treatment, *Scenic View of Yueyang Tower*, 1736–96. China, Qing dynasty (1644–1911), Qianlong reign (1736–95). Woodblock print with colors. Image: 99.5 × 54.5 cm (39 3/16 × 21 7/16 in.). Overall: 76 × 56.7 cm (69 5/16 × 22 5/16 in.). Private Collection. Courtesy of David Brichford.

conservation methods, prioritizing minimal intervention and potentially causing more harm than good to the artwork.

2. *Challenges in distinguishing inpainted passages*: In certain situations, even skilled conservators may find it difficult to distinguish between inpainted and original passages. This uncertainty can impact the artwork's authenticity from a Western perspective and pose challenges for future preservation if the inpainted passages cannot be easily reversed and distinguished.

CASE STUDY: TREATMENT OF AN 18TH CENTURY CHINESE PRINT

The case study involved the treatment of a rare 18th century Chinese print in a hanging scroll format titled *Scenic View of Yueyang Tower* (fig. 2). This unique print, part of a private collection, was on loan to the Cleveland Museum of Art (CMA) and displayed during the *China's Southern Paradise: Treasures from the Lower Yangzi Delta* exhibition from September 10, 2023, to January 7, 2024.

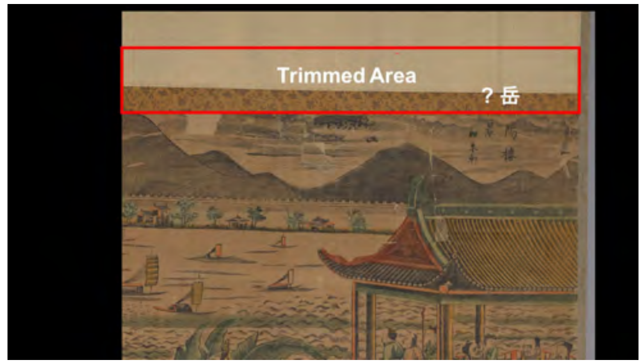

Fig. 3. The top edge of this print, potentially trimmed off during a previous remounting. Courtesy of David Brichford.

The print depicts the gathering of the Eight Immortals (八仙, *baxian* in Chinese). It has significant damage in the clouds and central figures, with two Chinese characters missing from the top edges. Specifically, the characters "*yue*" (岳) and another unidentified character are missing. Another missing character could possibly be "*seng*" (勝). This suggests that the top section may have been trimmed by the mounter due to damage (fig. 3).

In the upper section of the print, the lines in the sky and clouds were misaligned, with some pieces incorrectly placed (fig. 4). This area also suffered from notable losses. Additionally, the repair of the roof was not ideal, as it failed to integrate with the surrounding areas. Another issue was observed in the lower portion of the print, where two figures were depicted. The previous retouching efforts did not account for the stylistic requirements of a woodblock print, and the overall execution was rough, resulting in an unsatisfactory outcome (fig. 5). These issues highlighted the need for a meticulous and thoughtful approach to restoration, balancing traditional techniques with modern conservation ethics.

Fig. 4. The sky section showing misplaced outlines, misaligned lines, and several areas of loss. Courtesy of David Brichford.

Fig. 5. A significant loss in the figures with improperly executed inpainting. Courtesy of David Brichford.

Imitative Inpainting Using Creative Infilling Techniques
After several discussions with the curator and the owner, a decision was made to use imitative inpainting to maintain the Chinese aesthetic and historical integrity. This approach required reconstructing the losses and ensuring continuity in the images and background by correctly placing the misplaced fragments and by finding a solution to perform inpainting that matched the original state as closely as possible.

Fig. 6. Structure of a basic one-color Chinese hanging scroll.

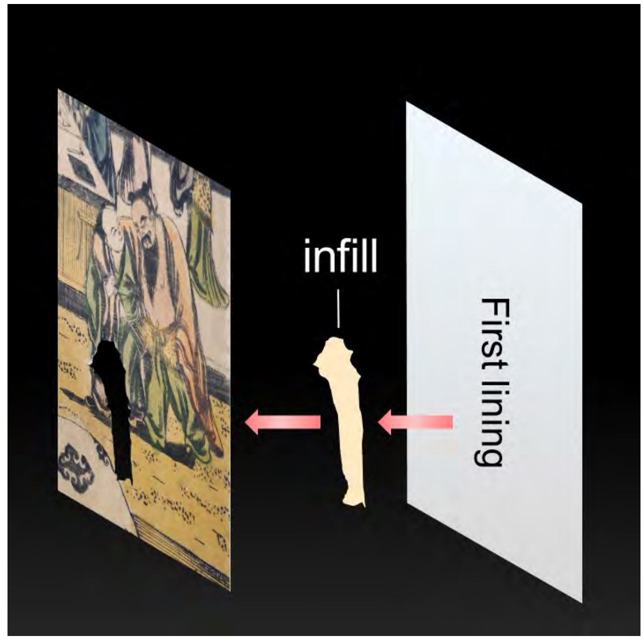

Fig. 7. The structure of direct infilling method.

This print is "rare" because it is the only known example that could be found. As a result, no comparable object could be used as a reference, especially for the inpainting process. The challenge was how to inpaint the losses to satisfy traditional mounting practices and Chinese aesthetics while meeting modern conservation standards.

When proceeding with treatments, the infilling and inpainting processes must be completed during remounting. Figure 6 shows the structure of a Chinese hanging scroll. After removing the old mounting silk and linings, the inpainting process is usually carried out after the artwork has been lined and dried on the drying wall before adding new mounting. Traditionally, there are two methods to infill the losses:

1. *Direct infilling on the verso*: This method involves infilling directly on the verso of the painting before applying the first lining (fig. 7).
2. *Infilling after lining*: This method involves doing the lining first, then infilling on the back of the first lining. The idea is to push lining paper into the losses, known as *yinbu* (隱補) in Chinese, which literally means "invisible infilling" (fig. 8).

After infilling, the artwork is flattened on the drying wall, and the restorer begins inpainting. Since inpainting is done directly on the infilled substrate or the lining paper, either method has limitations of reversibility, as any changes will require a full remount in the future.

For this project, a Japanese inpainting technique known as *hoshi hosai* (補紙補彩), which can be called *reversible infilling*

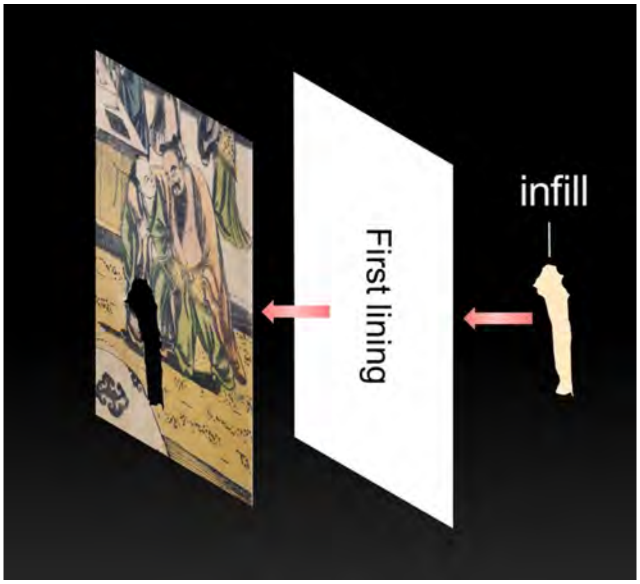

Fig. 8. The structure of the *yinbu* technique: infilling after the first lining.

and inpainting, was used (fig. 9). This fascinating technique was presented by Handakyuseido, a conservation studio accredited by the Association for Conservation of National Treasures in Japan, and was discussed by Mr. Handa Masaki during a 2006 talk in Taiwan (note 1).

Unlike traditional methods, *hoshi hosai* provides better reversibility. At the heart of this technique lies the use of thin infill paper, carefully cut to outline the lost areas, ensuring a precise fit to the damaged portions of the painting (fig. 10). In this project, a thin Chinese *Xuan* paper is chosen to match the texture of the original print substrate. Before the paper is affixed, a mixture of funori and wheat starch paste is applied to its back. Once the paper is securely inlaid, the losses are then inpainted. The infill acts as an isolated layer, which can be removed by simply applying water without requiring full remounting.

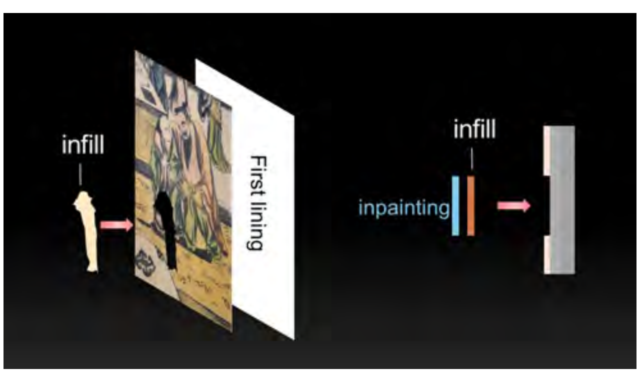

Fig. 9. The structure of the *hoshi hosai* technique: reversible infilling and inpainting.

Fig. 10. Prepared infills with precise fitting for the areas of loss.

This innovative technique offers a practical solution that respects both traditional Chinese aesthetics and modern conservation standards, providing a reversible method to restore the integrity and beauty of the artwork.

Inpainting Proposals

Given the absence of a reference object, the reconstruction of losses relied on thoroughly examining the surviving sections of the print to devise appropriate inpainting passages. The process began with composing mockups on spare sheets of paper to explore different inpainting approaches. Inpainting the sky fragments and addressing areas of loss were relatively straightforward, but the figures section was more challenging. The complexity of the figures' gestures and drapery required particular care in reconstructing the significant losses.

The author, alongside a dedicated team from the conservation department at the CMA, collaborated to devise and evaluate several proposals for the inpainting process. The team consisted of Dean Yoder, senior conservator of paintings; Julianna Ly, associate conservator of paintings; Sara Ribbans, conservator of Asian paintings; Mark Spisak, conservation technician; and David Piurek, paintings and frames technician. Together, we developed six initial proposals (fig. 11). After extensive discussion and careful reviewing with the curator, two of those proposals were selected for further refinement.

The final proposal was created based on its ability to reconstruct the loss in a way that appeared both logical and natural. Several key factors guided the final selection. The figures' body gestures had to be reconstructed in a way that would make sense within the original context of the artwork. For example, the figures' legs needed to be positioned in a way that maintained a natural alignment with the body's overall posture, ensuring that the reconstructed pose was both anatomically correct and visually coherent. Additionally,

Fig. 11. Six inpainting proposals created for the large loss in the figures.

the drapery of the figures' robe had to flow naturally, ensuring that the reconstructed folds and movement of the fabric blended seamlessly with the remaining portions of the print. By considering these elements, the final proposal achieved a reconstruction that integrated harmoniously with the original artwork (fig. 12). A challenging part of the entire inpainting process was using brushes to replicate the texture of the original print, ensuring a seamless blend between the newly inpainted areas and the existing sections of the artwork. This required meticulous precision to achieve a unified and coherent final result.

Fig. 12. Final version of selected inpainting proposals with outlines.

Adhering to Modern Conservation Principles

The modern conservation principle emphasizes keeping treatments and materials as simple as possible. Therefore, the focus was on using only three primary colors—yellow, blue, and red—to inpaint the losses. When considering the color wheel, these three colors can be mixed to create a wide range of hues (fig. 13). In rare cases, black was used if necessary.

The pigments used for this project were Holbein Artists' Pigment in Permanent Yellow Light (PG032), Oriental Blue (PG085), and Peony Red (PG008) (fig. 14). These are organic powdered pigments which are prepared for use in inpainting by using gelatin as a binder. These inpainting materials are

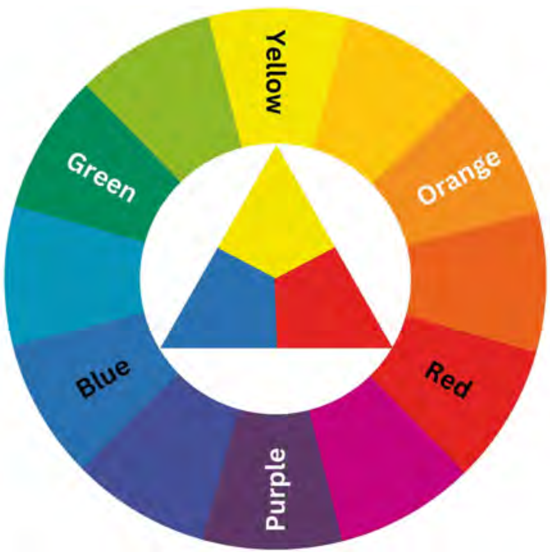

Fig. 13. Color wheel illustrating the primary colors and the hue system.

Fig. 14. Holbein Artists' Pigment used in this project: Permanent Yellow Light (PG032), Oriental Blue (PG085), and Peony Red (PG008).

lightfast and stable, and they were introduced for inpainting in Asian painting conservation in Japan. Additionally, these pigments offer enhanced visibility under ultraviolet (UV) light, which helps to differentiate the original elements by making the treatment areas easier to identify. Because of this, it was possible to inpaint the losses as closely as possible to adhere to traditional Chinese practices while meeting modern conservation standards (fig. 15).

CONCLUSIONS

This article offers a practical method for imitative inpainting, acknowledging its necessity within traditional Chinese aesthetics. The key to the approach was designing an inpainting method that satisfies both Chinese traditions and modern conservation standards. By affixing paper inserts within the losses and utilizing detectable pigments, the aim was to preserve the

Fig. 15. Comparison of inpainted areas: a. Sky and roof section: before treatment (left), after treatment (center), and after treatment under UV light (right); b. Figures section: before treatment (left), after treatment (center), and after treatment under UV light (right). Courtesy of David Brichford.

Fig. 16. Comparison of before and after treatment (overall image). Courtesy of David Brichford.

integrity of the original artwork while ensuring reversibility. The *hoshi hosai* technique, with its focus on reversibility and minimal intervention, allows for careful integration of inpainted sections without compromising the original work. Using primary colors and stable, lightfast pigments ensures that the inpainting endures over time and remains identifiable under UV light, aiding future conservation efforts.

This case study of the 18th century Chinese print *Scenic View of Yueyang Tower* demonstrates the challenges and solutions involved in reconciling traditional Chinese conservation practices with contemporary standards. The inpainting result is quite promising, especially when comparing the before and after treatment images (fig. 16). While the goal is not to achieve flawless inpainting, this work underscores the importance of thoughtful, reversible methods that respect both the artwork's original aesthetics and modern conservation ethics. This approach contributes valuable insights and techniques to the ongoing evolution of Chinese painting conservation.

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NOTE

1. The author attended Mr. Honda's presentation at the National Taiwan Museum of Fine Arts in Taichung City in 2006.

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MARCO VALLADARES PEREZ AND QUINN MORGAN FERRIS

New Applications of Lascaux Acrylic Adhesive for Book and Paper Conservation

INTRODUCTION

A Need for a New Repair Tissue

The initial impetus for this research came from a simple treatment problem: how to guard the spine folds of a book in repair without adding bulk with the chosen repair tissue. Based on experience, conservators at the University of Illinois (U of I) knew that one could sacrifice either a tissue's lightness for strength and stability or vice versa, but that it was difficult to find a material that allows the luxury of both.

While not always necessary in book conservation, there are cases where having both relative thinness and strength is important to the repair. If the cover or case is intact and the treatment attemps to fit a newly guarded and consolidated text block into its original binding without altering the spine depth, having a tissue that provides enough strength for resewing without bulk is ideal. Another instance when having a thin but robust tissue is paramount is when one is applying repair tissue over areas of fragile media without obscuring the media's legibility. A third example is the desire to have a thin tissue that is easy to work with during aqueous treatment, which would allow integration into treatment steps in where the object is already wetted out. These last two cases were particularly interesting to the U of I conservators since there had been much active work on establishing an in-house protocol for treating iron gall ink documents (fig. 1). Having a water-activated mending tissue that can be applied to fragile media while the object is already wet from the process of washing and chelation offers a convenient opportunity for repair without needing to rewet the object after calcium phytate has concluded. In short, while many problems can be resolved with a selective application of materials, a handful of instances where having a very fine but strong tissue would make book and paper treatment proceed more smoothly.

Once the need for such a material was identified, it was easy enough to figure out the necessary characteristics. The desired material would maximize the properties of lightweight tissues, such as transparency and minimal bulk during lining or guarding. Simultaneously, it would need to avoid weakening the tissue overall. Finally, the desired preparation had to be one that allowed consolidation of the paper matrix such that the precoated tissue would be more workable when remoistened, allowing it to be manipulated without separating or falling apart during brushing or handling during treatment.

Papers presented during the Book and Paper Group Session, AIC's 52nd Annual Meeting, May 20–24, 2024, Salt Lake City, Utah

Fig. 1. Repair over fragile iron gall media using Lascaux-WSP tissue applied during aqueous treatment steps.

Why Tengujo?

Tengujo paper, made by the Hidaka Washi company, is thin. So thin, in fact, that some retailers refer to it as "Spider Tissue," whereas the full Japanese name, *Tosa Tengujo-shi*, translates to "wings of the mayfly" in English (Hidakawashi 2024). The thinnest version is just 0.02 mm thick—the same as the diameter of a single kozo fiber (fig. 2). Traditionally handcrafted for more than 1000 years in Japan's Kochi and Gifu prefectures, the introduction of machines in the 20th century enabled even thinner production while maintaining flexibility and high strength relative to its fineness (Whang 2020).

Tengujo 5 gsm tissue has long been a favorite material for book and paper conservation treatment. Tengujo has many excellent properties without any modification—in addition to thinness, it has long fibers, which allow for fine, stable mends across breaks without being visually intrusive. It also exhibits high chemical stability, which gives conservators

Fig. 2. Tosa Tengujo-shi, or "wings of the mayfly".

confidence when using it in treating paper-based objects (EdoFiber 2024).

Although the thinness of Tengujo paper is one of its benefits, it can be challenging to work with, especially at low weights such as 2, 3, 5, or even 7 gsm. These delicate weights must be handled with care, especially in the presence of moisture. When precoated with reversible adhesives commonly used in conservation, like wheat starch paste (WSP), methylcellulose, or gelatin, the mechanical resistance of Tengujo increases to a degree. This works well for small mending and other focused stabilization. For treatments involving greater mechanical tension, such as guarding and sewing, the crystalline molecular structures of starch and cellulose are more rigid than flexible (Davidson and Richardson 1936, 68). Consequently, Tengujo tissue can tear easily.

Why Lascaux Acrylic Adhesive?

Acrylic dispersions have been used for decades to conserve textiles (Ragauskeinė et al. 2006, 57) and paintings (Duffy 1989, 67). Although the adoption of these adhesives came a bit later in book conservation, there have been innovative uses in paper and leather treatment since the early 2000s (Kelly et al. 2020, 24). Possibly due to our wariness of other acrylic polymers in paper conservation (i.e., pressure-sensitive tape and the problem of aging plastics in cultural heritage generally), Lascaux Acrylic has not been widely adopted for paper treatment beyond its applications for heat-set tissues and leather repair. That said, the idea of using a Lascaux formulation in lightweight tissue repairs came from a familiarity with the material in other contexts—for example, the use of Lascaux 498 HV in working with degraded leather components (St. John 2000, 134), or the use of Lascaux 303 HV for making temporary mounting hinges for exhibits—a practice at the U of I since 2018. It had been observed that when Lascaux's acrylic dispersions were cast in a film over repair tissue, they significantly improved both the paper's elasticity and the overall strength of the paper's fibers. Based on that, Lascaux could potentially be used to diminish the properties of weakness and difficult handling of the Tengujo.

With Lascaux 303 HV used as a coating over Tengujo 5 gsm, an improvement in both the elasticity and strength performance was immediately observed. Tissue coated with Lascaux 303 HV sticks to a secondary paper support through its ability to remain tacky when dry. It also remains easy to remove when freshly applied. However, although useful in some applications, this residual tackiness can attract dust and accidentally adhere to surrounding documents during storage. Additionally, limited experimentation in the Conservation Lab at the U of I suggested that the tissue may become harder to remove over time—similar to the cross-linking that occurs with the adhesive on sticky notes (Siegel 1989, 67)—which would not be ideal for most conservation applications that prioritize reversibility.

Adding Paste to the Mix

The questions became this: Is it possible to retain the strength and elasticity-enhancing properties of Lascaux 303 HV without having the repair tissue compromised by the problem of long-term tackiness? Is there a way to isolate or encapsulate Lascaux 303 HV without losing the acrylic film's flexibility? The idea of adding a secondary adhesive to manage tackiness again came during myriad experiments. WSP was a natural place to start, given its familiarity, working characteristics, and long-held position as the apex adhesive in book and paper conservation. Paste would satisfy the need for this new repair tissue to be water activated and easily reversible. In a low enough concentration, it theoretically should not obscure the effects of the Lascaux adhesive. Could paste be the answer?

The next step was a lot of trial and error. Early iterations included testing with gelatin (which caused too much static cling when used) and higher paste concentrations (which reduced the desired flexibility and strength). After multiple recipes and ratios, a final formula that met the core criteria was determined—Tengujo 5 gsm coated in layers, first with a 3% concentration of Lascaux 303 HV to add strength and flexibility, then with a 2% concentration of WSP to block the tackiness, enhance the water activation, and promote reversibility (fig. 3). The result was a remoistenable precoated tissue with the thinness and transparency of uncoated Tengujo and the strength and consolidation necessary for sewing through a single layer after guarding. It was suitable for lining or double mending and did not add bulk. Because it was water activated, it could be easily integrated into aqueous steps without needing to add any additional moisture to the object after the fact.

Could this new Lascaux-paste tissue be too good to be true? Possibly—especially given that no comparable data was available to evaluate the aging properties of Lascaux 303 HV in combination with WSP. Moreover, although observational tests immediately following application demonstrated that the Lascaux-WSP tissue had both high adhesion and reversibility,

Fig. 3. "T2," the main formulation of one layer of 3% Lascaux Acrykleber 303 HV, followed by two layers of 2% cooked Zen Shofu WSP.

U of I conservators were aware that if they wanted to be confident in using this material on special collections and sharing this methodology with the field, more information on how this tissue performed over time would be needed.

DESCRIPTION OF EXPERIMENTAL SETUPS

Base Experiment: 5 gsm Tengujo Tissue Prepared With Variations of Lascaux and Paste

The first goal was to test the performance and aging characteristics of the winning formula—Hiromi Tengujo 5 gsm tissue treated with a precoating of diluted Lascaux adhesive followed by cooked and thinned Zen Shofu WSP. For the base experiment, an uncoated control sample, "TControl," plus two prepared samples, "T1" (coated with paste) and "T2" (coated with the main Lascaux-paste formula), were included. The intention of starting with these three samples was to compare the Lascaux-paste formula to the performance and aging of uncoated Tengujo tissue, and Tengujo that had been precoated with WSP.

A third formulation that included pretoning with acrylic pigment was added. This is often a step during treatment meant to alter a repair tissue to be less visually disruptive to the object. For this variation, referred to as "T3," 5 gsm Tengujo was first toned with a wash of Golden Acrylic pigments before applying the same Lascaux-WSP combination as in the "T2" sample.

The final tissue preparation, referred to as "T4," swapped out Lascaux 303 HV for Lascaux 498 HV followed by coating with WSP (table 1). This was included for several reasons. First and foremost, the authors were curious to what extent WSP succeeded in encapsulating the Lascaux. Although early trials with the main formulation suggested that WSP could fully isolate the tackiness of Lascaux 303 HV, it was not clear how the adhesive characteristics of Lascaux were still operational when re-activated. Using Lascaux 498 HV, a solvent and heat-activated adhesive, was a clear way to test if the adhesive properties were still present in the Lascaux after being coated with WSP. Since the intended impact of the Lascaux was to lend the elasticity and strength of an acrylic film, the authors were not overly concerned with preserving the adhesive properties of the Lascaux but rather understanding how the adhesive properties were affected by WSP.

Second, the authors were curious whether there were any noticeable differences between using Lascaux 303 HV and 498 HV when cast over the tissue. Could the difference in application methods affect the relative strength or elasticity of the coated tissue? If not, one could attribute this feature to acrylic dispersions in general and consider 498 HV

Sample Name	Support	Preparation
TControl	Hiromi 5 gsm Tengujo	Uncoated
T1	Hiromi 5 gsm Tengujo	Coated with three layers of 2% concentration of TALAS Zen Shofu WSP applied on alternating sides
T2	Hiromi 5 gsm Tengujo	Coated with one layer of 3% Lascaux 303 HV + three layers of 2% concentration of TALAS Zen Shofu WSP on alternating sides
T3	Hiromi 5 gsm Tengujo	First toned with Golden Acrylic pigments, then coated with one layer of 3% Lascaux 303 HV + three layers of 2% concentration of TALAS Zen Shofu WSP applied on alternating sides
T4	Hiromi 5 gsm Tengujo	Coated with one layer of 3% Lascaux 498 HV + three layers of 2% concentration of TALAS Zen Shofu WSP on alternating sides

Table 1. Base Experiment Tissue Samples

"Oversized" historical end sheet paper "Maps" historical end sheet paper "Miner" historical end sheet paper

Fig. 4. Before-treatment recto images of selected historic paper stocks, "Oversized," "Maps," and "Miner" (left to right), under normal illumination.

as an alternative for this specific precoated tissue recipe. Furthermore, it would allow evaluation of the relative adhesion and reversibility of the prepared Lascaux-WSP tissue on the adhesive action of the paste alone, since it is established that Lascaux 498 HV is not water activated.

Last, including "T4" in the sample set might allow testing for different applications or benefits for a Lascaux 498 HV-WSP precoated Tengujo that the authors had not anticipated.

It is important to note that this experiment involved applying three layers of WSP, which is the maximum recommended by the authors. Although two layers are enough to achieve adhesion, using more than three will further reduce Lascaux's elasticity and strength. During the experimental phase, the most extreme formulation was used to test the limits of the adhesives in question. This detail is especially important when analyzing the results of mechanical testing.

Testing Lascaux-WSP Precoated Tengujo Over Historical Paper Samples

Once the base and variations of the tissue samples were selected and prepared, there were still further questions. Since mending tissues rarely act (or age) in isolation, the authors wondered if there was a fundamental impact on the performance and aging of the Lascaux-WSP coatings when applied to historical papers. It was quickly decided that it would be worthwhile to make a secondary sample set that consisted of the four Tengujo Lascaux-WSP formulations applied over historical papers throughout simulated treatment steps.

After a brief discussion, it was concluded that it would be useful to have several different paper stocks from which to create sample sets. Historical paper samples were selected from a collection of retained endsheet papers that were separated during repair before the formal creation of the Conservation Unit at the U of I. Three papers were selected that were different enough to yield visually distinctive results during later testing. To identify the papers individually throughout experimentation, they were each assigned names based on distinguishing characteristics.

Two of the selected historical papers (named "Maps" and "Oversized") appeared to have been handmade, with laid and chain lines visible under normal illumination, and were without printed media. The third paper selected was an anomaly in the historical endsheet collection—a print publication from 1899 called *The Michigan Miner*. "Miner" was clearly industrially produced wove groundwood pulp paper. Already discolored and embrittled, the authors were interested in how such a fragile and acidic support might impact the performance of applied mends. Each of the three papers was photographed at this "before-treatment" stage under normal illumination according to usual photo-documentation standards of practice (fig. 4).

It may have been prudent to stop with these two robust sample sets. However, the authors also wondered how the tissue might respond to aging if applied during different phases of treatment. Since each sample consisted of a full sheet, each sheet was divided into four quadrants. All quadrants were surface cleaned over the recto and verso using conservation-grade eraser crumbs combined with a soft-bristle brush. Three-quarters of the quadrants were washed following a typical procedure using successive baths of unconditioned deionized water, then allowed to dry between felts under moderate weight. Half of the quadrants received a final conditioned bath before drying, with the deionized water buffered to a pH between 8.5 and 9 using a calcium hydroxide saturated solution. The remaining quadrants were then resized after buffering, with a solution of gelatin at a concentration of less that 1%, before finally being allowed to dry between felts.

The result was the three historical papers now consisting of four pieces, each having received a different level of conservation treatment (table 2). To identify these individual historical paper samples throughout the rest of the experimentation, they were assigned two-part names, with the main paper identifier ("Oversized," "Maps," "Miner") followed by an alpha-numerical designation that indicated the treatment stage (B1–B4). With the preparation complete

Sample Name	Quadrant	Preparation
Oversized/Maps	B1 (Control, cleaned)	Historical handmade paper that has been surface cleaned
	B2 (Washed)	Historical handmade paper that has been surface cleaned and washed according to standard immersive washing practices
	B3 (Buffered)	Historical handmade paper that has been surface cleaned, washed, and buffered according to standard immersive washing practices
	B4 (Resized)	Historical handmade paper that has been surface cleaned, washed, and buffered according to standard immersive washing practices, then resized with <1% gelatine
Miner	B1 (Control, cleaned)	Historical industrial paper that has been surface cleaned
	B2 (Washed)	Historical industrial paper that has been surface cleaned and washed, according to standard immersive washing practices
	B3 (Buffered)	Historical industrial paper that has been surface cleaned, washed, and buffered according to standard immersive washing practices
	B4 (Resized)	Historical handmade paper that has been surface cleaned, washed, and buffered according to standard immersive washing practices, then resized with <1% gelatine

Table 2. Historical Paper Samples at Different Treatment Stages

for the historical paper samples, "during-treatment" photodocumentation was conducted for the four paper samples, individually capturing each of the four preparations for each sample group (fig. 5). To adhere the tissue samples to the historical paper quadrants, all four tissues were cut into strips and labeled. "T1–T4" tissue samples were applied consistently, as described in Appendix 2. This resulted in four pieces of paper with four strips of mending tissue each. For each sample, a portion of the historical paper was also left uncovered to test the paper's performance separate from the precoated tissues. Altogether, the process of preparing the historical paper samples with the Lascaux-WSP tissues took a total of 15 to 20 minutes.

Determining Accelerated Aging Test Parameters

Age testing was performed in multiple rounds to accommodate multiple sample sets. To allow for adequate working time to cycle through the progressive experimental variations, it was decided to limit the accelerated aging period to 28 to 31 days (roughly one month). To compensate for a relatively brief duration, the temperature and relative humidity parameters were set higher than the median levels suggested in the available literature so that this testing would be able to emulate the worst outcomes over time (Zou et al. 1993, 393). All samples were hung from one end through a punched hole inside a Memmert HCP50 Humidity Chamber and initially left to age for a four-week period with a relative humidity of 90% and a temperature of 90°C (fig. 6). It was quickly noticed that the first relative humidity set-point was too high, resulting in excessive condensation inside the test chamber. Subsequently, the relative humidity was adjusted to 65% for all rounds of samples.

Monitoring the aging process also included checking samples once weekly, at which point a quarter of each sample was

"Maps," recto "Maps," verso

Fig. 5. During-treatment images of "Maps" historic paper with documented phased simulated treatment.

Fig. 6. Tissue samples inserted into a Memmert HCP50 Humidity Chamber before accelerated aging has begun.

removed. This furnished a progressive set of paper coupons to document color, pH, adhesion, and reversibility changes over the four weeks.

POST-AGING QUALITATIVE TESTING: TOOLS AND PROCEDURES

Establishing Test Factors

Without having a resource on campus for mechanical properties testing, the authors began discussing what factors could be used to track differences between the aged and unaged samples. While previous research on a different project had yielded a set of qualitative criteria on which to base analysis, the context of this experimental tissue formulation presented different questions that could not be readily answered using scales designed for observed burst, foldability, and score retention. Early factors considered for qualitative testing included texture, sheen, translucency, tearing/cutting, and folding/flexing. Ultimately, however, creating a consistent test protocol for these factors that was repeatable and able to be documented proved infeasible.

The authors knew that the aged papers would likely have significant changes in both color and pH, factors for which general tools were available for evaluation. Throughout early discussion, other factors that kept surfacing were adhesion and reversibility, both immediately after first application and after accelerated aging. Finding the creation of general testing procedures for these four factors possible, the authors began drafting protocols before completing data collection on all samples.

Color Analysis

Color shift can be gauged visually—it is easy enough to discern if one thing is darker than another. That said, quantifying a change based on observation is challenging. The authors wanted to do color analysis in a way that captured the amount of change observed. Initially, familiar conservation tools were considered, such as the *Print Council of America Paper Sample Book: A Practical Guide to the Description of Paper* (Perkinson and Lunning 1996). The sample book is as advertised—a collection of historical paper samples that have been organized into scales for “Color,” “Thickness,” and “Texture.” A helpful tool in characterizing a paper object during conservation examination and documentation, the *Sample Book* presents a comparative set of standards so that anyone with a copy can understand how a particular paper might look or feel. However, it was obvious in examining the test samples after accelerated aging that the *Sample Book* would not be useful for this application, largely because only one color was classified as “brown” (fig. 7). Unfortunately, this was not a sufficient variety to accurately characterize the darkening shift across four weeks of aging.

Concurrent to this research at the U of I Library Conservation Lab, colleagues in Collection Care had long been working on responding to the growing national awareness of heavy metals in 19th century book cloth. Among other efforts, they had the idea to try using a colorimeter to see if there was a consistent diagnostic that would allow them either to more quickly identify specific hues of book cloth likely to have heavy metals present in the colorant or to eliminate hues that posed no risk. To do this, they turned to a device currently on the market, the Color Muse Colorimeter.

Color Muse is a tool that is promoted for use in interior design. Its main selling point is that one can take a reading from any color encountered in daily life and use it to get a customized paint color to match. While that aspect of its operation did not apply to this research, it does offer a diagnostic tool that tracks shifts in value by percentage. The device is straightforward to use (see Appendix 3), pairs with an app downloaded to a smartphone or tablet, and can give suggestions of color matches based on CIE L*a*b* color space metrics. Although not the intended use of this tool, the authors thought it would be a way to furnish quantitative results for the color shift observed after aging.

Once a testing protocol was established, evaluation was performed on the historical paper samples (on both recto and verso) and the test tissues. In recording the data, particular attention was paid to the L* value, which concerns the shift from lightness to darkness. “After-treatment” photography

Fig. 7. *Print Council of America Paper Sample Book* (Perkinson and Lunning 1996); a useful didactic for description but has only one "brown" sample for comparative use.

was also performed under normal illumination of all samples to document the color shifts and have a comparative guide available for each historical paper.

There were a few complications—the aperture of the Color Muse's sensor, which allows for data collection, is quite small, only about 8 mm. As a result, it was difficult to get readings without significant variation. Data collection had to be repeated three times in multiple locations for each sample and then averaged to create a representative value. The source of variation seemed to come from the fact that the discoloration of the aged samples was non-homogeneous and mottled, especially for the historical handmade papers. Similarly, when analyzing the color shift in the Tengujo tissues, it was a challenge to get accurate readings simply because the tissues were naturally quite open and translucent. To accommodate this, testing required that the each sample was folded over itself up to four times to make a surface dense enough to render a measurement.

pH Analysis

Testing the pH of a paper or solution is a standard aspect of conservation treatment. This is because the reaction mechanism that causes cellulose degradation—acid hydrolysis—presents a need to mediate the deleterious presence of acid by introducing alkaline buffering components (Joel et al. 1972, 119). Thus tracking pH fluctuation throughout the accelerating aging process was considered a valuable metric for evaluation. Previous research projects included testing in this category by using a cold-water pH extraction method with great success. Unfortunately, since only a limited amount of each sample was available, there was insufficient bulk to accurately perform cold-water extraction, especially without sacrificing the aged paper before other qualitative testing was completed. Likewise, for the Tengujo tissue formulations, initial assessments of the sample material available were deemed insufficient due to the fineness of the tissue.

The authors collected surface readings with a flat-head pH probe. Although surface pH can also be taken with pH strips, this methodology was not ideal. While arguably more consistent, the test strips do not allow for measuring smaller variations. Testing before and after aging was included across all samples. In addition, pH testing was conducted on all of the prepared tissues themselves, but because of the thinness of the Tengujo, it was again necessary to fold the tissue samples over themselves to get an accurate reading.

Once the pH testing methodology was selected, data collection was still laborious. The pH probe needed to be fastidiously calibrated to get reliable data before every measurement. It was also necessary to adjust the dwell time between 1 and 3 minutes to accommodate the absorption rate of different papers. This was particularly noticeable when comparing the historical handmade paper samples (which absorbed quite quickly) to the lignin-rich machine-made paper (which was generally hydrophobic). The process also required multiple passes to recheck and confirm measurements. The instructions for using a pH probe with recommended modifications are included in Appendix 4.

Adhesion

As mentioned previously, the chief concern in using an acrylic adhesive on paper was the extent to which aged Lascaux-coated tissues cross-linked or became intractable when applied to historical paper. Given how often conservators are left trying to remove or reverse the effects of tape, glue, and other types of acrylic adhesives from previous repair attempts, it is practical to be wary when using acrylic compounds to repair paper-based special collections objects. Previous peel and lap/shear strength testing for Lascaux and BEVA adhesives has been conducted in the context of canvas lining (Katz 1985, 60). However, similar mechanical testing on Lascaux adhesive for use with paper has not been conducted.

The idea behind this criterion is to gauge how aged tissues might stick fast to a secondary paper support and therefore be able to draw conclusions on the ability of Lascaux-WSP tissue to retain its working characteristics over time. In lieu of mechanical testing, the authors chose to keep it simple by creating a protocol for the samples that was flexible but empirical. The samples were evaluated on a sliding scale using observational language to characterize each formulation's performance. The scale was rated from 1 to 5, and a rubric of clear definitions for each numerical value was available for consultation throughout the evaluation process. A worksheet was created to record the rating and additional observations about the tissue's performance (see Appendices 5 and 6 for adhesion evaluation instructions and a worksheet). Aged and unaged samples of each tissue sample set were applied in a consistent manner over commercial white Somerset 100% Cotton paper. The authors opted for a good-quality unaged stock to focus adhesion testing on the aged Lascaux-WSP tissues' performance rather than the interaction between the tissues and the historical papers. The aged and unaged tissues were applied to the Somerset paper as described in Appendix 2. After being allowed to dry, the adhesion was tested by pulling, scraping, and otherwise manipulating the dry tissue to see how its attachment to the secondary support remained intact or separated.

Reversibility

For the purposes of this article, adhesion and reversibility are, in many ways, two sides of the same coin. The authors were interested in judging how fully removable the precoated mending tissues were immediately after application versus after accelerated aging and whether the aging process on Lascaux's acrylic medium impacts how reversible the tissues remains over time. Like adhesion, a sliding scale with a clearly defined rubric for evaluation was developed, using much of the same observational language contextualized to the process of removing the tissues from a secondary support rather than applying it. However, one significant difference from the adhesion testing was that rather than preparing new samples using a commercial paper stock, instead testing was performed on the tissues applied to historical papers that had been treated and aged earlier in the experimental process (see Appendices 7 and 8). This was an important distinction since, in this case, the focus was on the interaction between the tissues and the historical papers to which there were applied. The hope was that this evaluation would clearly demonstrate a change in reversibility within the tissues over the aging process. When the evaluation of reversibility began, a 1:1 solution of deionized water (DiH_2O) and ethanol (EtOH) was used to re-activate and reverse the adhesive bond between the tissue and the paper. This ratio was adopted from personal experience of trying to reverse the adhesion of Lascaux 303 HV without significant deformation to the paper. Based on previous testing, this formula was generally successful, but the solution was later changed to a 4:1 DiH_2O to EtOH ratio, which improved the ease of removal after aging.

POST-AGING QUALITATIVE TESTING: RESULTS

Color Analysis: Results

Handmade Papers "Oversized" and "Maps"

Color analysis of both the Lascaux-WSP tissues and the prepared historic samples was as expected. Predictably, the discoloration worsened over the course of aging and was most significant for the historical paper samples that were aged for the full four weeks. Table 3 and Table 4 show the two handmade historical papers with the four tissue formulations ("T1–T4") applied to each quadrant of phased treatment preparations ("B2–B4") and aged one month. While the color shift was more significant in "Oversized" than in "Maps," numerically, each sample is mostly consistent in how much color change occurred, showing +/– 2% from one treatment phase to the next, except for "T3," where the variation is slightly higher.

The exception seems to be in the areas of the "Oversized" historical paper samples without mending. Although there is a clear and expected difference in performance between samples that received limited versus full treatment, the biggest data gap exists in comparing the percentage of color shift between recto and verso of the non-mended area (see table 3). Although true for all of the samples without mending regardless of treatment phase, it is especially noticeable in the B2 samples where the percentage of color shift in the verso compared to recto was a

"OVERSIZED" HANDMADE PAPER
Total Percentage of Color Shift After Accelerated Aging
Temperature was maintained at 90°C, RH at 65% for a period of one month

Before Aging Average
L* = 78.66

Before Aging	MENDED WITH T1 (WSP only) Recto		MENDED WITH T2 (LA303HV + WSP) Recto		MENDED WITH T3 (Toned, LA303HV + WSP) Recto		MENDED WITH T4 (WSP+LA498HV) Recto		WITHOUT MENDING Recto		WITHOUT MENDING Verso	
B2 L*=78.57	L*=52.62	–33.03%	L*=53.18	–32.32%	L*=51.70	–34.20%	L*=55.14	–29.82%	L*=55.28	–29.64%	L*=48.92	–37.74%
B3 L*=79.14	L*=54.25	–31.45%	L*=54.72	–30.86%	L*=50.38	–36.34%	L*=55.32	–30.10%	L*=50.08	–36.72%	L*=52.35	–33.85%
B4 L*=78.28	L*=53.95	–31.08%	L*=53.96	–31.07%	L*=57.78	–33.85%	L*=53.54	–31.60%	L*=50.84	–35.05%	L*=55.17	–29.52%

Table 3. Color Shift in "Oversized" Historical Paper After Accelerated Aging

full 8 points. This is a significant difference when compared to the +/–2% change of the rest of the sample set. Trying to make sense of these results, the authors hypothesized that a more dramatic color shift on verso that on recto might have been caused by a combination of inherent vice in the specific paper stock and/or the relative position of the endsheet paper to other materials or components of the original binding context. In particular, acidic boards or leather in contact with endsheets can lead to acid migration into the paper substrate over time, which may have remained latent or less obvious but for the extremities of the accelerated aging process (fig. 8).

It was also observed for many of the handmade paper samples that the presence of the precoated tissue acted as a barrier to a more extreme color shift. The exception was the "T3" Tengujo, the formulation that was first toned with Golden Acrylic pigments, then Lascaux-WSP. It showed higher darkening when applied over historical paper compared to the other tissue preparations. Despite having data that clearly quantified the darkening, it was still difficult to distinguish where the shift was happening. Was the discoloration in the tissue? In the pigment? In the paper? A combination of all? Or is it even just an artifact of seeing the normal color shift of the historical paper support through the toned translucent layer of the "T3" tissue? Ultimately, it could not be conclusively determined based on the collected data and was noted as a possible future path of inquiry.

Industrial Groundwood Pulp Paper "Miner"

The color shift observed in the third historical paper sample, "Miner," was less extreme—both numerically and visually—when compared to the handmade paper samples. Whereas "Maps" and "Oversized" both shifted 30% and above, "Miner's" percentage of color change was in the mid-high 20%. The lesser shift and overall data stability despite "Miner" having arguably higher factors of inherent vice is surprising at first glance. Lignin-rich papers have their own internal accelerated rate of embrittlement and discoloration due to the amount of naturally occurring acid present in the paper

"MAPS" HANDMADE PAPER
Total Percentage of Color Shift After Accelerated Aging
Temperature was maintained at 90°C, RH at 65% for a period of one month

Before Aging Average
L*=89.36

Before Aging	MENDED WITH T1 (WSP only) Recto		MENDED WITH T2 (LA303HV + WSP) Recto		MENDED WITH T3 (Toned, LA303HV + WSP) Recto		MENDED WITH T4 (WSP+LA498HV) Recto		WITHOUT MENDING Recto		WITHOUT MENDING Verso	
B2 L*=90.65	L*=60.60	–33.15%	L*=60.79	–32.94%	L*=59.36	–34.52%	L*=62.89	–30.62%	L*=62.13	–31.46%	L*=59.72	–34.12%
B3 L*=89.82	L*=60.92	–32.18%	L*=63.12	–29.73%	L*=60.82	–32.29%	L*=61.04	–32.04%	L*=59.59	–33.66%	L*=63.44	–29.37%
B4 L*=88.98	L*=62.42	–29.85%	L*=62.86	–29.35%	L*=59.17	–33.50%	L*=61.06	–31.38%	L*=60.93	–31.52%	L*=65.39	–26.51%

Table 4. Color Shift in "Maps" Historical Paper After Accelerated Aging

Fig. 8. During-treatment and after-treatment images of "Oversized" historic paper with precoated Lascaux-WSP tissue samples, with recto (above) and verso (below) showing uneven darkening over four weeks of aging.

matrix. This often results in acid hydrolysis autocatalysis, the reaction mechanism that accounts for industrial papers' rapid degradation rate. The authors surmise that the less extreme color shift in the "Miner" sample is simply because the paper had already aged poorly all on its own, having reached the exponential peak of darkening earlier in the object's history and resulting in a comparatively smaller range of color shift overall during accelerated aging (table 5).

Looking again at the "T3" tissue sample applied over "Miner," there is a more dramatic color shift in week 4. The authors suppose that the acrylic paint emulsion and/or Lascaux adhesive break down, so the color suspension is possibly

"MINER" INDUSTRIAL PAPER
Total Percentage of Color Shift After Accelerated Aging
Temperature was maintained at 90°C, RH at 65% for a period of one month

Before Aging Average
L*=72.83

Before Aging	MENDED WITH T1 (WSP only) Recto		MENDED WITH T2 (LA303HV + WSP) Recto		MENDED WITH T3 (Toned, LA303HV + WSP) Recto		MENDED WITH T4 (WSP+LA498HV) Recto		WITHOUT MENDING Recto		WITHOUT MENDING Verso	
B2 L*=73.84	L*=55.35	–25.04%	L*=55.45	–24.91%	L*=54.00	–26.87%	L*=54.58	–26.08%	L*=55.28	–25.14%	L*=55.62	–24.67%
B3 L*=71.64	L*=54.51	–23.91%	L*=55.40	–22.67%	L*=53.68	–25.07%	L*=54.03	–24.58%	L*=54.45	–23.99%	L*=56.00	–21.83%
B4 L*=73.03	L*=53.78	–26.36%	L*=55.28	–24.31%	L*=54.00	–26.06%	L*=53.54	–26.69%	L*=51.56	–29.40%	L*=55.11	–24.54%

Table 5. Color Shift in "Miner" Historical Paper After Accelerated Aging

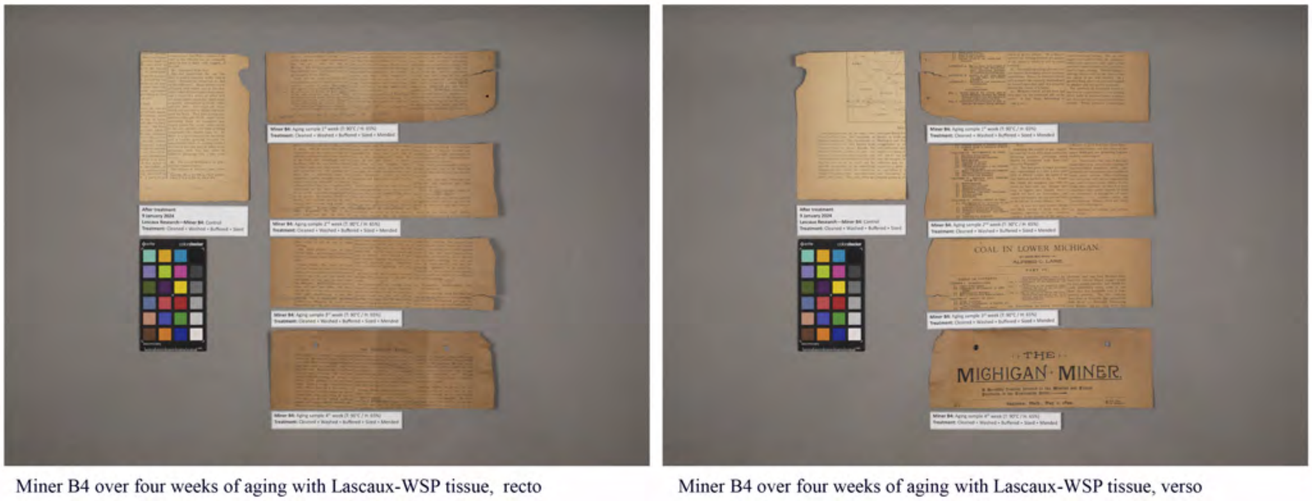

Fig. 9. "Miner B4" industrial paper with precoated Lascaux-WSP tissue samples, recto (left) and verso (right), showing significant discoloration in the area where "T3" was applied.

transferring to the paper support itself. After the reversibility testing, when the "T3" tissue was removed from the "Miner" paper sample, it was observed that the darkening was, in fact, in the historical sample and not a visual effect of the toned tissue being layered over the historical paper (fig. 9).

This effect is just visible in "Miner" only in the fourth week, and under the most extreme conditions of accelerated aging, although exactly why is difficult to say. It may be related to the major differences between "Miner" and the other historical handmade paper samples. "Miner" has both the presence of lignin and other contemporary industrial additives or coatings that might have been popular at the time.

One could posit that adhesive film and/or acrylic pigment have migrated into the paper during the aging process, leading to a more significant color shift overall. To better understand where the darkening was happening, the authors followed up the planned qualitative analysis by taking one of the "Miner" samples aged four weeks, splitting it in two, and washing one half to see if the stronger darkening in the paper support where the "T3" tissue had been applied could be diminished or reversed (fig. 10). After washing and allowing it to dry, it was clear that the preferential color shift remained as visible in the washed half as it was in the unwashed half. Although the percentage color shift numbers themselves remain stable,

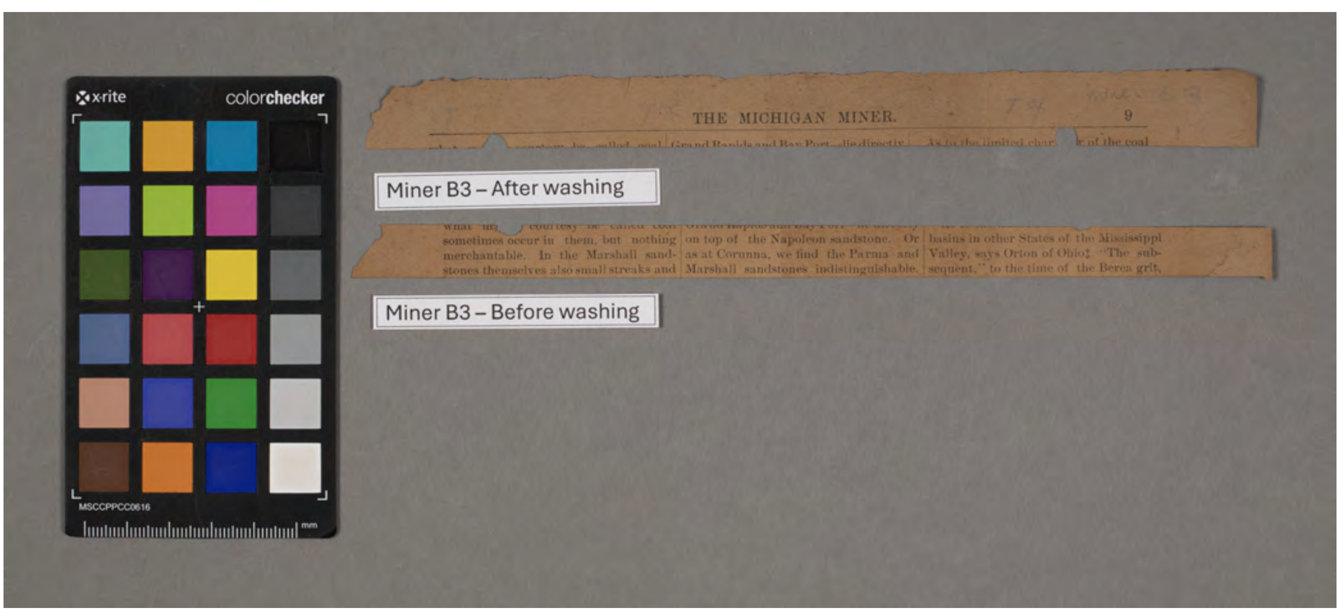

Fig. 10. "Miner B3" industrial paper divided and then washed to see if the discoloration caused by contact with "T3" could be removed or reversed. The discoloration appears unchanged.

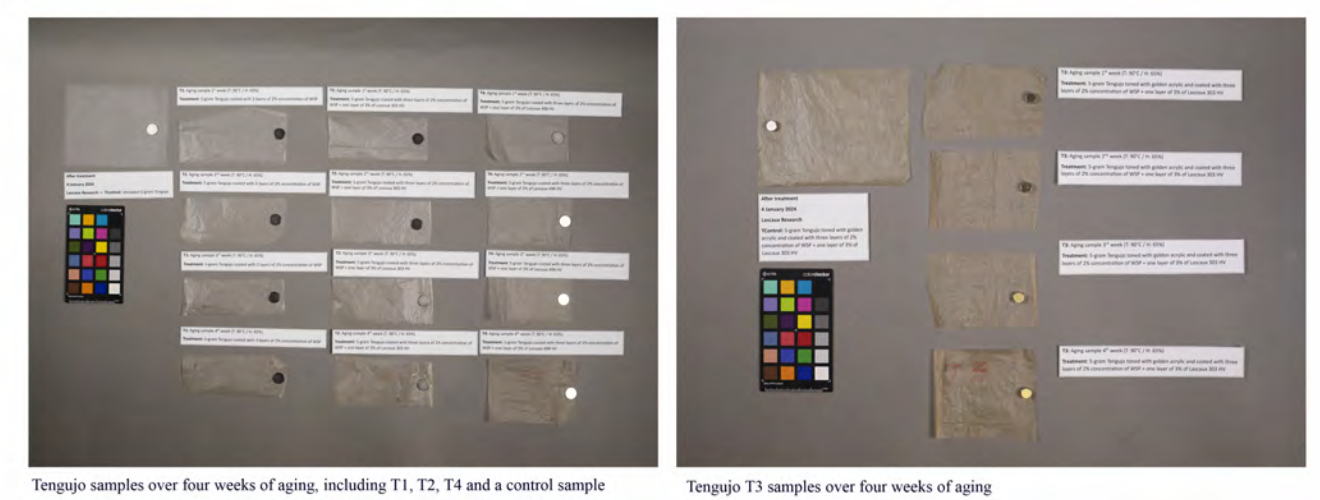

Fig. 11. Four formulations of precoated Tengujo, plus the control, showing the progression of physical changes as a result of accelerated aging over four weeks.

the more significant darkening of the industrial paper in the presence of toned Lascaux-WSP tissue suggests that use of the "T3" formulation could potentially pose risks for use in certain papers. It is imperative to do more experiments using acrylic color in paper conservation to establish the risk of using this material in archival materials.

Tengujo 5 gsm Precoated With Lascaux and Paste

As mentioned previously, the openness of the paper matrix in the Tengujo tissue makes the impact of the observed color shift much less significant compared to the perceived changes in the historical papers (fig. 11). The tissue showed a lower percentage of darkening overall, only 14% to 16% inclusive of formulations "T1–T4" (table 6). It is evident that both acrylic and paste influence paper degradation. The uncoated control sample of Tengujo was quite stable, with a total change of –3% by the end of four weeks and no change at all from the first to the second week and the second to third week of aging. For the rest of the samples, any coating applied to the paper—regardless of whether they are WSP only or Lascaux-WSP—makes a notable difference in the overall tissue aging. In handling, the week 4 samples of the tissues (compared to the base control sample) universally shift brown rather than yellow, and in handling, they feel weaker and more fragile when manipulated by hand. The "T3" sample (toned) again is harder to evaluate based on color analysis alone, but observationally looks and feels changed from its unaged control sample.

While the precoated tissues underperformed compared to the uncoated Tengujo, seeing a weakening of the coated tissue is still preferable to potential cross-linking or the development of intractable adhesion, as we often see in pressure-sensitive tape or other acrylic-based materials, or the migration of components into the secondary support, as discussed earlier in the "Miner" + "T3" combination. This aspect is more thoroughly discussed in later sections of this article.

pH Analysis

Handmade Papers "Oversized" and "Maps"

Like color analysis, pH analysis met predicted expectations. Before aging, the pH of all sample set improved throughout phased treatment, with an increase in the initial pH after the document was treated (tables 7, 8). Once inserted into the humidity chamber, the pH values sharply drop after the first week, followed by a more stable decrease in subsequent weeks. Based on the data collected, it could be deduced that when comparing an untreated and treated sample, most of the decrease in pH had to do with the inherent vice of the historical paper stock, presumably for similar reasons as discussed previously. The change of the unmended recto and verso in "Oversized" is much smaller in pH than observed in color shift. This suggests that the pH of the aged sample is potentially more evenly distributed throughout the paper matrix than the discoloration, which appears to be operating on the surface of either side.

Another difference between the two handmade papers is that while the change in pH in the "Maps" sample set is quite consistent across the different tissue formulations and from one treatment phase to the next, the "Oversized" pH data is much more irregular. The authors attribute this to the mottled and non-homogeneous character of the paper that became visible after aging, which could also be an artifact of acid migration, as discussed in the previous section.

Industrial Groundwood Pulp Paper "Miner"

A few unusual trends were noted—specifically, a decrease in pH after aging directly related to buffering and sizing. This

PRECOATED TENGUJO TISSUE FORMULATIONS Total Percentage of Color Shift After Accelerated Aging Temperature was maintained at 90°C, RH at 65% for a period of one month				
Coated Tengujo Formulation/Week	Initial Color L*	Weekly Color Value Shift	Total % Decrease Week to Week	Average % Compared to the Previous Week
TControl (Uncoated)	96.59			
TControl (Uncoated)/Week 1		94.75	–1.90%	–1.90%
TControl (Uncoated)/Week 2		94.62	–2.04%	–0.14%
TControl (Uncoated)/Week 3		94.38	–2.29%	–0.25%
TControl (Uncoated)/Week 4		93.57	–3.13%	–0.84%
T1 (WSP Only)	94.07			
T1/Week 1		90.96	–3.31%	–3.31%
T1/Week 2		87.27	–7.23%	–3.92%
T1/Week 3		82.54	–12.26%	–5.03%
T1/Week 4		81.35	–13.52%	–1.26%
T2 (LA303HV + WSP)	94.12			
T2/Week 1		91.20	–3.10%	–3.10%
T2/Week 2		86.78	–7.80%	–4.70%
T2/Week 3		82.18	–12.69%	–4.89%
T2/Week 4		79.12	–15.94%	–3.25%
T3 (Toned, LA303HV + WSP)	71.30			
T3/Week 1		70.90	–0.56%	–0.56%
T3/Week 2		70.61	–0.97%	–0.41%
T3/Week 3		69.49	–2.54%	–1.57%
T3/Week 4		67.00	–6.03%	–3.49%
T4 (LA498HV + WSP)	94.17			
T4/Week 1		93.34	–0.88%	–0.88%
T4/Week 2		89.48	–4.98%	–4.10%
T4/Week 3		85.07	–9.66%	–4.68%
T4/Week 4		81.00	–13.99%	–4.33%

Table 6. Color Shift in Precoated Tengujo After Accelerated Aging

"OVERSIZED" HANDMADE PAPER Total Average Percentage of Decrease of pH After Accelerated Aging Temperature was maintained at 90°C, RH at 65% for a period of one month													
		MENDED WITH T1 Recto Avg. Decrease: 34%		MENDED WITH T2 Recto Avg. Decrease: 34%		MENDED WITH T3 Recto Avg. Decrease: 34%		MENDED WITH T4 Recto Avg. Decrease: 35%		W/O MENDING Recto Avg. Decrease: 34%		W/O MENDING Verso Avg. Decrease: 34%	
	Initial pH	Final pH	% D.	Final pH	% D.	Final pH	% D.	Final pH	% D.	Final pH	% D.	Final pH	% D.
B1	3.70	–	–	–	–	–	–	–	–	–	–	–	–
B2	6.00	4.14	–31.00%	4.04	–32.67%	4.20	–30.00%	3.97	–33.83%	3.99	–33.50%	3.97	–33.83%
B3	6.16	3.97	–35.55%	4.15	–32.63%	3.99	–35.23%	4.09	–33.60%	4.04	–34.42%	4.04	–34.42%
B4	6.18	3.93	–36.41%	3.86	–37.54%	3.88	–37.22%	3.92	–36.57%	4.04	–34.63%	4.03	–34.79%

Table 7. Change in pH in "Oversized" Historical Paper After Accelerated Aging

“MAPS” HANDMADE PAPER Total Average Percentage of Decrease of pH After Accelerated Aging Temperature was maintained at 90°C, RH at 65% for a period of one month													
		MENDED WITH T1 Recto Avg. Decrease: 34%		MENDED WITH T2 Recto Avg. Decrease: 34%		MENDED WITH T3 Recto Avg. Decrease: 34%		MENDED WITH T4 Recto Avg. Decrease: 35%		W/O MENDING Recto Avg. Decrease: 34%		W/O MENDING Verso Avg. Decrease: 34%	
	Initial pH	Final pH	% D.	Final pH	% D.	Final pH	% D.	Final pH	% D.	Final pH	% D.	Final pH	% D.
B1	4.75	–	–	–	–	–	–	–	–	–	–	–	–
B2	5.72	4.35	–23.95%	4.32	–24.48%	4.34	–24.13%	4.37	–23.60%	4.32	–24.48%	4.35	–23.95%
B3	6.15	4.36	–29.11%	4.35	–29.27%	4.34	–29.43%	4.34	–29.43%	4.34	–29.43%	4.36	–29.11%
B4	5.82	4.26	–26.80%	4.28	–26.46%	4.23	–27.32%	4.24	–27.15%	4.24	–27.15%	4.23	–27.32%

Table 8. Change in pH in “Maps” Historical Paper After Accelerated Aging

decrease was present in samples for all of the historical papers but was of particular note in the industrial “Miner” paper stock (table 9). Given that “Miner” had the lowest pH to start, it is reasonable to hypothesize that washing the samples had a disproportionately positive effect on the pH. At the same time, the less than 1% gelatin solution used during sizing caused the pH to dip slightly. Despite buffering and sizing consistently causing a dip in pH, the pH data from the “Miner” sample set shows a stable change in percentage decrease overall, with the peak in acidity being minor and consistent regardless of the tissue formulation being applied. While the effect of buffering with calcium carbonate followed by gelatin sizing on industrial—or indeed any—paper is not the focus of this research, it might be an interesting topic for future investigation. Since the most dramatic change is observed in lignin-rich wood pulp paper, one could postulate that it may be related to other industrial additives. However, it is hard to draw firm conclusions since this may depend highly on individual paper manufacturers’ era, location, and practices.

Tengujo 5 gsm Precoated With Lascaux and Paste

For the Tengujo tissue samples, the overall change between initial and final pH measurements has a narrower range. As with the historical paper samples, the change in pH for the precoated tissues decreased steadily over the four weeks of aging. Regarding the “T2” tissue, the initial pH of the Tengujo was 6.2, which increased to 6.45 immediately after coating and decreased to 5.08 after aging. The total decrease is 23%. Although this clearly indicates that precoating with Lascaux-WSP does have an impact on how much the pH decreased, it is important to note that the “T1” formulation—coated only with WSP—is just a few percentage points behind the tissues with the Lascaux-WSP combination. The uncoated control sample’s pH value decreased from 6.2 to 5.01 over the four weeks, registering a 19% decrease (table 10). Even though the pH percentage decreases at first glance, it is higher in the case of Lascaux-WSP-coated formulations of Tengujo and the change overall is not radically different from Tengujo aging on its own.

Adhesion

“T1” and “T2” formulations both adhered to the paper support uniformly and without visible delamination, regardless of the length of aging. Subtle planar deformation was noted in the area where the mending was applied, but there was no puckering, cupping, or warping; the deformation was only

“MINER” INDUSTRIAL PAPER Total Average Percentage of Decrease of pH After Accelerated Aging Temperature was maintained at 90°C, RH at 65% for a period of one month													
		MENDED WITH T1 Recto Avg. Decrease: 23%		MENDED WITH T2 Recto Avg. Decrease: 25%		MENDED WITH T3 Recto Avg. Decrease: 24%		MENDED WITH T4 Recto Avg. Decrease: 24%		W/O MENDING Recto Avg. Decrease: 23%		W/O MENDING Verso Avg. Decrease: 24%	
	Initial pH	Final pH	% D.	Final pH	% D.	Final pH	% D.	Final pH	% D.	Final pH	% D.	Final pH	% D.
B1	3.4	–	–	–	–	–	–	–	–	–	–	–	–
B2	6.00	4.98	–17.00%	4.78	–20.33%	4.80	–20.00%	4.83	–19.50%	4.91	–18.17%	4.90	–18.33%
B3	6.58	4.75	–27.81%	4.75	–27.81%	4.85	–26.29%	4.84	–26.44%	4.84	–26.44%	4.83	–26.60%
B4	6.50	4.87	–25.08%	4.83	–25.69%	4.82	–25.85%	4.83	–25.69%	4.82	–25.85%	4.80	–26.15%

Table 9. Change in pH in “Miner” Historical Paper After Accelerated Aging

PRECOATED TENGUJO TISSUE FORMULATIONS Total Percentage of pH Change After Accelerated Aging Temperature was maintained at 90°C, RH at 65% for a period of one month				
Tengujo Formulation/Week	Initial pH	Weekly pH Decrease	Total % Decrease Week to Week	Average % Compared to the Previous Week
TControl (Uncoated)	6.20			
TControl/Week 1		5.45	–12.10%	–12.10%
TControl/Week 2		5.36	–13.55%	–1.45%
TControl/Week 3		5.20	–16.13%	–2.58%
TControl/Week 4		5.01	–19.19%	–3.06%
T1 (WSP Only)	6.40			
T1/Week 1		5.93	–7.34%	–7.34%
T1/Week 2		5.70	–10.94%	–3.59%
T1/Week 3		5.53	–13.59%	–2.66%
T1/Week 4		5.25	–17.97%	–4.38%
T2 (LA303HV + WSP)	6.56			
T2/Week 1		6.00	–8.54%	–8.54%
T2/Week 2		5.52	–15.85%	–7.32%
T2/Week 3		5.21	–20.58%	–4.73%
T2/Week 4		5.08	–22.56%	–1.98%
T3 (Toned, LA303HV + WSP)	6.56			
T3/Week 1		5.93	–9.60%	–9.60%
T3/Week 2		5.73	–12.65%	–3.05%
T3/Week 3		5.49	–16.31%	–3.66%
T3/Week 4		5.28	–19.51%	–3.20%
T4 (LA498HV + WSP)	6.52			
T4/Week 1		5.71	–12.42%	–12.42%
T4/Week 2		5.41	–17.02%	–4.60%
T4/Week 3		5.21	–20.09%	–3.07%
T4/Week 4		5.09	–21.93%	–1.84%

Table 10. Change in pH in Precoated Tengujo After Accelerated Aging

visible under raking light. This is likely due to a combination of brief drying time and an absorptive secondary paper support. The mechanical resistance of the tissue—that is, the ability of the tissue to remain in a consolidated sheet when pulled or manipulated—diminished over the four-week period of testing. Regardless, this did not have any visible effect on the ability of the tissue formulations to adhere to the secondary support. The adhesives in “T1” and “T2” appeared to retain their adhesive capacity, as demonstrated through physical attempts to pull the tissue away from the paper surface, and lift or abrade it away using a microspatula.

The adhesion of the “T1” tissue (WSP only) was significantly stronger than the tissues precoated with the Lascaux-WSP combination. Whereas for “T2” the tissue broke at the line of adhesion when pulled or abraded, “T1” would also cause delamination or skinning to the surface of the secondary support. “T2” additionally showed some diminishment of the adhesive capacity in the final week of aging, going from a rating of 5 (strong adhesion) to 4 (moderate observed resistance).

The other two formulations, “T3” (toned, Lascaux 303 HV + WSP) and “T4” (Lascaux 498 HV + WSP), did not perform nearly as well as the previously discussed tissues. Both tissues had much lower initial adhesive properties, disappearing almost completely as early as the first week of aging (fig. 12). Likewise, the mechanical resistance to manipulation was lower and diminished as the aging process progressed. Additionally, when examined under magnification, it was easily observed how the acrylic film suspended in the interstices between the Tengujo fibers had largely diminished or disappeared after four weeks of aging (figs. 13, 14).

This bifurcation in the data is curious. In considering why “T3” and “T4” might behave similarly in their inability to adhere after aging, the authors hypothesize that there must be some physical and chemical similarities between the acrylic

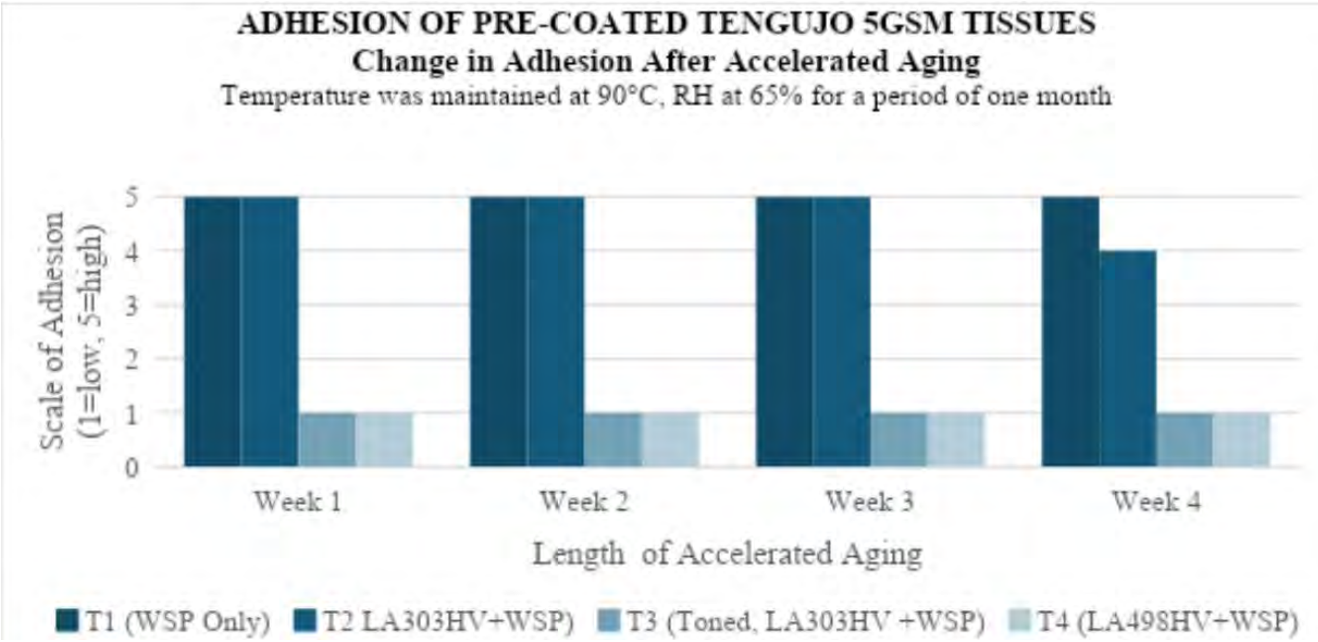

Fig. 12. The adhesion performance of “T1” and “T2” compared to “T3” and “T4” is significant and distinct.

paint emulsion and Lascaux 498 HV—something about how the acrylic film is cast over this tissue in both Golden Acrylics and Lascaux 498 HV must be similar, resulting in the adhesive properties failing quite early in the aging process for both formulations.

Another thing to note, however, is that this adhesion failure is only observed in the Tengujo tissue samples that were first aged and then applied to the new Somerset 100% Cotton stock. The historical paper samples with the “T3” and “T4” formulations applied before aging showed no signs of weakening and delamination before reversibility was attempted by introducing the 1:1 DiH_2O and EtOH solution.

Reversibility

Reversibility testing began using a 1:1 solution of DiH_2O and EtOH applied to the “Oversized” sample set. It quickly became clear, especially for the samples with more aging, that a solution with a higher proportion of water was more effective in

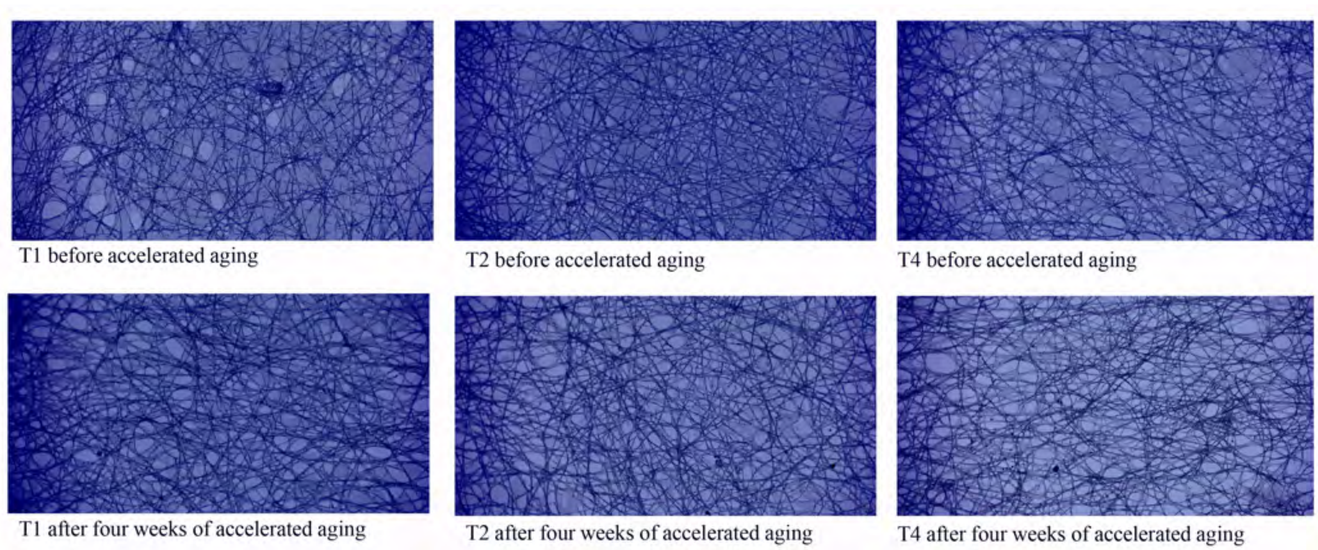

Fig. 13. “T1,” “T2,” and “T4” Tengujo tissue formulations before and after four weeks of aging under 40x magnification. While they all show some change to the adhesive coat suspended between the paper fibers, T4 show significant change after aging.

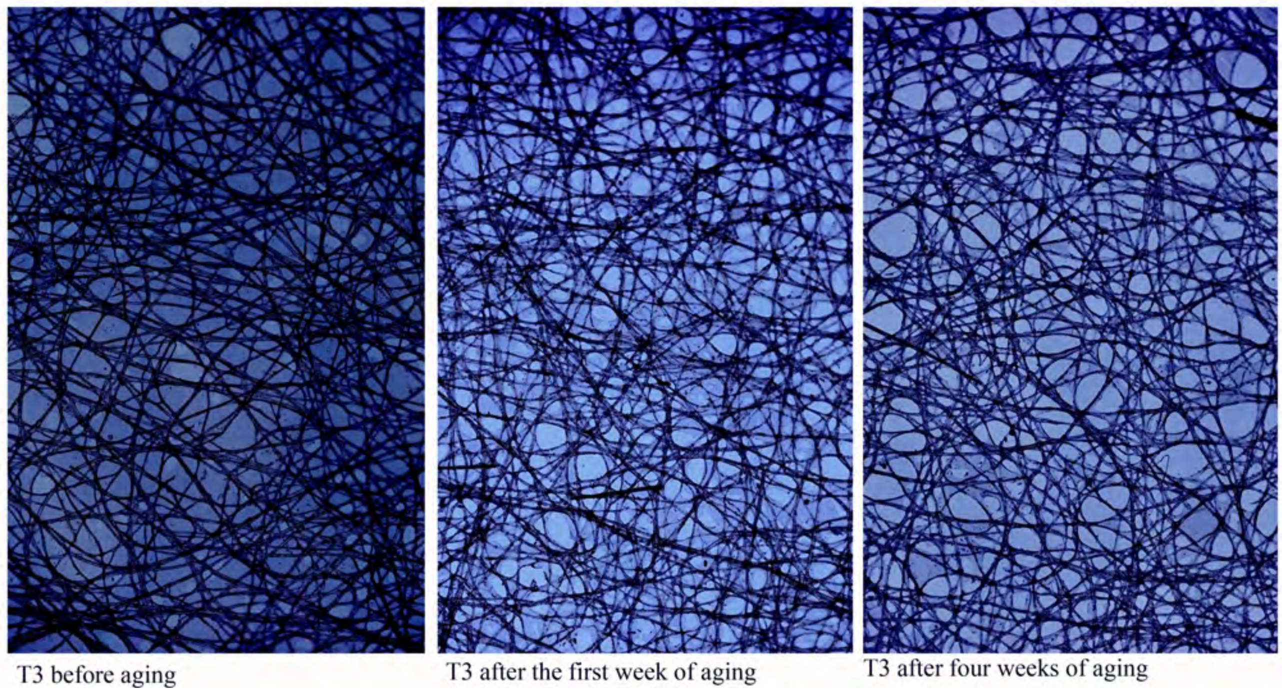

Fig. 14. "T3" Tengujo tissue formulation throughout the accelerated aging process under 40x magnification. The film suspended between the tissue fiber began to degrade as early as the first week of the aging process.

reversing adhesion (table 11). In subsequent testing, the solution was adjusted to 4:1 DiH_2O and EtOH. This change resulted in consistently high reversibility scores of 4.7 to 5 across all historical paper samples aged one to four weeks.

The efficacy of water in reversing adhesion supports the idea that the paste successfully encapsulates the Lascaux film and is the primary, if not only, source of adhesion in the coated tissue. After removing the tissue, no discoloration was observed in the samples with the "T2" formulation, and the tissue was removed easily, retained its original shape, and did not cause any delamination. Throughout reversibility testing, it was additionally observed that there were no signs of detachment occurring between the tissue and the paper samples without trying to actively remove them.

Only a few fibers of the historical paper remained attached to the tissue after reversibility testing. This seemed more likely when the paper was not sized. For the samples that had undergone resizing, there was less resistance to separating the tissue from the paper support, probably because of the sizing process consolidating historical paper samples to which it was applied.

One observation that encouraged caution was that some adhesive coating from the tissue remained on the secondary support after removal. While only visible under magnification, it was clear that the coating and tissue were separating, especially in the larger interstitial spaces between the fibers. Subsequently, after examining the secondary support when the tissue was removed, significant adhesive deposits left behind were not evident (unless mixed with fragments of Tengujo fiber), nor were they visible under magnification. The authors hypothesize that it could be due to the transparency of the adhesive, that the adhesive has broken or diminished as part of the mechanical action of removing it, or because it has broken down and migrated into the paper. This was evident for all tissue formulations and could be observed as early as after the first week of aging.

MECHANICAL TESTING

Since the main argument for the use of Lascaux adhesives in conjunction with paste for precoated repair tissue is that the acrylic film changes the morphology and strength of the Tengujo, the authors desired to add limited mechanical testing to see if it was possible to quantify that physical change. A control sample and "T1–T4" formulations were prepared both aged and unaged, and sent to SGS IPS Testing. This company conducts ISO and TAPPI standard tests on industrial paper-based products. Specific tests included ISO 12625-9 Ball Burst and ISO 12625-4 Tensile Strength (Dry).

ISO12625-9 Ball Burst

According to their website, SGS-IPS describes ISO 12625-9 Ball Burst as a test method for the determination of the resistance to mechanical penetration (ball burst strength

REVERSIBILITY OF AGED PRECOATED TENGUJO 5 GSM TISSUES T1–T4 Tissues Applied Over "Oversized" Treated Papers B1–B4 Temperature was maintained at 90°C, RH at 65% for a period of one month (Scale 1–5; 1=Low reversibility, 5=Highly reversible)						
OVERSIZED	AGING TIME	T1	T2	T3	T4	SOLVENT
B2	1st week	5	4.7	4.7	5	DiH_2O:EtOH (1:1)
B2	2nd week	5	4.7	4.7	5	DiH_2O:EtOH (1:1)
B2	3rd week	5	4.7	4.7	5	DiH_2O:EtOH (1:1)
B2	4th week	5	4.7	4.7	5	DiH_2O:EtOH (1:1)
B3	1st week	5	4.7	4.7	5	DiH_2O:EtOH (1:1)
B3	2nd week	5	4.7	4.7	5	DiH_2O:EtOH (1:1)
B3	3rd week	5	4	4.7	5	DiH_2O:EtOH (1:1)
B3	4th week	5	3	3	4	DiH_2O:EtOH (1:1)
B4	1st week	5	4.7	4.7	5	DiH_2O:EtOH (1:1)
B4	2nd week	5	4.7	4.7	5	DiH_2O:EtOH (1:1)
B4	3rd week	4.7	4.7	4.7	4.7	DiH_2O:EtOH (1:1)
B4	4th week	3	4.7	4.7	5	T1:DiH_2O:EtOH (1:1) T2–T4: DiH_2O only
MAPS	AGING TIME	T1	T2	T3	T4	SOLVENT
B2	1st week	5	5	4.7	5	DiH_2O:EtOH (4:1)
B2	2nd week	5	5	5	5	DiH_2O:EtOH (4:1)
B2	3rd week	5	5	5	5	DiH_2O:EtOH (4:1)
B2	4th week	5	5	5	5	DiH_2O:EtOH (4:1)
B3	1st week	5	5	4.7	4.7	DiH_2O:EtOH (4:1)
B3	2nd week	5	5	5	5	DiH_2O:EtOH (4:1)
B3	3rd week	5	5	4.7	4.7	DiH_2O:EtOH (4:1)
B3	4th week	5	5	5	4.7	DiH_2O:EtOH (4:1)
B4	1st week	5	5	5	5	DiH_2O:EtOH (4:1)
B4	2nd week	5	5	5	5	DiH_2O:EtOH (4:1)
B4	3rd week	5	5	5	5	DiH_2O:EtOH (4:1)
B4	4th week	5	5	5	5	DiH_2O:EtOH (4:1)
MINER	AGING TIME	T1	T2	T3	T4	SOLVENT
B2	1st week	5	5	5	5	DiH_2O:EtOH (4:1)
B2	2nd week	5	5	5	5	DiH_2O:EtOH (4:1)
B2	3rd week	5	5	5	5	DiH_2O:EtOH (4:1)
B2	4th week	5	5	5	5	DiH_2O:EtOH (4:1)
B3	1st week	5	5	5	5	DiH_2O:EtOH (4:1)
B3	2nd week	5	5	5	5	DiH_2O:EtOH (4:1)
B3	3rd week	5	5	5	5	DiH_2O:EtOH (4:1)
B3	4th week	5	5	5	5	DiH_2O:EtOH (4:1)
B4	1st week	5	5	5	5	DiH_2O:EtOH (4:1)
B4	2nd week	5	5	5	5	DiH_2O:EtOH (4:1)
B4	3rd week	5	5	5	5	DiH_2O:EtOH (4:1)
B4	4th week	5	5	5	5	DiH_2O:EtOH (4:1)

Table 11. Reversibility Observed in Precoated Tengujo on Historical

ANALYSIS OF FIVE UNAGED PRECOATED TENGUJO SAMPLES ISO 12625-9 Ball Burst specifies a test method for the determination of the resistance to mechanical penetration (ball burst strength procedure)					
Ball Burst (ISO 1265-9)	TCONTROL (UNAGED)	T1 (UNAGED)	T2 (UNAGED)	T3 (UNAGED)	T4 (UNAGED)
Bursting Strength (lbf)					
Average	0.430	1.335	1.413	1.467	1.481
Std. Dev.	0.0451	0.2033	0.2068	0.1953	0.2248
Maximum	0.512	1.582	1.763	1.793	1.789
Minimum	0.371	1.039	1.163	1.195	1.153
n=	10	10	10	10	10
Bursting Strength (N)					
Average	1.91	5.94	6.29	6.52	6.59
Std. Dev.	0.20	0.90	0.92	0.87	1.00
Maximum	2.28	7.04	7.84	7.97	7.96
Minimum	1.65	4.62	4.62	5.32	5.13
n=	10	10	10	10	10

Table 12. Physical Properties, Ball Burst of Unaged Precoated Tengujo

procedure) of tissue paper and tissue products. Testing Ball Burst consists of measuring the resistance force of a highly polished stainless steel burst ball, moving at a constant speed, penetrating a tissue test piece perpendicularly that is clamped between two concentric rings. SGS-IPS typically uses a clamping ring with an internal diameter of 4.45 cm.

Looking at the data (tables 12, 13) for both the aged and unaged Tengujo papers, adding a coating to the 5 gsm tissue imparts strength, even if it is only paste. That said, there is an increased resistance across all of the Lascaux-WSP samples compared to the "T1" sample coated only with WSP. Interestingly, of the Lascaux-WSP precoated tissues, "T3," with its layer of acrylic pigment followed by the adhesives, appears to have the smallest change in ball burst strength between unaged and aged samples.

ISO 12625-4 Tensile Strength (Dry)
SGS-IPS describes the ISO 12625-4 Tensile test as a method for the determination of the tensile strength, stretch at break, and tensile energy absorption of tissue paper and tissue

ANALYSIS OF FIVE AGED PRECOATED TENGUJO SAMPLES ISO 12625-9 Ball Burst specifies a test method for the determination of the resistance to mechanical penetration (ball burst strength procedure)					
Ball Burst (ISO 1265-9)	TCONTROL (AGED)	T1 (AGED)	T2 (AGED)	T3 (AGED)	T4 (AGED)
Bursting Strength (lbf)					
Average	0.226	0.482	0.577	0.713	0.585
Std. Dev.	0.0521	0.1221	0.0832	0.1325	0.0825
Maximum	0.337	0.711	0.737	0.924	0.708
Minimum	0.169	0.358	0.463	0.500	0.483
n=	10	10	10	10	10
Bursting Strength (N)					
Average	1.01	2.14	2.57	3.17	2.60
Std. Dev.	0.23	0.54	0.37	0.59	0.37
Maximum	1.50	3.16	3.28	4.11	3.15
Minimum	0.753	1.59	2.06	2.23	2.15
n=	10	10	10	10	10

Table 13. Physical Properties, Ball Burst of Aged Precoated Tengujo

ANALYSIS OF FIVE UNAGED PRECOATED TENGUJO SAMPLES ISO 12625-4 Tensile strength test specifies a method for the determination of the tensile strength, stretch at break, and tensile energy absorption					
Tensile (ISO 12625-4)	TCONTROL (UNAGED)	T1 (UNAGED)	T2 (UNAGED)	T3 (UNAGED)	T4 (UNAGED)
Tensile Strength (Newtons per meter)					
Average	106	311	354	457	307
Std. Dev.	16	72	24	44	25
Maximum	126	456	394	514	347
Minimum	84.3	232	323	390	276
n=	10	10	10	10	10
Tensile Strength (pounds-force per inch)					
Average	0.60	1.78	2.02	2.61	1.75
Std. Dev.	0.090	0.411	0.140	0.250	0.141
Maximum	0.72	2.61	2.25	2.94	1.98
Minimum	0.481	1.33	1.84	2.23	1.58
n=	10	10	10	10	10
Stretch at Maximum Force (%)					
Average	1.9	3.6	3.3	3.9	3.5
Std. Dev.	0.31	0.60	0.20	0.20	0.29
Maximum	2.3	4.8	3.7	4.2	3.9
Minimum	1.3	2.7	3.0	3.5	2.9
n=	10	10	10	10	10
Tensile Energy Absorption (Joules per square meter)					
Average	1.4	2.6	7.7	11.0	7.0
Std. Dev.	0.30	0.60	0.87	1.17	0.71
Maximum	1.8	4.8	9.0	12.3	7.8
Minimum	0.8	2.7	6.4	8.5	5.3
n=	10	10	10	10	10
Test Parameters					
Width (mm)	50	50	50	50	50
Nominal Gage Length (mm)	100	100	100	100	100
Crosshead Speed (mm/min)	50.0	50.0	50.0	50.0	50.0

Table 14. Tensile Properties of Unaged Precoated Tengujo

products. It uses a tensile-testing apparatus operating with a constant rate of elongation. The authors provided multiple test pieces of Tengujo paper of given dimensions. The samples were then stretched to break at a constant rate of elongation using a tensile-testing apparatus that measures and records the tensile force as a function of the elongation of the test piece. From the recorded data, the tensile strength, the corresponding stretch at break, and the tensile energy absorption were calculated.

The results of the tensile strength testing were consistent—applications of coatings to the Tengujo 5 gsm did improve performance. In this case, where the unaged "T3" formulation vastly outperformed the other sample preparations, it also lost the most strength after aging. Another notable finding in this data is that it appears that without considering the stretch at maximum force or the tensile energy absorption, the initial tensile strength data shows that all other tissue formulations tested besides "T3" actually increase in tensile strength after aging (tables 14, 15).

Although tear resistance was initially another area of mechanical testing that the authors were interested in, there was not a tear resistance testing protocol that was for tissue weight papers. More mechanical testing in the future would help deepen the understanding of how the precoatings are

ANALYSIS OF FIVE AGED PRECOATED TENGUJO SAMPLES ISO 12625-4 Tensile strength test specifies a method for the determination of the tensile strength, stretch at break, and tensile energy absorption					
Tensile (ISO 12625-4)	TCONTROL (AGED)	T1 (AGED)	T2 (AGED)	T3 (AGED)	T4 (AGED)
Tensile Strength (N/m)					
Average	184	343	327	258	321
Std. Dev.	59	29	47	47	38
Maximum	323	382	397	335	396
Minimum	127	281	257	186	285
n=	10	10	10	10	10
Tensile Strength (lbf/in)					
Average	1.05	1.96	1.87	1.47	1.83
Std. Dev.	0.335	0.164	0.269	0.271	0.217
Maximum	1.85	2.18	2.26	1.91	2.26
Minimum	0.73	1.61	1.47	1.06	1.63
n=	10	10	10	10	10
Stretch at Maximum Force (%)					
Average	1.0	1.4	1.8	2.1	1.7
Std. Dev.	0.16	0.19	0.32	0.37	0.32
Maximum	1.2	1.8	2.1	2.8	2.2
Minimum	0.7	1.1	1.3	1.6	1.2
n=	10	10	10	10	10
Tensile Energy Absorption (J/m^2)					
Average	1.0	2.4	3.4	3.1	3.0
Std. Dev.	0.45	0.40	0.54	0.80	0.69
Maximum	2.1	2.9	4.3	4.3	4.2
Minimum	0.5	1.5	2.6	2.1	2.1
n=	10	10	10	10	10
Test Parameters					
Width (mm)	50	50	50	50	50
Nominal Gage Length (mm)	100	100	100	100	100
Crosshead Speed (mm/min)	50.0	50.0	50.0	50.0	50.0

Table 15. Tensile Properties of Aged Precoated Tengujo

affecting the physical behavior and working characteristics of the Tengujo.

CONCLUSIONS

While any adhesive can eventually affect the aging characteristics of paper, the evidence presented here supports the idea that precoating repair tissue with a Lascaux-WSP combination does not present serious risks to paper objects, even under extreme aging conditions. While the decrease in pH is observed, it is stable and predictable and not as much as one might expect based on the observable color shift. The properties of adhesion and reversibility remain high after aging, suggesting that the proposed precoated tissue formulation is safe for most special collections materials. Furthermore, the mechanical testing results confirmed that the Tengujo's overall strength was improved upon with acrylic coatings, which supported the original goal of having a fine but strong tissue for conservation work.

Although the development of this tissue formulation addressed a very specific need, this research has unlocked other possible avenues of inquiry. Additional testing of the same formulations focusing on application methods or continued experimentation with other concentrations or proportions of the adhesives could provide useful iterations. However, the aging data and performance of Lascaux 303

HV acrylic adhesive have encouraged the authors to consider other book and paper conservation applications, such as Lascaux as an alternative to Klucel G in leather consolidation.

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APPENDIX 1. PROCEDURE FOR THE PREPARATION OF PRECOATED TENGUJO TISSUE WITH LASCAUX 303 HV ADHESIVE + 2% ZEN SHOFU WHEAT STARCH PASTE

Introduction

Precoated/remoistenable tissue is a common material used in book and paper conservation. It is useful for mending tears, guarding gatherings, and sometimes even facing or lining fragile paper supports. Thin paper especially Hiromi's Tengujo tissues which are available on the market from 1.6 grams on wards, is ideal for certain conservation treatments because of its thinness. Traditional conservation adhesives, such as gelatin, WSP, or methylcellulose, are commonly used for these preparations, but their chemical structure can produce a crystallization effect on the paper fibers to which they are applied. This can sometimes cause rigidity and weakness, especially in fine papers, which can be hard to work around.

The following methods outlines how to prepare fine tissues with a precoating of Lascaux Acrylic 303 HV followed by a low concentration of WSP. This yields a repair paper that has the elasticity and flexibility of an acrylic dispersion and the same adhesive and reversibility properties of precoated tissues prepared with paste.

Material and Equipment

Deionized water (200 mL)	Stir bars
Uncooked Zen Shofu wheat starch powder (2 g)	Gloves
Lascaux Acrylic 303 HV (3 g)	Silicone release Mylar
Hiromi Tengujo 5 gsm tissue	Trays
Beaker	Spatula
Glass stirring rod	Hake brushes (2)
Heated magnetic stir plate	Hair dryer

Procedure

1. Prepare a 3% solution of Lascaux Acrylic 303 HV:
   a. Measure 3 g of Lascaux 303 HV into an empty beaker.
   b. Add 100 mL of deionized water.
   c. Using a magnetic stir bar and plate, thoroughly mix the adhesive in the water until the mixture appears homogeneous.
2. Apply one layer of 3% Lascaux Acrylic 303 HV to Tengujo paper:
   a. Start with a clean sheet of silicone release Mylar that is 2 to 3 inches larger than the sheet to be coated on all sides. Then lay out the sheet of Tengujo.
   b. Using a large hake brush, apply an even layer of the Lascaux mixture to the Tengujo on top of the silicone release Mylar:
      i. Begin in the center and work your way out in a cross or starburst pattern to make sure the Tengujo wets out evenly.
      ii. Be gentle to avoid disrupting the paper fibers.
   c. Once the Tengujo is fully and evenly coated, clean the perimeter of the silicone release Mylar with a laboratory wipe or paper towel to remove any drops of adhesive solution (this makes handling in the following steps easier and ensures that the silicone release Mylar can be used multiple times).
   d. Using a hair dryer to speed drying time and prevent dust from settling, fully dry this first coat of adhesive before proceeding to the next step.
3. Prepare a 2% solution of WSP:
   a. Measure 2 g of powdered WSP into an empty beaker.
   b. Add 100 mL of deionized water.
   c. Using a hotplate with a magnetic stir bar and a temperature probe, thoroughly cook and mix the adhesive in the water until the mixture reaches 100°C.
   d. Remove from heat; add a volume of deionized water until the total volume is 100 mL (this replaces any liquid that evaporated during the cooking process).
4. Apply two to three layers of the WSP solution on alternating sides of the Tengujo, allowing it to dry between coats:
   a. Start with a clean sheet of silicone release Mylar that is 2 to 3 inches larger than the sheet to be coated on all sides. Then lay out the sheet of Tengujo coated with Lascaux.
   b. Using a large hake brush, apply an even layer of the paste solution to the Tengujo on top of the silicone release Mylar:
      i. Begin in the center and work your way out in a cross or starburst pattern to make sure the Tengujo wets out evenly.
      ii. Be gentle to avoid disrupting the paper fibers.
   c. Once the Tengujo is fully and evenly coated, clean the perimeter of the silicone release Mylar with a laboratory wipe or paper towel to remove any drops of adhesive solution (this makes handling in the following steps easier and ensures that the silicone release Mylar can be used multiple times).
   d. Using a hair dryer to speed drying time and prevent dust from settling, fully dry this first coat of adhesive before proceeding to the next step.
   e. Carefully remove the Tengujo from the silicone release Mylar, and flip over. Apply a second coat of paste to the new side.

f. Repeat, if desired, for three layers of paste. *Note: More than three layers of paste are not recommended, since they greatly diminish the elasticity of the Lascaux.*

5. To use in mending, reactivate using gellan gum or deionized water directly applied to the shiny side of the tissue.
6. Consult https://www.youtube.com/watch?v=SBV8J372scQ&t=189s for a full video tutorial.

APPENDIX 2. PROCEDURE FOR SAMPLE PREPARATION FOR LASCAUX-WSP TISSUE APPLIED OVER HISTORICAL PAPERS

Note: Because the tissue is activated with a 10% EtOH gellan gum formulation, the moisture evaporates fairly rapidly, leaving the dried mending tissue in place. If the area of the mending tissue is larger, the object needs to stay weighted down to dry longer.

1. Use gellan gum to moisturize the paper:
   a. Cut or tear the precoated paper to obtain the piece you need for the conservation treatment.
   b. Place the piece of paper over the gellan gum.
   c. Place a piece of silicone release Mylar over the paper.
   d. When the paper is wet enough (about 4 or 5 seconds), remove both the silicone release Mylar and the paper together.
2. Place the paper and the silicone release Mylar over the item to be treated.
3. Apply pressure using a Teflon or bone folder. Pressure is essential to obtain good adhesion.
4. Remove the silicone release Mylar.
5. Place the following four layers in order on top of the treated area:
   a. first, a piece of Hollytex;
   b. on top of the Hollytex, a piece of blotter;
   c. then a glass;
   d. and finally, a weight.
6. Wait until the treated area is flat and dry. This will take a maximum of 5 minutes.
7. If you need to remove the precoated paper from the document, apply light moisture with a brush or a piece of gellan gum.

APPENDIX 3. COLOR ANALYSIS USING THE COLOR MUSE COLORIMETER

Parameters for Color Data

- Evaluation is to be performed both on prepared historical paper samples and test tissues.
- Photo Doc will need to be performed to capture the color shift.
- Incorporate the use of Color Muse to quantify the color shift and to what extent it is impacted (if at all) by the presence of mending tissue on the historical sample.
- Testing includes the recto/verso of each historical treated paper with mending and without mending.

Instructions for the Use of a Color Muse Colorimeter

1. Download the Color Muse app on a smartphone. Open the app and press "Connect device."
2. Follow directions to connect and calibrate the device.
3. Once calibrated, remove the lens protection, place the device on a flat paper surface, and press it lightly so it is flush with the paper.
4. Hit "reference" on the app and record data from whichever color space is desired.
5. Repeat at least three times to collect enough data to average, moving the device randomly to different areas of the sheet of paper. Do not select the placement; rather, try to place it randomly, as this will give the most accurate data.

Link to Color Muse information and app: https://colormuse.io/color-muse.html.

APPENDIX 4. COMBINATION PH ELECTRODE INSTRUCTION MANUAL + EXPERIMENTAL USE

Introduction

This combination pH electrode comes in many styles and is designed for maximum reliability, accuracy, and ease of use. The outer body can be glass, epoxy, or other plastic materials. The plastic body electrode is available with a permanent non-removable bulb guard or a removable guard that is shipped and attached to the cable. The reference half-cell can be refillable or permanently sealed at the factory and underneath the cap at the top of the electrode. All styles of electrodes are shipped with an electrode soaker bottle wetting solution.

Preparation

1. Remove the electrode soaker bottle covering the pH bulb, and raise the bulb area with deionized water or pH buffer. Gently shake the electrode downward in the same manner as a clinical thermometer to remove any air bubbles that might be trapped behind the pH bulb.
2. For electrodes shipped with fill hole plugs, remove the shipping tape covering the rubber fill hole plug and withdraw the plug to expose the fill hole. For electrodes shipped with a sleeve over the fill hole(s), slide the rubber sleeve down and remove the shipping tape to expose the fill hole. Fill the refillable electrodes with the proper fill solution(s) to a level just below the fill hole(s).
3. Attach the removable bulb guard if provided with an epoxy electrode by sliding the guard over the end of the electrode.
4. If stored dry for an extended time, immerse the pH bulb in the pH buffer for 30 minutes. This hydrates the pH

bulb and wets the reference junction for optimum performance. The electrode is now ready for use.

Required Materials

1. *pH meter*: This electrode will work with any commercially available pH and/or millivolt meter. Connect the pH electrode to the meter or operate the meter.
2. *Buffers*: For precise electrode standardization, two buffers are required, one of which should be close to the desired pH.

Electrode Standardization

1. Place the electrode in a fresh pH 7.00 buffer and stir. Allow the meter to read and stabilize for 30 seconds to 1 minute. Adjust the meter to read 7.00 with the standardization control.
2. Rinse the electrode in distilled water and place it in a fresh pH 4.00 buffer or fresh pH 10.00 buffer depending on whether the sample is acidic or basic. Stir and allow the meter reading to stabilize for 30 seconds to 1 minute. Adjust the meter reading to the second pH value with either the slope or temperature compensation adjustment. If impossible, see the cleaning procedure.
3. Rinse the electrode with distilled water. Place in the sample and stir. Allow the meter reading to stabilize for 30 seconds to 1 minute. Record the reading. For best accuracy, the temperature of the buffers and samples should be identical and at room temperature.

Electrode Storage

For the best results, always keep the pH bulb wet, preferably in pH 4.00 buffer with 1/100 part of saturated KCl added. Other pH buffers or tap water are acceptable storage media, but avoid storage in distilled water. The electrode storage bottle filled with a buffer will provide an ideal storage chamber for long periods.

Electrode Cleaning

Electrodes that are mechanically intact with no broken parts can often be restored to normal performance by one of the following procedures:

1. *Salt deposits*: Dissolve the deposit by immersing the electrode in 0.1M HCl for 5 minutes, then immerse in 0.1M NaOH for 5 minutes and thoroughly rinse with distilled water.
2. *Oil/grease films*: Wash the electrode pH bulb in a little detergent and water. Rinse the electrode tip with distilled water.
3. *Clogged reference junction*: Heat a diluted KCl solution to 60°C to 80°C. Place the sensing portion of the pH electrode into the heated KCl solution for approximately 10 minutes. Allow the electrode to cool while immersed in some unheated KCl solution.
4. *Protein deposits*: Dissolve the deposit by immersing the electrode in a 1% pepsin solution with a background of 0.1M HCl for 5 minutes, followed by thorough rinsing with distilled water.

If these steps fail to restore normal electrode response, replace the electrode.

Modifications to Recommended Procedure for Experimental Application (MVVP 1/2024)

1. Before each use, calibrate the pH probe. Slightly humidify the testing paper with deionized water. The absorption time varies depending on the type of paper: handmade paper absorbs quickly, whereas machine-made, lignin-rich paper absorbs more slowly. Allow the electrode measurement to stabilize, which may take up to 3 minutes, with a minimum of 1 minute needed to ensure an accurate reading.
2. After each measurement, cleanse the electrode with deionized water and corroborate the results by taking a second reading at a different location using the same procedure.
3. If the readings appear anomalous—either excessively high or low or not progressing as expected—halt the process and recalibrate the electrode according to the manufacturer's instructions.
4. Verify the results using pH strips. First, immerse the strip in deionized water, then place it on the test paper (which should be isolated on Mylar to prevent additional absorption from surrounding materials). Allow the strip to remain in contact with the test paper for approximately 1 minute.

APPENDIX 5. PROCEDURE FOR EVALUATING ADHESION OF AGED LASCAUX TISSUE SAMPLES AND SAMPLES APPLIED OVER HISTORICAL PAPERS

- The purpose of this criterion is to gauge how well-aged tissues can adhere to the paper and therefore be able to draw conclusions on the ability of Lascaux-coated paper to retain its working characteristics over time.
- For adhesion testing, we applied small samples from our prepared test tissues according to the standard application procedure. The test tissue can be applied over any high-quality Western paper stock.

Procedure for Applying Prepared Tissue Samples to Paper

1. Use gellan gum to moisturize the paper:
   a. Cut or tear the precoated paper to obtain the necessary piece for the experiment.
   b. Place the piece of paper over the gellan gum.
   c. Place a piece of silicone release Mylar over the paper.

   d. When the paper is wet enough (about 4 or 5 seconds), remove both the silicone release Mylar and the paper together.
2. Place the paper and the silicone release Mylar or polyethylene strapping over the item to be treated.
3. Apply pressure using a Teflon or bone folder. Pressure is essential to obtain good adhesion.
4. Remove the silicone release Mylar.
5. Place the following four layers in order on top of the treated area:
   a. first, a piece of Hollytex;
   b. on top of the Hollytex, a piece of blotter;
   c. then a glass;
   d. and finally, a weight.
6. Wait until the treated area is flat and dry. This will take a maximum of 5 minutes.

Procedure for Evaluating Adhesion of Applied Tissue to Stock Paper

1. Before proceeding, observe the level of adhesion extant between the dried tissue and the support paper:
   a. Does it appear uniformly stuck down?
   b. Do you observe delamination between the tissue and the paper?
   c. Under raking light, are any fibers visible out of plane with the paper?
   d. Is there any puckering, cupping, warping, or other planar distortion in the area where the tissue is applied to the paper?
2. In its dried state, without applying any moisture, begin trying to remove the tissue from the paper by peeling the strip from the paper at a sharp angle. Based on your observations, classify the adhesion process based on the following scale, where
   a. (1) equals little to no adhesion with exerted force to remove; the tissue comes cleanly away from the support paper without delamination or separated fibers
   b. (2) equals minor observed resistance with exerted force to remove, but with effort, the tissue and the paper still separate cleanly
   c. (3) equals minor observed resistance with exerted force to remove, resulting in light delamination of the tissue only but leaving the paper relatively intact
   d. (4) equals moderate observed resistance with exerted force to remove, resulting in delamination of the tissue as well as possible minor skinning of the surface of the paper
   e. (5) equals strong adhesion at work between the tissue and paper; resistant to separation with exerted force to remove, resulting in significant tearing, skinning, and delamination of the paper
3. Record your observation and additional comments in the "Qualitative Testing: Adhesion" Form.

APPENDIX 6. WORKSHEET: ADHESION OF AGED LASCAUX TISSUE SAMPLES AND SAMPLES APPLIED OVER HISTORICAL PAPERS

Please evaluate each test sample for adhesion using the procedure described in "Procedure for Evaluating Adhesion of Aged Lascaux Tissue Samples and Samples Applied Over Historical Papers.

Low				High
1				5

Adhesion Rubric

(1) equals little to no adhesion with exerted force to remove; the tissue comes cleanly away from the support paper without delamination or separated fibers
(2) equals minor observed resistance with exerted force to remove, but with effort the tissue and the paper still separate cleanly
(3) equals minor observed resistance with exerted force to remove, resulting in light delamination of the tissue only but leaving the paper relatively intact
(4) equals moderate observed resistance with exerted force to remove, resulting in delamination of the tissue as well as possible minor skinning of the surface of the paper
(5) equals strong adhesion at work between the tissue and paper; resistant to separation with exerted force to remove, resulting in significant tearing, skinning, and delamination of the paper

Tissue Sample Name	Support Paper	Adhesion Scale 1–5
Additional comments:		

Tissue Sample Name	Support Paper	Adhesion Scale 1–5
Additional comments:		

APPENDIX 7. PROCEDURE FOR EVALUATING REVERSIBILITY OF AGED LASCAUX TISSUE SAMPLES AND SAMPLES APPLIED OVER HISTORICAL PAPERS

- The purpose of this criterion is to gauge how fully removable mending tissue is immediately after application versus after aging and whether the aging process on the acrylic medium of the Lascaux has an impact on how reversible it remains over time.
- For reversibility of Lascaux-WSP precoated papers (particularly if the samples have undergone accelerated aging), a 4:1 solution of DiH_2O to EtOH is recommended.
- Testing included historical paper samples with applied tissue before and after aging.

Procedure for Testing Reversibility of Applied Tissue to Stock and Historical Papers

1. Before proceeding, observe the level of adhesion extant between the dried tissue and the support paper:
   a. Does it appear uniformly stuck down?
   b. Do you observe delamination between the tissue and the paper?
   c. Under raking light, are any fibers visible out of plane with the paper?
   d. Is there any puckering, cupping, warping, or other planar distortion in the area where the tissue is applied to the paper?
2. Using a brush, apply the 80:20 solution of DiH_2O mixed with EtOH over a small area of the sample where the tissue has adhered to the paper.
3. Directly after application, using fingers, a spatula, or a pair of blunt tweezers, attempt to separate the tissue from the paper in the area where the solvent was applied. Based on your observations, classify the reversibility process based on the following scale, where
   a. (1) equals not reversible at all with applied solvent to remove; resistant to separation with exerted force to remove, resulting in significant tearing, skinning, and delamination of the paper
   b. (2) equals low observed reversibility with applied solvent to remove, resulting in delamination of the tissue as well as possible minor skinning of the surface of the paper
   c. (3) equals minor observed resistance to reversibility with applied solvent to remove, resulting in light delamination of the tissue only but leaving the paper relatively intact
   d. (4) equals paper negligible observed resistance to reversibility with applied solvent to remove, but with effort, the tissue and the paper still separate cleanly
   e. (5) equals high reversibility with applied solvent to remove; the tissue comes cleanly away from the support paper without any delamination or separated fibers

APPENDIX 8. WORKSHEET: REVERSIBILITY OF AGED LASCAUX TISSUE SAMPLES AND SAMPLES APPLIED OVER HISTORICAL PAPERS

Please evaluate each test sample for reversibility using the procedure described in “Procedure for Evaluating Adhesion and Reversibility of Aged Lascaux Tissue Samples and Samples Applied Over Historical Papers.

Low				High
1				5

Reversibility Rubric

(1) equals not reversible at all with applied solvent to remove; resistant to separation with exerted force to remove, resulting in significant tearing, skinning, and delamination of the paper

(2) equals low observed reversibility with applied solvent to remove, resulting in delamination of the tissue as well as possible minor skinning of the surface of the paper

(3) equals minor observed resistance to reversibility with applied solvent to remove, resulting in light delamination of the tissue only but leaving the paper relatively intact

(4) equals paper negligible observed resistance to reversibility with applied solvent to remove, but with effort, the tissue and the paper still separate cleanly

(5) equals high reversibility with applied solvent to remove; the tissue comes cleanly away from the support paper without any delamination or separated fibers

Tissue Sample Name	Support Paper	Reversibility Scale 1–5
Additional comments:		

Tissue Sample Name	Support Paper	Reversibility Scale 1–5
Additional comments:		

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MITCHEL GUNDRUM, DEBORA MAYER, AND KELLI PIOTROWSKI

Soft Clouds: Analytical Pigment Identification for Historical Paste Papers From Harvard University's Rosamond B. Loring Collection

INTRODUCTION

In *A Yorkshire Source for Decorated Paper in the Eighteenth Century*, Tanya Schmoller relates the story of a colleague introducing her to the Moravian Church archives and the fascinating history she unraveled through the records there. Two points are of particular note: her colleague's casual mention of marbled papers, which were later found to be "not really marbled," and a historical anecdote from a 1763 church ledger (2003, 5). According to the ledger, a visitor to the English Moravian community in Yorkshire observed the making of paste papers by boiling red rags, mixing the resulting liquid into paste, and "appl[ying] neat clouds to the paper with one's fingers" (2003, 7). This anecdote is included in some of the best-researched reference works for paste paper and other decorated papers as a production insight. None of these resources, however, ask the obvious follow-up question: How were the rags colored in the first place?

Paste paper is a distinct category of heritage artifact that is largely unacknowledged in academic literature and under-recognized compared with other types of decorated paper. Paste papers have been misdescribed by booksellers, librarians, and conservators, and have historically been considered of lower intrinsic and artistic value than marbled, block-printed, or brocade (a.k.a. Dutch gilt) papers. The few specialist books discussing historical paste papers focus on their social history and pattern description rather than physical characterization. Given the competitive nature of color production in the pre-industrial era, contemporary recipes and "books of secrets" often contain dubious or unscrupulously copied information, leaving modern historians and conservators with little more than the artifacts themselves as testimony to their composition, production, and provenance. This project aimed to improve our understanding of historical paste papers by using analytical pigment identification to uncover their cultural, material, and bibliographic contexts.

The literature review portion of this project was limited to English language resources and rough translation of German, Spanish, and Dutch language texts. Many relevant resources on historical bookbinding and the production of decorated papers were originally published in German. While the present research cannot be called comprehensive, it is still confidently among the first to carry out analytical pigment identification for historical paste papers. The authors hope that readers will share any relevant sources that may have been neglected.

BACKGROUND

Paste paper (German: *Kleisterpapier*) is a style of surface-decorated paper characterized by colored starch paste modified with various tools and techniques to render an array of designs (fig. 1). The technique originated in southern Germany around 1600 and remained popular across Europe for book papers, wallpapers, and furniture linings through the early 1830s (Haemmerle 1977, 137; Wolfe 1991, 24–25; Schmoller 2008, 47–49; Krause and Rinck 2016, 110).

Although distinct from more popularly recognized marbled papers, ambiguous terminology and a lack of academic literature have led to confusion and nescience of paste papers among both public and specialized audiences (Haemmerle 1977, 137–44; Schmoller 2003, 5; Krause and Rinck 2016, 110; Beattie 2018). Paper marbling developed across East Asia and the Ottoman Empire for centuries before it was introduced into Europe in the 17th century (Wolfe 1991, 2–13). Germany was already established as a producer of woodblock-printed fabrics and papers by 1600, and the earliest extant paste-colored papers date from around 1650 (Gurbat 1971, 12; Haemmerle 1977, 137; Wolfe 1991, 18–25). The simplicity and affordability of the paste paper technique spurred its adoption by bookbinders across Europe who could produce "fancy" papers without the expense or expertise required for marbled, gilt, or block-printed papers (Zaehnsdorf 1890, 35; Wolfe 2008, 43, 45).

Papers presented during the Book and Paper Group Poster Short-format Session, AIC's 52nd Annual Meeting, May 20–24, 2024, Salt Lake City, Utah

Fig. 1. Examples of 18th-century paste papers. (a) Multicolor (quadrille) veined paper with impressed designs, previously a book covering, Rosamond B. Loring Collection [LOR.IV.33.c]. (b) Blue veined paper, Rosamond B. Loring Collection [LOR.IV.2.d]. (c) Multicolor (quadrille) veined paper with block-printed designs, Rosamond B. Loring Collection [LOR.IV.34.d]. Images M. Gundrum.

Paste papers are often associated with the Unity of Brethren (Latin: *Unitas Fratrum*), a Protestant sect founded in 1457 and suppressed to near extinction by the early 18th century. In 1722, exiles from Moravia and Bohemia found asylum and established the settlement of Herrnhut on the estate of one Count Nikolaus Ludwig, Graf von Zinzendorf, in the German state of Saxony. Missions were established in England by the 1730s and in the American colonies by the 1740s, and in 1764, the Sisters in those communities officially began producing decorated papers as a means of income. The distinctive quality and style of the so-called "Herrnhuter" papers earned them such popularity that the term prevails today as an imprecise catchall for paste-decorated papers (Haemmerle 1977, 139; Wolfe 1991, 24–25; Schmoller 2008, 49; Verheyen 2015; Beattie 2021; Britannica 2023; Dubansky 2023).

Beyond this social history, published literature limits material awareness of paste papers to pattern categorization, whereas associated colorants, origins, and usage trends for those patterns remain obscure. While colorant identification research is well developed for paintings, textiles, objects, illuminated manuscripts, and wallpapers, English language literature concerning analytical pigment identification for decorated book papers is lacking. Recent research on bookbindings (Delbey et al. 2019; Ortegon 2023; Tedone 2023), 18th- and 19th-century marbled papers (Torner, Sil, and Tirado 2006: Spanish language), and starch mediums used in historical paste papers (Maier 2019b: German language) approach this gap while leaving plenty of room for exploration.

In their discussions of historical decorated paper production, the major reference works defer to the plethora of 17th- to 19th-century manuals and "books of secrets" for compositional data (Haemmerle 1977, 137–44; Wolfe 1991, 166–78; Krause and Rinck 2016, 110–39; Rinck and Krause 2021). The commoditized nature of color and decorated papers in the pre-industrial era made methods of production valuable secrets—contemporary recipes and manuals are often unscrupulous reprints of popular treatises that proliferate apocryphal or even purposefully misleading information (Harley 1982, 2; Kirby, van Bommel, and Verhecken 2014, 45–47). Alchemical recipes, wide experimentation, and nonstandardized language for materials and techniques further contribute to a tangled history of traditional knowledge that is often counter to a modern understanding of effectiveness (Vest and Wouters 1999; Porter 2001, 2005; Kirby, van Bommel, and Verhecken 2014; Baty 2018; Maier 2019a). This combination of factors calls for skepticism: While the claims of historical recipes are not unilaterally inaccurate, they are, at best, unproven. Recent research refuting long-standing claims about the use of the Tyrian purple pigment (derived from *Murex* molluscs) on valuable manuscripts demonstrates the necessity of verifiable data to trace the production of cultural artifacts (Aceto et al. 2017, 2019). To let extant paste papers demonstrate their own composition was the goal of this research.

ANALYSIS

The Rosamond B. Loring Collection of Decorated Papers was assembled by Loring during her career as a maker and historian of decorated papers and was donated to Houghton Library in 1952. It contains around 10,000 pieces of decorated paper from around the world dating from the 16th to the mid-20th centuries, along with papers made by Loring, photographs, reference texts, and tools (Rosamond B. Loring collection of Decorated Papers (*52L-1000). Houghton Library, Harvard University; Loring 1942, vii–viii, 65–70).

The survey included an assessment of every cataloged paste paper item in the Loring collection. The analytical sample was selected by focusing on (1) items ostensibly produced from 1680 to 1830 and (2) papers with distinct areas of blue coloring. In its earliest stages, this project focused on the measurement of mineral pigments via X-ray fluorescence spectroscopy (XRF). Blue was thus chosen as the target color family considering the number of blue mineral pigments—including azurite, Prussian blue, smalt, and cobalt blue—which have well-researched histories spanning the target time period and would be readily identifiable via XRF. Organic indigoids, it was reasoned, could be distinguished from these by their lack of XRF signal (Berrie 1997, 192–95, 211; Eastaugh et al. 2004; Douma 2008; Delamare 2013, 37–98, 119–94; Berrie 2015, 312–22; Baty 2018, 44–67).

Thus, this project included an item-level survey of 229 samples of paste papers and paper-covered objects from the Loring collection, plus 26 paste paper-containing 18th-century book objects from private collections, for a total of 255 items. Of the Loring collection papers, approximately 169 were of the appropriate time period based on available evidence, 122 contained suitably distinct areas of blue coloration, and 16 were ultimately selected for analysis at the Weissman Preservation Center, Harvard Library.

Visual Assessment

Visual examination of paste papers from the collection was conducted in the Houghton Reading Room. A spreadsheet was used to catalog format, colors, and patterns for each object, along with inscriptions and bibliographic information recorded by Loring.

Microscopy

Microscopic assessment and imaging was carried out using reflected light at approximately 60x magnifications with a Leica MZ16 stereomicroscope (.63 objective, 10x binocular eyepieces, and adjustable Ergo tube 10°–50°), Leica IC90 E camera, Leica KL 1500 LCD fiber optics system, and Leica LAS X imaging software.

Spectral Examination and Imaging

A Foster and Freeman Video Spectral Comparator (VSC 8000) facilitated various types of spectral examination. Near-infrared imaging was captured between 780 and 925 nm. Reflectance spectra were measured between 400 and 1000 nm at 15x with a nearly 122 nm spot size. Spectra from the paste paper samples were compared to reference spectra for presumed colorants. Composite false-color imaging was completed with RGB channels set to 555 nm, 996 nm, and 405 nm, respectively.

Fig. 2. Orientation of paste papers for XRF analysis. Image M. Gundrum.

X-ray Fluorescence Spectroscopy

XRF measurements were taken using a Bruker TRACER III-V XRF portable analyzer equipped with a rhodium X-ray tube, silicon pin detector, and 3 × 4 mm oval spot size. All measurements were taken without filters or vacuum with the energy and current set at 40 kV and 10 μA, respectively. The collection time for each analysis was 120 seconds. Spectra were collected with S1PXRF software (3.8.30) and processed with ARTAX software (8.0.0.446). To avoid sampling irrelevant background materials behind the thin paper, the samples were mounted upright on boards with cutouts behind the sample site (fig. 2).

RESULTS

Visual Assessment

Visual examination of the collection in the Houghton Reading Room suggested that many historical paste papers from the Loring collection were removed from bookbindings (fig. 3). Forty-two items were determined to be endpapers through the presence of sewing holes or edge decoration. An additional 30 items were paper-decorated boards or other book coverings no longer connected to a bookblock. These items contribute useful color, pattern, and object orientation data, but unfortunately, no bibliographic information was preserved for the book objects from which these papers were taken.

From the full 255-item sample, 183 were single-color, 23 two-color, 13 three-color, and 23 four-color papers. Color information was not recorded for the remaining 13 items which were modern productions falling outside the scope of the project. Single-colored papers are ubiquitous across the sample; two-color papers, interestingly, skewed toward the 19th and

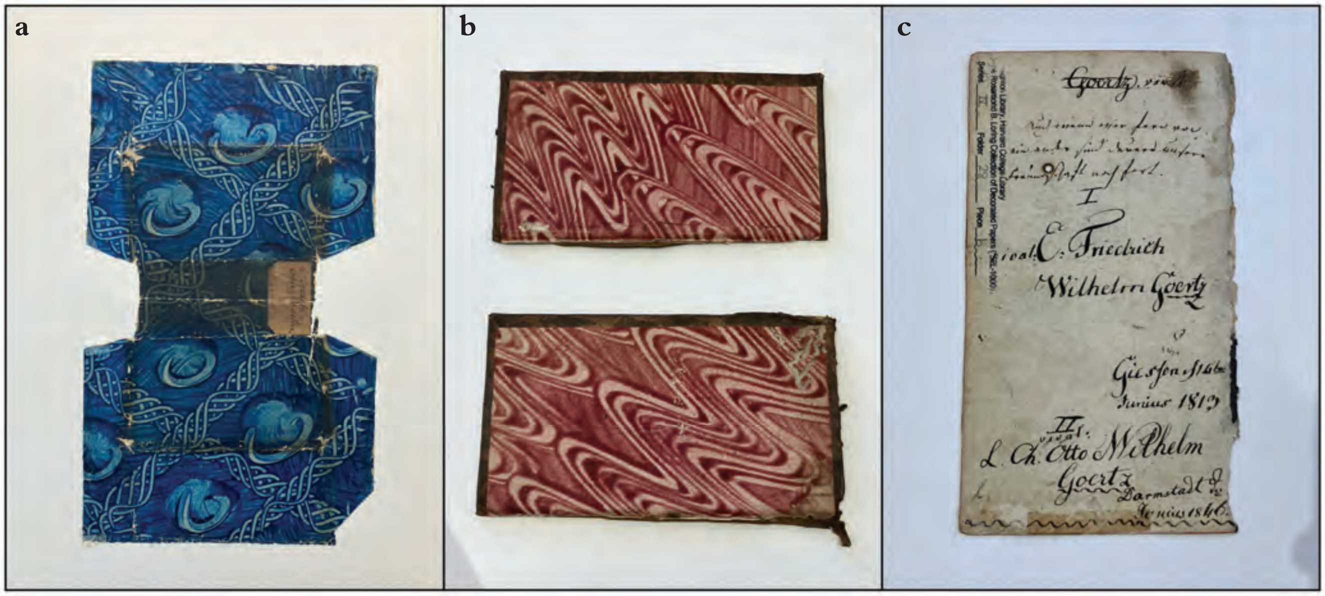

Fig. 3. Paste papers previously used in bookbindings. (a) Blue veined paper with impressed designs previously used as a book covering or over-cover, Rosamond B. Loring Collection [LOR.IV.111]. (b) Crimson brushed papers with impressed designs, used as pastedowns for now loose boards, Rosamond B. Loring Collection [LOR.XII.20]. (c) Reverse of paste paper fragment previously used as a decorative flyleaf, showing ink ownership inscriptions, trimmed edges, and edge sprinkling, Rosamond B. Loring Collection [LOR.IV.28.b]. Images M. Gundrum.

20th centuries in this sample, whereas three- and four-color papers are most prevalent from the first half of the 18th century. Among dated samples, multicolor checkerboard- or quadrille-patterned papers (fig. 4) seem to peak from the 1730s to around 1780; the 18 undated examples of this feature are cataloged by Loring as 18th-century productions. The most prevalent colors across the sample were red (109 examples), blue (81), purple (41), yellow (34), brown (33), green (27), and black (17).

Of 60 items with discernible geographic association (usually the imprint of a book including paste papers), 26 reference cities in Germany. Most of the French (12), American (8), and Italian (4) examples are presumed to be 20th-century productions based on pattern style, substrate, and bibliographic information provided by Loring. While associations of this type can be problematic—both decorated papers and printed texts were traded beyond their countries of origin—the correlation between paste papers and German imprints is expected and strengthened by this dataset.

Pattern analysis began with categorization of the sampled papers by the method of application used for their primary or

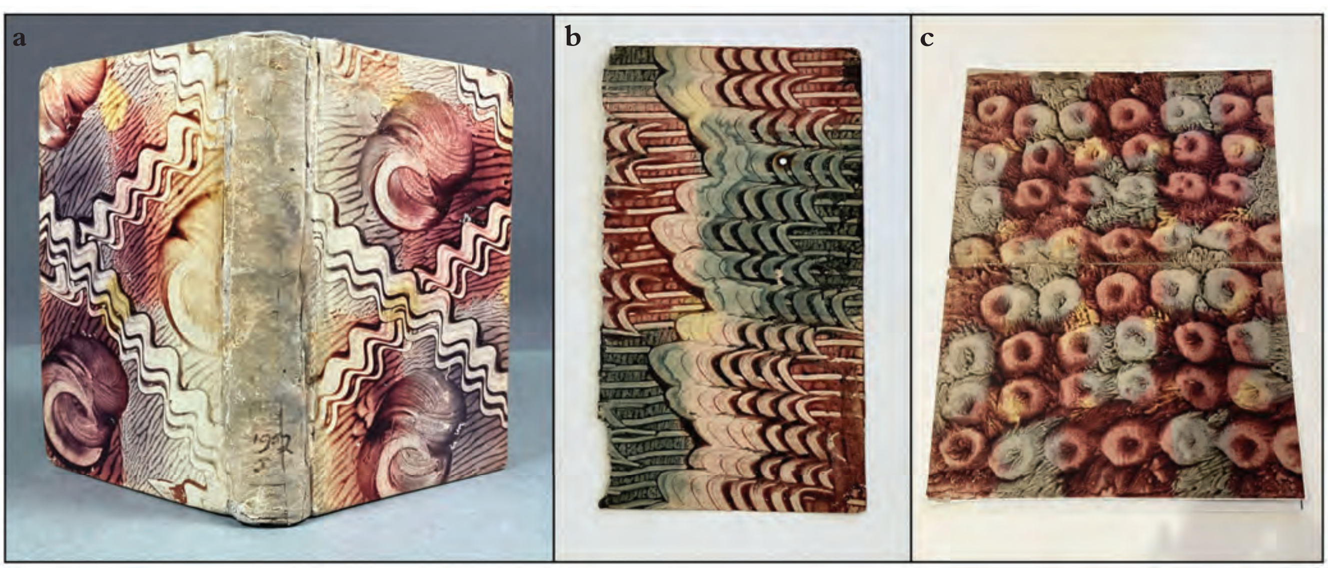

Fig. 4. Examples of checkerboard- or quadrille-patterned paste papers. (a) Personal collection [MG.21.085]. (b) Rosamond B. Loring Collection [LOR.IV.28.b]. (c) Rosamond B. Loring Collection [LOR.IV.17]. Images M. Gundrum.

Fig. 5. Examples of directly (left) and indirectly (right) impressed decorations. Images M. Gundrum.

base paste layer. The categories included veined, brushed, and brush-patterned papers, each of these with or without additional impressed designs, keeping in mind that many of the surveyed papers involve a combination of decoration techniques. A further distinction was made between directly and indirectly impressed designs—that is, marks made directly into the wet paste layer versus those made through the back of a paper sheet either while folded or while two sheets are sandwiched with paste in between. Indirect impressions are discerned by their softer edges and by transverse veins formed after the impressions were made, as the paper sheets were pulled apart (fig. 5).

While many papers from the Loring collection were recovered from bindings and are thus undated, it was possible to derive a few preliminary trends from the dated objects. Veined-patterned (German: *geädert*) papers—with or without additional impressed designs—are by far the most popular in the sample (148 examples) and persist across the full timeframe. As derived from dated samples, veined papers with impressed designs are distinctly prevalent from around 1730 to 1790. A prevalence of extra-finely veined papers appears to begin around 1790 and persist through the 1830s. Several of these examples are on French imprints, suggesting perhaps a local production and aesthetic preference.

Microscopy

Under magnification, the fiber content of the paper substrates was observed where the reverse face of the samples was not obscured by lining or mounting materials. The presence of blue, red, and yellow fibers in some samples evidences the production of paper from recycled textiles, along with the "bluing" technique of optically brightening yellowish organic fibers by adding blue fibers or pigments to the pulp mixture (Delamare 2013, viii; Baty 2018, 55).

Visual distinctions were made between two major colorants (Prussian blue and indigo), which were identified by later analyses. Prussian blue, a synthetic iron colloid with a less than 1 µm particle size, rendered a uniform color layer that was sky blue and slightly shimmery in the paste binder. Indigoids (chemically identical compounds derived from various organic sources) have larger, irregular particles that appear clumpy, opaque, and unevenly distributed in the paste layer (fig. 6).

Spectral Examination and Imaging

Items imaged under near-infrared radiation (780–925 nm) demonstrated the reflectance (brightness) of indigo versus the absorption (darkness) of Prussian blue (fig. 7). As these

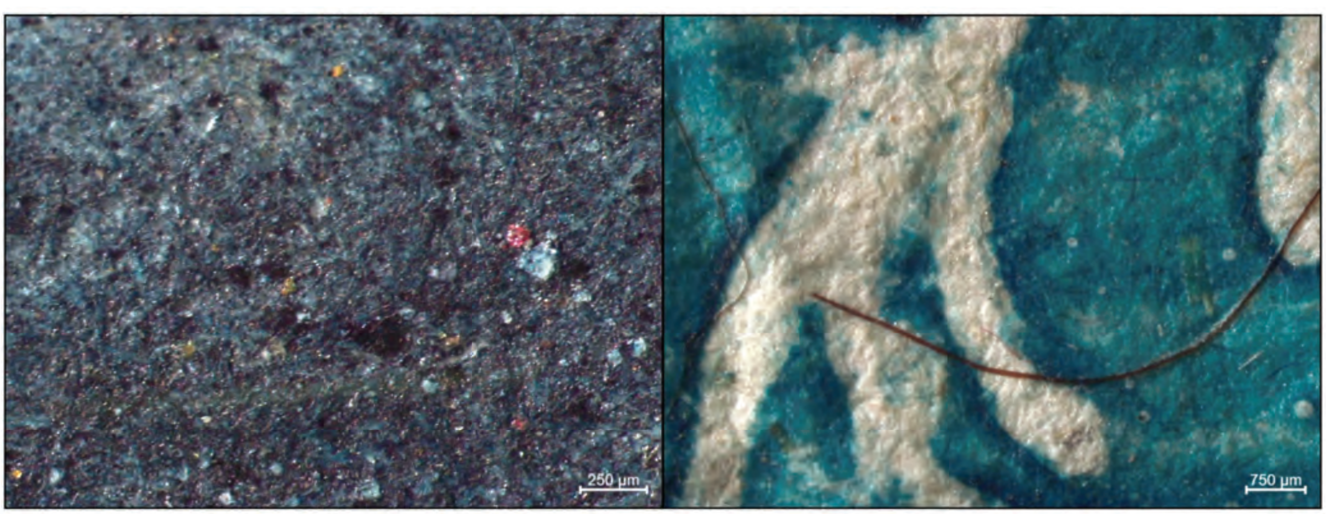

Fig. 6. Characteristics of indigo (left) and Prussian blue (right) at 50x magnification. Images M. Gundrum.

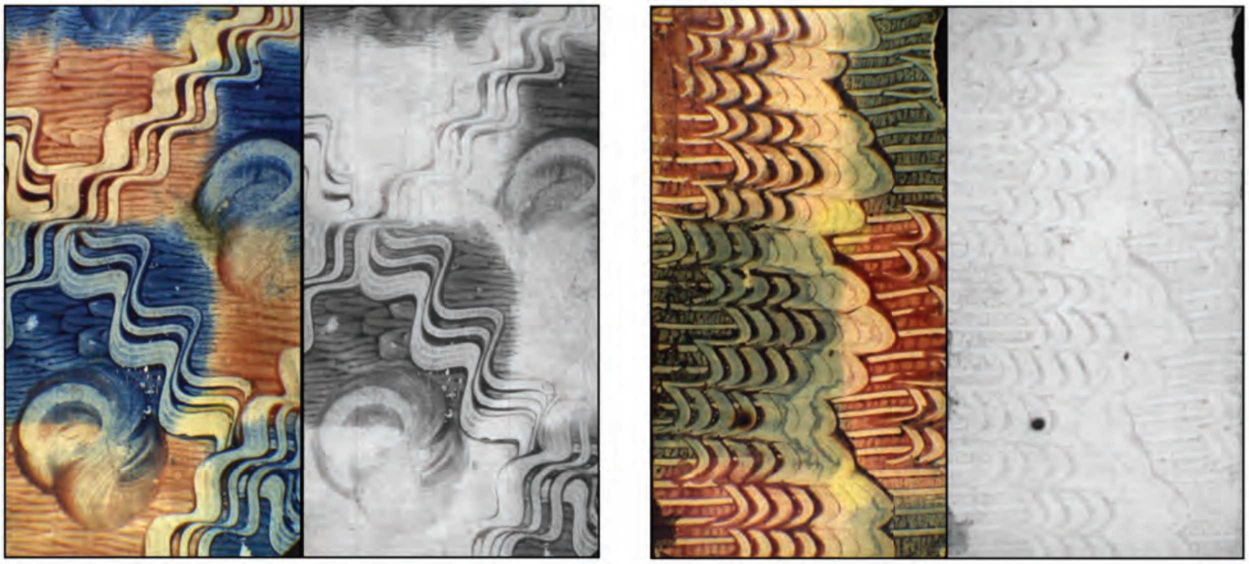

Fig. 7. Near-infrared imaging of inorganic Prussian blue (LOR.IV.33.c, left) and organize indigo/woad (LOR.IV.28.b, right). Images D. Mayer.

behaviors are not unique to these two colorants, near-infrared imaging served as a quick screening technique rather than conclusive identification. This technique provided a tentative identification for all but two of the sample items, which underwent additional testing.

Reflectance was measured across a range of wavelengths from 400 to 1000 nm to produce a spectral reflectance fingerprint for several papers (fig. 8). Comparing these fingerprints against reference spectra for known pigments rendered reliable identification for six of the seven items analyzed with this

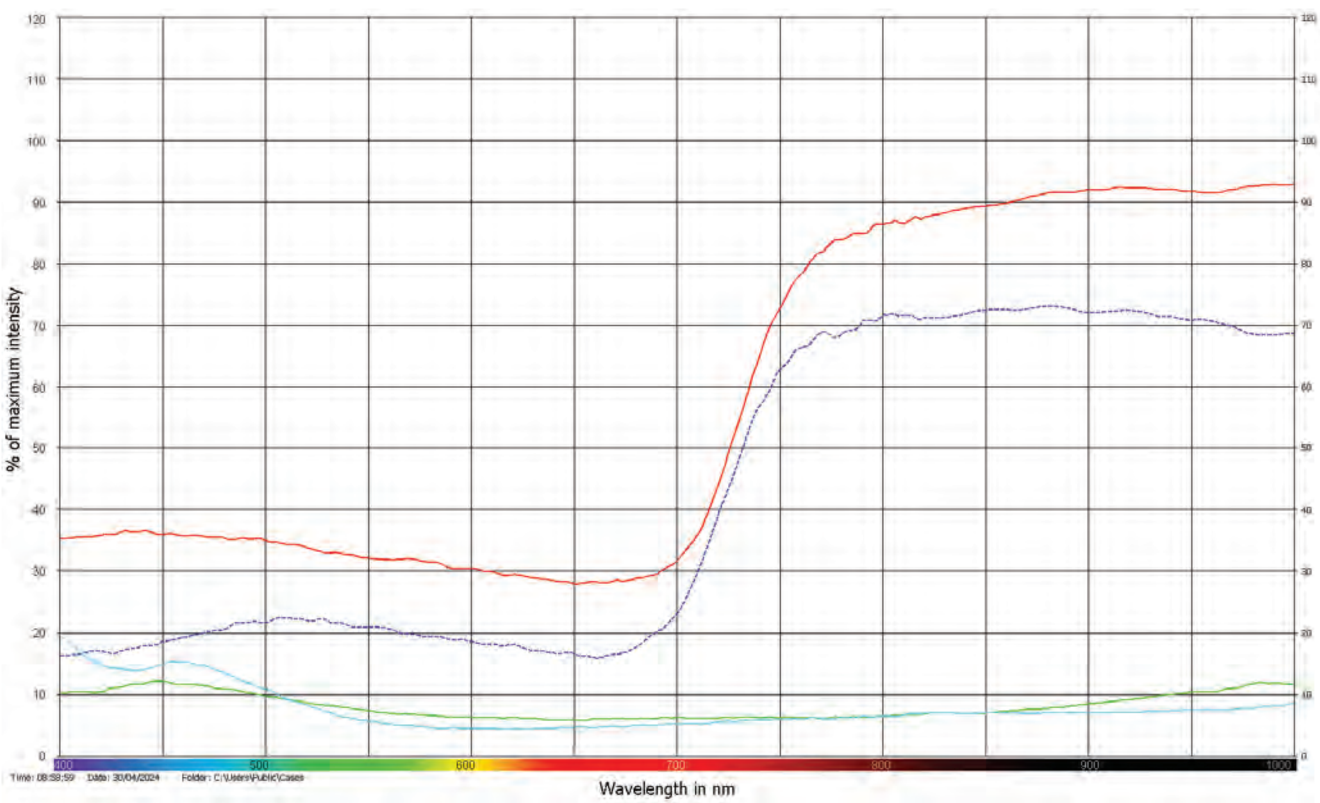

Fig. 8. Example of reflectance spectra showing characteristic lines for indigo (red: Cheryl Porter reference pigment, blue: paste paper sample LOR.IV.2e) and Prussian blue (turquoise: Kremer reference pigment, green: paste paper sample LOR.IV.33c). Spectra D. Mayer.

Sample	Elements Detected	Materials Inferred
Item 2.c	Ca	Organic blue colorant; calcium carbonate from paper manufacture
Item 2.e	As, Ca, S, Fe	Orpiment, organic blue colorant; calcium carbonate and iron from paper manufacture
Item 33.c	Fe, Ca	Prussian blue; calcium carbonate from paper manufacture
Item 35.a	Fe, Pb, Cr	Prussian blue and lead chromate
Item 36.e	Fe, Ca, K	Prussian blue; calcium carbonate and alum from paper manufacture
Item 48	Fe, Ca, K	Prussian blue; calcium carbonate and alum from paper manufacture

Table 1. XRF analysis results and inferred mineral constituents. Analysis and interpretation K. Piotrowski

technique. Results that could not be matched to reference spectra could be attributed to colorant mixtures or to colorants for which reference spectra were not available for this experiment.

X-ray Fluorescence Spectroscopy

Of the six items analyzed, three displayed primary iron (Fe) peaks (table 1). While molecular analyses such as RAMAN or FTIR would be required for definitive identification of this compound, the lack of other historical iron-based blue pigments prompted a confident identification as Prussian blue (ferric ferrocyanide, $Fe_7(CN)_{18}$). Item 35.a displayed peaks for iron, lead, and chromium, suggesting a mixture of Prussian blue and chrome yellow (lead chromate). Item 2.e displayed arsenic (As) and sulfur (S) peaks, suggesting the presence of yellow orpiment (arsenic sulfide, As_2S_3) plus a nonregistering organic blue colorant (indigo or woad), which was corroborated by additional infrared imaging analyses. Item 2.c returned only a peak for calcium, which, considering the pale blue hue and flocked appearance of the pigment layer under magnification, is suggested to be attributable to calcium carbonate (chalk), plus a nonregistering organic blue colorant.

All six samples displayed peaks for calcium and/or potassium, elements associated with calcium carbonate and potassium aluminum sulfate (potassium alum or alum), which are common fillers and surface treatments from the papermaking process (Brückle 1993). Alum, notably, is also used as a mordant in the production of marbled papers.

Colorant Identification

Of the 16 analyzed samples, 8 samples were confidently identified as indigo (*Indigofera tinctoria*) or a related organic colorant such as woad (*Isatis tinctoria*), 7 samples as Prussian blue, and 1 sample remained inconclusive from the tests performed. Because VSC methods require comparison with known reference samples, the inconclusive paper may be colored either with a mixture of pigments or with a colorant that was outside of the suspected palette and for which a reference sample was therefore not available at the time of analysis. Inherent variation in the composition, origin, processing, and application of natural colorants precludes the organization of anything like a comprehensive reference palette without analyzing and compiling data for a larger sample of historical paste papers.

DISCUSSION AND CONCLUSIONS

This research is believed to be the first to analytically identify Prussian blue and indigo as primary colorants for historical paste papers, characterizing the physical composition of these artifacts in a manner previously only accomplished by anecdotal evidence. While these findings are certainly open to adjustment through larger, broader, and more analytically intensive surveys in the future, they do present several useful benchmarks upon which new work can be built:

- Complementary analyses proved more effective than any individual technique in identifying paste colorants. Through the use of a suite of analytical tools, it was determined that spectral analysis and XRF in tandem were particularly effective at nondestructive characterization of a range of historical colorants.
- Surveying a collection of objects offered the opportunity for more holistic characterization of a family of artifacts in context than any comprehensive investigation of a single item would have done. For historical paste papers, building this generic material characterization will help inform baseline ideas of commonality/rarity, and contribute to defining trends in their development and use over time.
- While analytical samples were chosen based on their hues to maximize potential colorants, the binary results demonstrated similarities between and variation within indigoid and Prussian blue subsets, which may be attributed to production methods, color mixtures, or degradation. This suggests that hue alone is not a reliable method of colorant identification for historical paste papers. Pattern data, by contrast, revealed compelling temporal trends even across this small sample. Changes in the use of particular patterns during the 18th century provide a degree of precision—trends of 30 to 50 years—which is sure to improve as more data is gathered. Proposed trends in the use of quadrille, fine vein, and veined with impressed design patterns were supported by both the research data and the experience of consulting subject matter experts. Statistical analysis of combined colorant and pattern data points might provide more precision than either individual technique.
- Decisive provenance trends are only possible through an expanded dataset, especially with objects tied to explicit geographic and temporal data points. This research would benefit greatly from additional surveys measuring more hue families, organic colorants, and broader time periods,

and utilizing other analysis techniques. Furthermore, while the work of individual researchers can make significant contributions to art history knowledge, the combined efforts of a global community can be of immeasurable benefit. The publication of a web-based decorated paper database will make instantly available the relevant compositional data from relevant research projects and serve itself as a dataset from which new insights can be derived. Collaborative art–historical databases such as the University of Delaware's Poison Book Project and Penn Libraries' BASIRA have demonstrated the productivity and wider engagement facilitated by this crowdsourced approach (Ellertson and Herman, n.d.; Tedone and Grayburn, n.d.).

During the more than 200 years that have passed since the 1763 Moravian church ledger entry describing red rags and neat clouds, the colorant composition for historical paste papers has not been verified. To finally move beyond anecdotal evidence lends credibility to paste papers as a category of decorated paper with a distinct and critical role in the history of book arts, craft tradition, and art history in general. These findings contribute to a refined characterization of paste papers as unique cultural heritage artifacts with distinct contextual values and conservation needs, prompting more informed consideration by heritage professionals and researchers at large and highlighting the potential for additional research in this field.

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Additional data and analytical results from this research are available by request.

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Analysis and Assessment of the Degradative Properties of Strawboard as a Secondary Support

INTRODUCTION

The earliest paperboards were originally made by laminating layers of paper together using a variety of papers and glues, including starches, gelatin, and varnishes (Bower 2002, 18). These early boards were often made by artists and craftsmen but rarely by paper mills. Boards were used for a variety of things, including boxes, binders' boards for books, and artists' drawing boards. By the late 19th century, pasteless boards for artists began to be made by mills where several pieces of paper were couched one on top of the other to create a single board. Millboard was a product of the paper industry, as it did not use any glue but rather a deep deckle to hold the pulp and extreme compression to form the board. The multi-vat process was similar to pasteless boards and used the cylinder mould machine to move a sheet from vat to vat, adding to the previously couched sheet. This allowed for varied thickness as well as varied fiber content layers (Bower 2002).

The shift from handmade to machine-made paper began with the introduction of the Fourdrinier paper machine in 1806 and led to increased paper production as well as demand for fibers (Joint Textbook Committee of the Paper Industry 1983, 155). Prior to the 1800s, paper was made almost exclusively from rags, but rags alone could not meet the demand for fiber, so experimentation with other fibers increased. One of the new fiber types derived from various forms of straw including barley, rye, wheat, and oat (Bevan and Cross 1888, 58). Paperboards, including strawboard, have traditionally been used as secondary support for artworks; this research will focus on the degradative properties of strawboard and whether it is a safe material to be in contact with artwork.

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HISTORY AND MANUFACTURE OF STRAWBOARD

Strawboard was originally introduced in Holland during the 19th century. The boards were made using pure straw pulp on a multi-vat board machine (Bower 2002). Strawboard made in the United States for paperboard was unbleached (American Society for Testing Materials 1963, 75), and typically about 80% to 100% of the fiber furnish was straw, with the remainder being wastepaper (Joint Textbook Committee of the Paper Industry 1983, 173), likely made from rag fibers or other new materials such as esparto, wood pulp, and bagasse. Straw was used widely in the United States and other countries for making paper and paperboard during the 19th century, beginning around 1829 in the United States. The introduction of wood pulping in the 1840s quickly dominated papermaking, and its use was relatively short lived, lasting only until the 1890s (Joint Textbook Committee of the Paper Industry 1983, 155). By the 20th century, straw had been largely replaced by wood for use in papermaking, but its use in other products continued, especially in corrugated boards for packaging; the last mill using straw closed in the 1960s.

A patent from 1929 for making corrugated strawboard suggests that the production of both a strong and flexible material is particularly difficult due to the nature of the fiber (Weston and Clark 1929). The processing of the fibers influences the properties of the board: caustic cooked straw produces a fine fiber that creates a strong sheet; however, it requires the machine to run much slower and has a higher cost due to the chemicals used. Lime-cooked straw produces a sheet that can be run quickly through the machine but creates a shorter and coarser fiber, leading to brittleness (Weston and Clark 1929). The expense of strawboard production and the introduction of the more cost-effective wood pulping process likely contributed to the decline of straw paper and strawboard. A reference in *Pulp and Paper Manufacture* (Joint Textbook Committee of the Paper Industry 1983, 155) notes that straw was easily pulped by using inexpensive lime, which contributed to its early success. This likely led to a brittle

 Board A1 (primary board material)	Sample Source: Backing board for a mid-19th century etching,* adhered to perimeter Fiber Distribution: Relatively small and even Color: Yellow/tan Texture/Structure: Fluffy, paper-like, flexible Thickness: 4 mm overall (2 × 2 mm layers) **The etching paper was stark white.*
 Board A2 (central layer)	Sample Source: Backing board for a mid-19th century etching,* adhered to perimeter Fiber Distribution: Larger size variations with clear pieces of straw visible Color: Pale yellow Texture/Structure: Stiff, brittle, rough Thickness: Approximately 0.5 mm **The etching paper was stark white.*
 Board B	Sample Source: Backing board for a late-19th century print, adhered overall Fiber Distribution: Small, even distribution, some larger pieces Color: Pale tan Texture/Structure: Compact, relatively flexible, one layer, faced with paper* on both sides Thickness: 2 mm **Facing papers were removed for testing.*

Table 1. Board Sample Descriptions

material that would not be very durable and, in the case of art, did not provide adequate support.

SAMPLES

For this study, two samples of strawboard were compared (table 1). The first sample (Board A) was a mid- to late 19th-century board used as a backing for an 1850s etching depicting Niagara Falls. The board was extremely brittle, with a tendency to easily fragment, crumble, and separate (fig. 1), but the print paper was pristine white, which raised the question of whether the board was adversely affecting the print. Contact with poor-quality materials can often lead to the formation of degradation products resulting in staining, which was not present in this case. Fiber samples were taken from the exposed margins of the board. When cutting an approximately 0.5 × 6 cm sample, the board layers separated naturally through their thickness along a middle layer

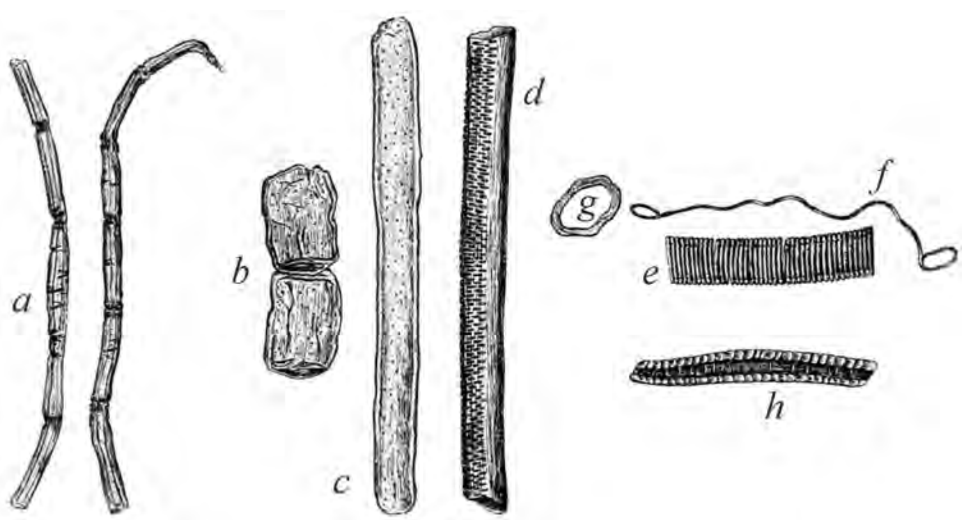

Fig. 1. Characteristic features of straw fibers: Bast fibers (a); thin-walled parenchyma, short (b) and long (c); pitted vessel elements (d) with tightly packed pores; spiral vessels fully intact (e), unraveled (f), and as individual annular wall thickenings (g); and sclerenchyma elements (h). From Herzberg 1902, 77–78.

of different composition from the primary board material. This suggests that the board was made in the multi-vat process. The primary board material was darker in color and had an almost fluffy composition. The central layer was thinner, much lighter yellow, and more brittle. In testing, Board A1 refers to the primary board material, and Board A2 refers to the lighter central layer.

The second sample (Board B) was a backing board attached to a late 19th century print. In contrast to Board A, this board was faced with paper on the recto and verso, and the core was a single layer of compressed fibers. The use of facing paper on strawboard is common, as it tends to be brittle and requires additional support (Etherington and Roberts 1982). The furnish of the board had large distinct pieces of straw fibers visible and was quite compact. When a sample was taken similar in size to Board A, the board held together firmly.

MATERIALS AND METHODS

Several analytical techniques were used to investigate the properties and materials comprising the strawboard samples. Polarized light microscopy (PLM) and scanning electron microscopy (SEM) were used to characterize the fibers and surface structure of the samples. PLM is commonly used in fiber identification, and SEM has been used to identify different structural elements of straw (Liu, Yu, and Huang 2005). Fiber staining (Herzberg) enhanced the visible morphology and aided in confirming specific fibers based on the colors observed. Attenuated total reflection (ATR) Fourier transform infrared (FTIR) spectroscopy has been used in other paper fiber research (Kostadinovska, Spirovska, and Taylor 2016) and helped identify possible adhesives and binders present. The pH of the samples was determined by a cold extraction method (TAPPI 509). This method is used in the paper industry but is not typically viable for conservation due to the large sample size required. It was possible here based on the experimental design and size of the sample boards used in this study.

PLM and Fiber Staining

A Leica DM750P polarized light microscope equipped with an ICC50W camera was used to identify and photograph the fiber components of the strawboards. Fiber samples from each of the two boards were taken for observation: the primary board component of the Niagara sample (A1), the center layer of the Niagara sample (A2), and the board material of the second sample (B, facing papers removed). Each sample was dyed using Herzberg stain following the TAPPI/ANSI T 401 om-15 standard for fiber analysis of paper and paperboard (TAPPI 2015b).

Scanning Electron Microscopy

Secondary electron and backscatter electron images were obtained using a Tescan Vega3 XMU tungsten variable pressure scanning electron. Samples were analyzed under high vacuum at an accelerating voltage of 5.0 kV. They were prepared by adhering them to a stub covered with carbon tape and coating them with platinum/gold to reduce charging and improve image quality. PELCO Colloidal Graphite was used to help hold the fragile samples together and aid in reducing charging.

ATR-FTIR Spectroscopy

FTIR analysis was used to identify sizing and adhesives in the strawboard samples. Infrared spectra were collected using a Nicolet 6700 FTIR spectrometer (Thermo Scientific) with a Thermo Scientific Smart iTR ATR accessory. Samples were analyzed by pressing them against the Diamond ATR crystal. The spectra are the average of 32 scans at 4 cm^{-1} spectral resolution. An ATR correction routine was applied to compensate for variations in penetration depth with wavenumber. Sample identification was aided by searching a spectral library of common conservation and artists' materials (Infrared and Raman Users Group, http://www.irug.org) and other available spectral databases using Omnic software (Thermo Scientific).

Hydrogen Ion Concentration (pH) of Paper Extracts (Cold Extraction Method)

The hydrogen ion concentration (pH) of three samples was obtained following the TAPPI 509 om-15 standard (TAPPI 2015a): the primary board component of the Niagara sample (A1), the center layer of the Niagara sample (A2), and the board material of the second sample (B, facing papers removed). Samples were cut from the interior of the boards to reduce contaminants found along exposed edges. Each sample (1 +/− 0.1 g) was macerated and soaked for 1 hour in a covered beaker of deionized water, brought to a total volume of 70 mL. The solution was tested at ambient room temperature of 22.7°C using a Horiba B-713 LAQUAtwin Compact pH Meter equipped with a glass electrode with temperature compensation and accuracy within ±0.1 pH. Each sample was tested twice, with the average pH rounded to the nearest 0.1 pH unit. Proprietary buffer solutions were used for a two-point calibration (4.01 and 7.00). Some modifications were made to the standard due to the availability of materials: reagent grade water was replaced with deionized water, and a Mylar cover was placed on the surface of the water while waiting rather than passing pure nitrogen or CO_2-free air through the sample.

Material Suitability Testing

Oddy testing was performed on a sample of the Niagara strawboard (Board A). The strawboard was tested using the British Museum version of the Oddy test. Borosilicate test tubes (50 mL) were rinsed with deionized water, followed by a low-water acetone wash. The tubes were placed in a 60°C oven for approximately 30 minutes to dry. Coupons of 0.004

Fig. 2. a. Board A1, Herzberg stain, long fiber bundle; b. Board A1, Herzberg stain, serrated epidermal cells over a fiber bundle; c. Board B, Herzberg stain, serrated epidermal cells over fibers

in thick pure copper, lead, and silver were cut into approximately 1 × 3.5 cm pieces. Each coupon was sanded using 1800 grit MicroMesh, being careful to handle the surface as little as possible. To prepare the platinum-cured silicone stoppers, they were first rinsed in deionized water and patted dry with Kimwipes. Three 1 cm wide parallel slits were cut into the underside of each stopper to hold the coupons. To assemble the package, a 2 g sample of material was placed in the bottom of the test tube. A small borosilicate culture tube containing approximately 0.65 mL of deionized water was added next to the sample. The metal coupons were rinsed with low-water acetone, patted dry with a Kimwipe, and fitted into the slots in the stopper using tweezers. The coupons were adjusted so that they were firmly in place in the stopper and would also not be in contact with other coupons or the side of the test tube once assembled. The stopper was added and sealed with several pieces of Parafilm M, followed by Teflon tape wrapped around the top of the tube and up over the stopper. This was done to prevent built-up pressure inside the tube from dislodging the stopper while in the oven. A control test tube was prepared in the same way without adding any sample material. After the tubes were sealed, they were placed in a 60°C oven for 29 days. The tubes were removed from the oven, the stoppers removed, and the coupons imaged. Samples were compared to Buffalo State University Lab Oddy Test Coupon Grading Guides to determine appropriate ratings.

RESULTS AND DISCUSSION

PLM and Fiber Staining Analysis

There are many different elements of straw that can be observed using PLM, and several look quite similar to hardwood elements. The drawings provided in *Papierprüfung: Eine Anleitung zum Untersuchen von Papier* by Herzberg (1902, 76–79) were essential to identifying key elements of straw fibers (see fig. 1). Throughout all three samples, long bundles of fibers were observed (fig. 2a). Serrated epidermal cells, a diagnostic feature of straw, were a common occurrence in all samples with cells appearing interlocked on top of the long fibers (see figs. 2b, 2c) and also individually. These types of cells exhibit a wavy or serrated edge with their width-to-length ratio ranging anywhere from 1:1 to 1:10. Figure 3a shows a bast cell with evenly spaced nodes that are similar to esparto; however, they curve rather than bend at the nodes (Brückle, n.d., Western Papermaking). Board A and Board B have rings that are part of the cell wall (see fig. 3b) and a few pitted vessel elements, which are abundant in hardwood but not as commonly seen in straw. A good example is found in the main material of Board A (fig. 4, see fig. 3c). Both long and short parenchyma are seen throughout, which are a cell type not seen in esparto (Herzburg 1902, 78). Some of the longer parenchyma are very ribbon-like and appear like twisting cotton fibers (see fig. 4); however, the length and rounded ends are characteristic of the longer parenchyma found in straw.

Overall, the composition appears to be primarily straw in both boards, although this is based on limited sampling from each. The center layer has no discernable difference in composition based on the photomicrographs; however, the composition is visually much more varied in size, with rough pieces of straw visible to the naked eye. There may be esparto in Board A2 and Board B (fig. 5), with the purple stain suggesting esparto in both samples and a possible comma-shaped hair indicative of esparto in Board B; fibers also tend to be much shorter in esparto samples, as is seen in figure 5. The overall yellow staining of most fibers is in line with an unbleached pulp. There was no blue, which would indicate a chemical pulp (TAPPI 2015b).

SEM Analysis

Four samples of Board A and one sample from Board B were taken and prepared for analysis: front of A1; back of A1, A2, and B; and cross section of A. The samples taken represented different areas of the board as well as different structural aspects (fig. 6). Due to the varied surface of the samples, initial imaging using carbon coating resulted in heavy amounts of charging from uneven coating, which prevented acquiring usable images. A second set of samples was made and

Fig. 3. Fiber elements. a. Board A1, straw bast cell; b. Board B, cell wall annular thickenings; c. Board A1, pitted vessel element; d. Board A2, sclerenchyma cell.

coated, this time with a conductive coating of platinum/gold. Charging was still an issue, and a second coating was necessary for resolving information and preventing the charging of the surface. The cross section proved particularly difficult to

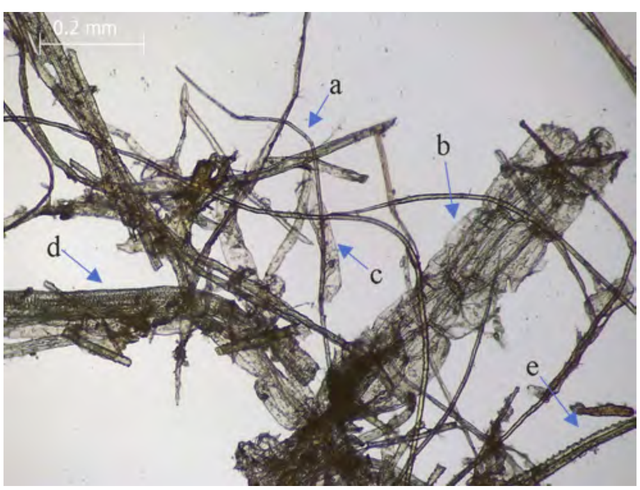

Fig. 4. a. Board A2, bast fiber; b. Short parenchyma; c. Long parenchyma; d. Pitted vessel element; e. Serrated epidermal cells.

image without charging due to the texture and was unable to be captured. However, it was observed that there were five distinct layers in Board A, two even layers on the top and bottom (A1), and one thinner central layer (A2).

Board A1 (see fig. 6a) appears more uniform than Board B (see fig. 6d) with a mat of large bundles and individual fibers throughout. Images of both A and B samples show the distinct serrated epidermal cell features with the teeth interlocking (see fig. 6b). Some elements of straw can resemble hardwood, such as the pitted vessel element shown in figure 6c; however, the pitting in straw is closer together and round or slit-like (Herzberg 1902, 78).

ATR-FTIR Spectroscopy Analysis

ATR-FTIR was helpful in identifying potential adhesives and binders used in the production of the boards. When analyzing Board A, it was interesting to find that the only sample with a possible resin was the exterior of the board, which had a carbonyl peak (fig. 7a). There was no sign of proteinaceous material, resin, or oil detected in the interior of the board. Sample Board A1 was split into two layers to analyze the join between the material (Board A interior). This lack of material

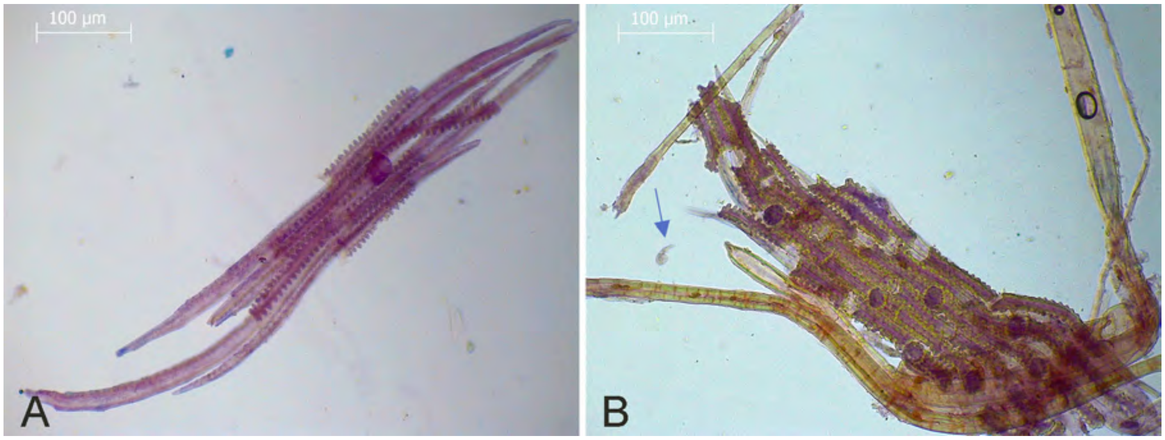

Fig. 5. Possible esparto. a. Board A2, purple Herzberg stain, serrated epidermal cells over fibers; b. Board B, Herzberg stain, serrated epidermal cell, bast cell, and long parenchyma. Possible comma-shaped hair (arrow) and purple stain associated with esparto.

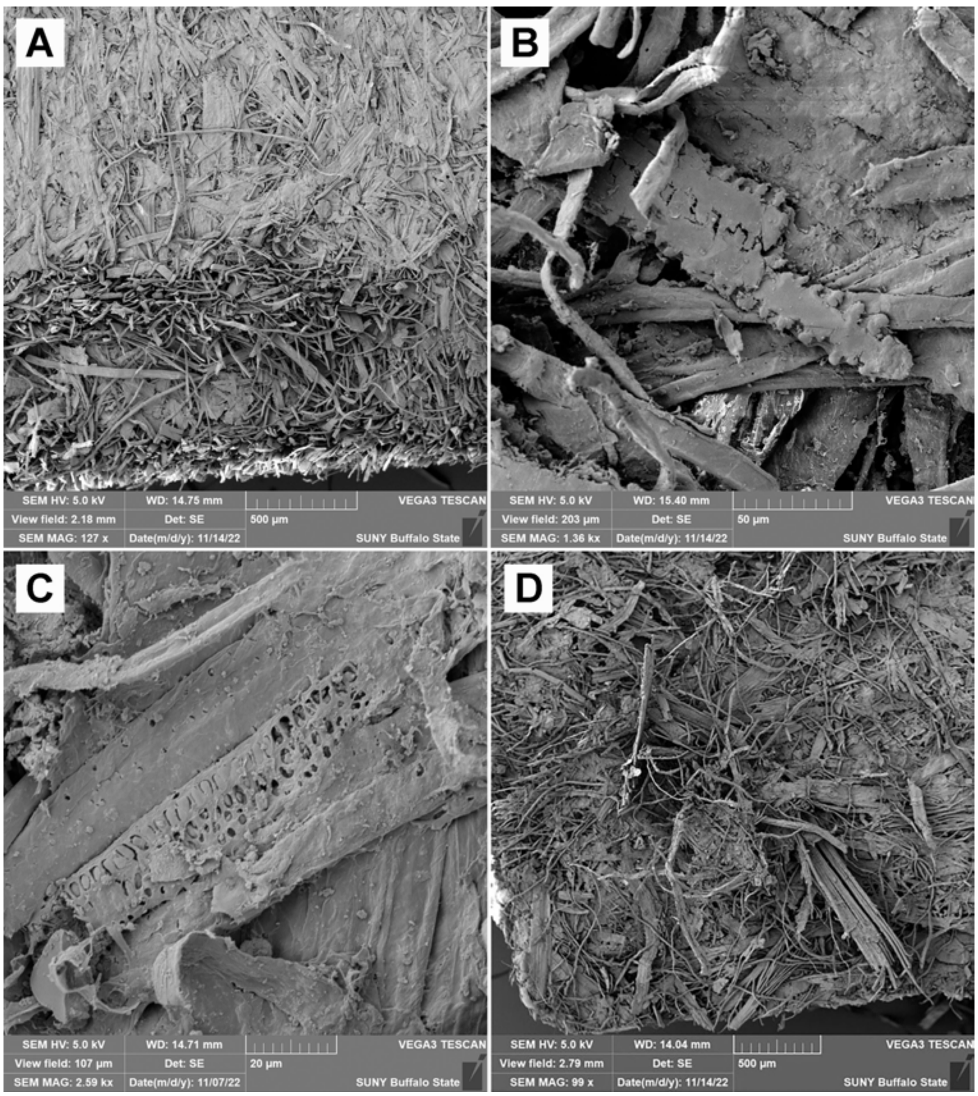

Fig. 6. SEM images. a. Board A1, recto; b. Board A1, verso, detail of interlocking serration; c. Board A2, center layer; d. Board B showing fiber bundles.

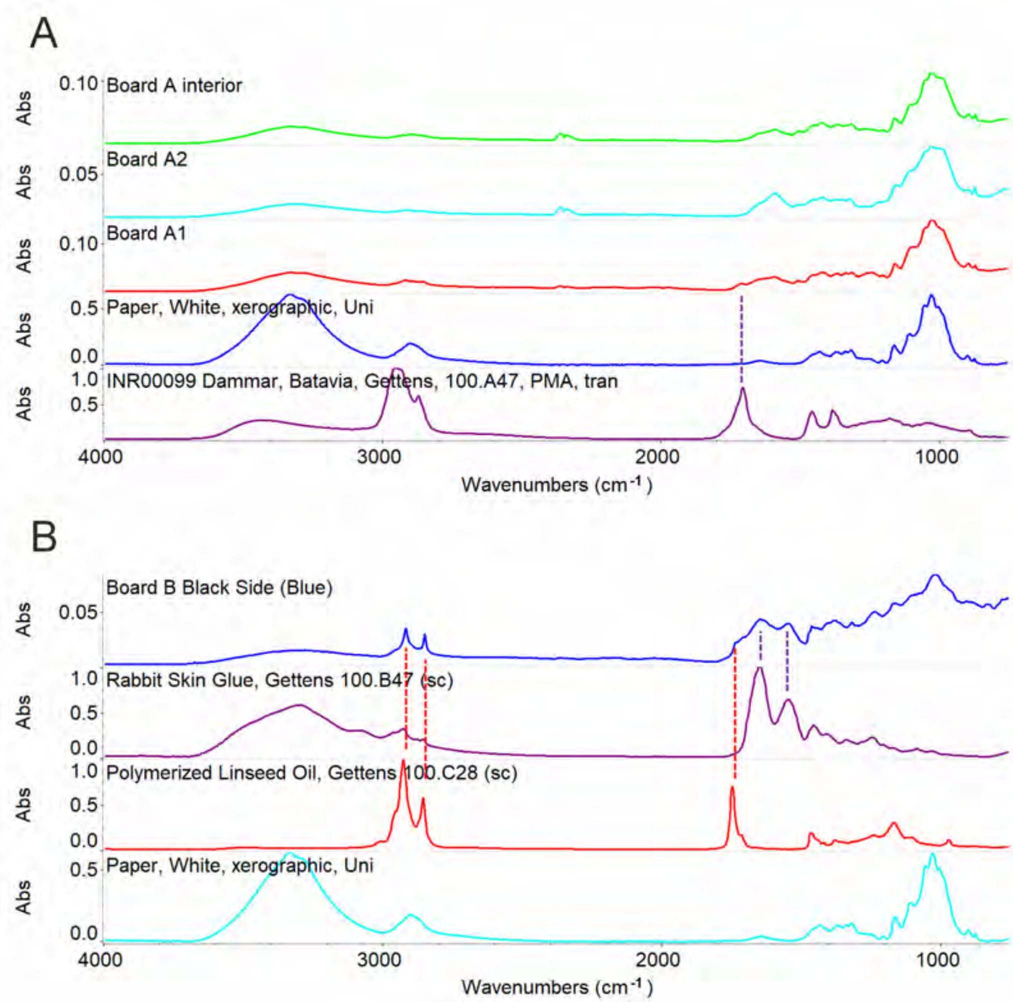

Fig. 7. ATR-FTIR spectra. a. Board A1 (exterior) shows potential evidence of an oil or resin, whereas the interior sample of the board does not; b. Board B, facing paper, artwork side. Possible proteinaceous material and an oil or resin.

on the interior supports the literature reference to strawboard being made on a multi-vat cylinder mould machine that would couch together the wet sheets, moving from one vat to the next without the use of adhesive. This would also explain how the central layer (Board A2) was incorporated as a different composition.

Both sides of Board B had papers adhered: on one side was a mounted print, and on the other side was black facing paper. Facing papers were removed for testing. The spectrum for the artwork side shows a possible match to a proteinaceous material, such as an animal glue used to attach the artwork, and also an oil or resin, which may be from the binding medium in the printing ink (see fig. 7b).

TAPPI 509 Analysis

The pH of both boards was taken (Table 2). A 1.0 g sample of Board A1 (the primary component) was cut into approximately 5 × 5 mm pieces and soaked for 1 hour before testing the pH. Upon addition of the sample to deionized water, discoloration immediately began to leach out into the solution. Over the course of an hour, the color of the solution did not change markedly from the initial 10 minutes of soaking. Before acquiring the pH, the solution was stirred and a small amount decanted for the pH reading. The meter was

Sample	Average pH	Observations
Board A1 (primary board material)	8.0	Produced the most discoloration
Board A2 (central layer)	8.9	Significantly higher pH, possibly from interior location and fiber processing
Board B (facing papers removed)	7.6	Slowest to wet up

Table 2. Average pH From the Cold Extraction Method

Fig. 8. Control coupon (left) and Board A strawboard coupons (right) after 29 days. Copper (left), lead (center), and silver (right).

calibrated with two-point calibration using pH 4.01 and 7.00 proprietary buffer solutions. The sample was measured twice with a pH of 8.0 both times. The remaining samples were prepared in the same way and measured twice with resulting pH of 8.8 and 8.9 for Board A2 (central layer), and 7.6 and 7.6 for Board B samples. During sample preparations, observations were made that Board B did not absorb water as readily as Board A samples. This may be due to the adhesive on Board B, which could inhibit the water from easily penetrating the sample. The lower pH of Board B may also be attributed to the presence of the proteinaceous material and oil or resin identified by FTIR, which has likely degraded and subsequently lowered the overall pH of the board.

Unlike wood fibers, straw is a naturally alkaline material with a pH above 7 and buffering capabilities (Halvarsson, Norgren, and Edlund 2010). The alkaline pH reading also supports the historic use of either caustic soda or lime cooking processes, which would impart an alkaline reserve in the strawboard material. The significant difference between Board A1 and Board A2 may be related to the processing method used. The central layer is extremely rough and brittle, which is in line with the description of the lime pulping process described in the 1929 patent (Weston and Clark 1929). The primary board material may have been made with caustic soda pulping, which would produce a finer furnish and less brittle board. Another contributing factor for the difference in pH between Board A1 and Board A2 is that the central layer (Board A2) is not exposed to the environment and therefore would degrade at a slower rate than the exposed outer layers.

Material Suitability Testing

Material suitability testing, such as the Oddy test, can be used to determine if destructive components of a material will off-gas and cause damage to an object. Samples are compared to a control and based on visual observations are given a rating of permanent, temporary, or unsuitable (fig. 8). When the test tube was opened, it smelled strongly of fermented plant material, and the culture tube was nearly empty of water, the board having likely absorbed it. The sealed test tube was weighed before aging and recorded as having a weight of 51.5 g; after aging, it weighed 51.4 g. This suggests a strong seal and an anaerobic environment that would result in decomposition, much like a sealed bag of leaves being turned into compost. Possible volatile organic compounds (VOCs) created during this decomposition process of plant material include hydrogen sulfide, mercaptans, organic acids, ammonia, methane, and carbon dioxide (Texas AgriLife Extension Service 2009).

The copper coupon showed no signs of corrosion and was rated as permanent. Both the lead and silver coupons were rated as temporary. The lead coupon had an overall white discoloration and a concentration of dense yellow corrosion located on the portion of the coupon that was inserted into the stopper. It was rated as temporary due to the bulk of the corrosion occurring on the part of the coupon inserted into the stopper. It is possible that the stopper may have been contaminated inside. The silver had a thin white hazy swatch on both sides. The relatively good results could be attributed to the age of the sample, with the bulk of any possible VOCs having already been off-gassed. Based on the results, this sample should be considered temporary.

FUTURE WORK

This research would benefit from the use of a much larger sample pool. This would help with gaining a better understanding of the typical composition of strawboard. Comparison of boards with and without facing papers would help determine whether there is a correlation in pH as was seen in this study. Additionally, studying the artwork associated with the boards could further the understanding of the interaction between the two materials. Because material suitability testing was only run on one sample and is a subjective test, it could be helpful to use additional tests. For example, microchemical tests and direct isothermal desorption gas chromatography mass spectrometry (DID-GC-MS) could be used to identify specific VOCs harmful to the works on paper. Finally, differentiating between the sources of straw (barley, wheat, rye, and oats) would require an extensive collection of fiber element measurements, as the ranges for the different types tend to overlap. Better separation and staining of the fiber samples, possibly using additional staining techniques such as Graff C, could help identify these different fiber elements and types of straw.

CONCLUSIONS

Based on the fiber elements seen using PLM and SEM analysis of the two samples, the composition of both boards appears to be predominantly straw with some other fiber inclusions. FTIR suggests that the interior of the boards does not contain adhesive, which is consistent with a multi-vat cylinder mould production process associated with strawboard. The carbonyl peak associated with a resin found on the surface of Board A is likely a contaminant rather than something introduced during the production of the board. The addition of facing papers was common due to the brittle nature of strawboard, and FTIR was able to detect both a proteinaceous and possible oil or resin material suggesting an adhesive and binding medium. While facing papers may add structural support that the board lacks, they can introduce acidic degradation products into the artwork through contact with the poor-quality facing papers and the adhesive used to attach them. The difference in pH between the two board samples, one with facing papers and one without, supports the idea that the materials associated with the facing papers could lower the board's pH. Straw is naturally more alkaline than wood pulp, and both possible processing methods involve alkaline chemicals. The stark white of the artwork attached to Board A prompted this research and can reasonably be attributed, in part, to the alkaline nature of the bare strawboard on which it was mounted. As a secondary support, strawboard without facing papers does not appear to present a threat to artwork in the form of chemical degradation through acidic hydrolysis and the production of degradation products; however, it cannot adequately provide the structural support that the artwork requires and could cause staining if it comes into contact with moisture.

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CHRISTOPHER SOKOLOWSKI

Repairing Modern First Edition Dust Jackets Without Fills or Inpainting: A Conservative Approach

INTRODUCTION

The modern first edition dust jacket—so often discarded in its day—has become the part of a book that holds the most historical and commercial value (Tanselle 1971, 2003). Despite this increase in the artifactual status of dust jackets, I have observed over the years extensive cosmetic restorations to them that do not honor their original integrity. So, when tasked with repairing a damaged dust jacket for E. E. Cummings's *The Enormous Room* (1922) from Harvard's Houghton Library for display and storage on its book thereafter, I saw an opportunity to investigate this unique category of paper object (fig. 1). In addition to exploring present attitudes about dust jacket restoration, I will describe stepwise nearly invisible repairs made using a lightweight kozo tissue precoated with Klucel G (hydroxypropylcellulose) adhesive and the rationale for leaving losses to be filled visually by a toned or printed secondary jacket placed underneath the original. The goal was to make the jacket appear as though it did not have losses from a short distance in an exhibition while avoiding invasive and time-consuming fills and leaving the jacket as it was found.

Leaving dust jackets wholly unrestored is the clear preference of experts who work with rare modern first editions. The curator of modern books and manuscripts at the Houghton Library tries to obtain books with jackets in good original condition but admitted that she is "not as picky as a private collector might be" (note 1). Similarly, the rare book market caters to discerning collectors who value jackets in their original state. For instance, Swann Auction Galleries highlighted a copy of Virginia Woolf's *Mrs. Dalloway* (1925) in a recent sale as having a dust jacket that "a clumsy hand did not mar with an ill-advised repair." Likewise, First and Fine UK advertised a first edition copy of George Orwell's *Animal Farm* (1945) with an original wrapper that "has NOT been restored in any way." And Peter Harrington Rare Books described their copy of F. Scott Fitzgerald's *The Great Gatsby* (1925) as having "the first issue dust jacket, a stupendous example, untouched by restoration or repair." These examples underscore the preference for unrestored jackets, and they all pertain to the most expensive books on the market, with finer condition copies of *The Great Gatsby* now exceeding $300,000 (note 2).

Papers presented during the Book and Paper Group Poster Short-format Session, AIC's 52nd Annual Meeting, May 20–24, 2024, Salt Lake City, Utah

AVOIDING REPAIR

Observing the rare book marketplace in person and online indicates that tattered and even partial dust jackets significantly enhance the interest and value of modern first editions. Many such jackets bear older tape repairs, often applied on the show side. Another informal survey of books offered by rare book sellers and auctioneers (notably Swann Auction Galleries) reveals a trend toward preserving such tape repairs rather than risking damage during removal, especially if the tape covers color printing.

Preserving an original dust jacket, regardless of condition, and keeping it on its book merely requires setting it into a common archival-quality protector made from 1.5 mil Mylar (clear polyester film) and acid-free white paper. Alternatively, because jackets in pieces may not stay in place inside a commercial protector, creative solutions like modifying an archival 2 mil polyethylene bag using an ultrasonic welder can secure the jacket pieces in the correct position on the book (fig. 2).

REPAIR

Since the brief for *The Enormous Room* jacket was to display it without a protector, some repair was necessary. Working as dryly as possible was important to maintain the jacket's original feel and appearance. Using a lightweight kozo tissue precoated with a nonaqueous adhesive such as Klucel G in ethanol can be an effective method (Pataki 2009) for subtle mending or lining without risking alterations to the paper's texture or dimensions (fig. 3). By contrast, bathing a dust jacket in water or using aqueous adhesives such as wheat

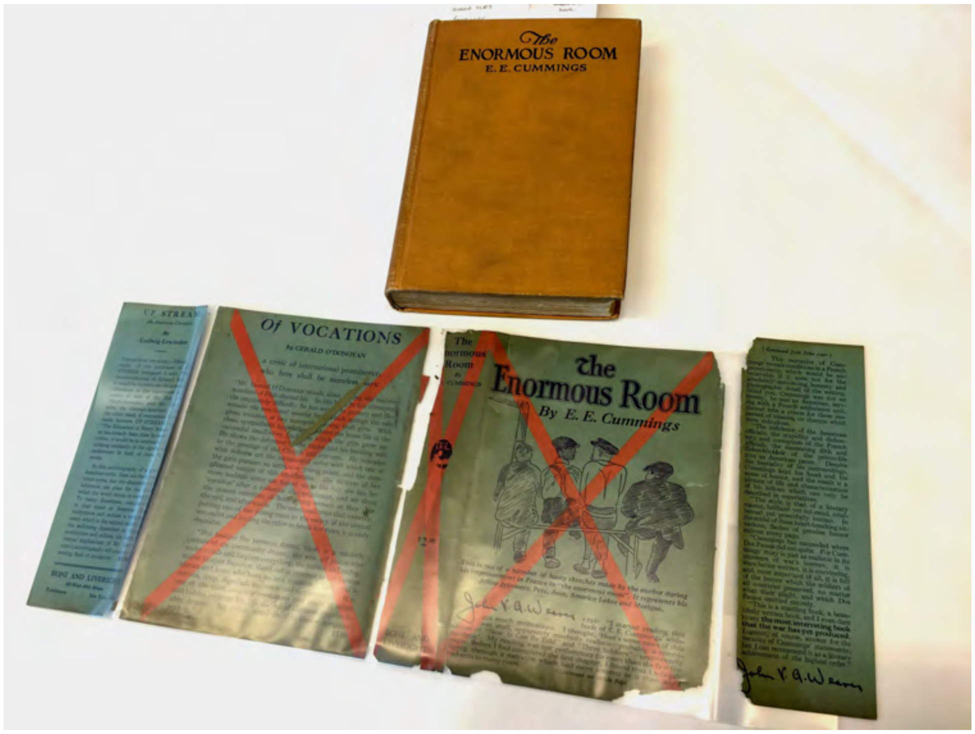

Fig. 1. First edition dust jacket and book for *The Enormous Room* (1922) by E. E. Cummings. Credit: AC9.C9125.922e (A) Houghton Library, Harvard University.

starch paste or methylcellulose may inadvertently change the jacket's surface finish or dimensions, impacting its original fit—a critical consideration for collectors, particularly with highly sought after jackets like the first edition of *The Great Gatsby*, known to have been trimmed slightly tall by the publisher (note 3).

Fig. 2. A 2-mil archival poly bag welded and trimmed into a more supportive jacket protector.

Fig. 3. The lining paper is a 2 gsm toned kozo tissue precoated with 5% Klucel G.

Fig. 4. Pieces of the dust jacket are held in place by a suction platen (hidden under Hollytex and thin blotter), making it easy to brush down the precoated tissue with 1% Klucel G in ethanol.

Fig. 5. Brushing down the last piece of precoated tissue to complete the lining.

In the case of Houghton Library's copy of *The Enormous Room*, my initial attempts at local mending using 3.5 gsm toned kozo tissue strips precoated with 5% Klucel G caused damage due to the jacket's fragile state from age and tape stains. Given its condition, I cautiously undertook a more invasive approach and decided to line this jacket overall so that it would safely conform to its book. Starting by aligning the pieces of one-half of the jacket face down on smooth Hollytex over a thin blotter set on a flush-mounted bench suction platen, a 2 gsm toned kozo tissue precoated with 5% Klucel G was then brushed down onto the jacket with a flat synthetic brush repeatedly dipped into 1% Klucel G in ethanol as a reactivation solution (fig. 4).

Once dry, the lined half of the jacket was easily assembled with the remaining loose jacket pieces over the suction platen. A metal straight edge was placed along the bottom to ensure overall alignment. A second piece of precoated tissue was set down with an overlap that spanned the spine of the jacket to provide more reinforcement in this weak area. A third 8 × 10 inch sheet of tissue was butted to the second to complete the lining (fig. 5). Using a spatula, the dry, lined jacket was separated from the Hollytex, and loose bits of jacket were set back into place using tweezers and more 1% Klucel G. Any tissue that showed in areas of loss was carefully scraped away using a curved blade scalpel on a glass tabletop.

In general, I do not consider lining a conservative approach, so in this sense the title of this article is misleading. However, I do feel this is a conservative repair technique in that the lining is very thin, applied without water, and visually discreet. The look and feel of *The Enormous Room* jacket is unchanged on the exterior, but it is slightly shinier on the book-facing side (fig. 6).

AVOIDING FILLS

Losses in older dust jackets are common, and filling these in a manner sympathetic to the original can be exceedingly time consuming. While lining a dust jacket with a similar paper that reinforces it and fills losses can be efficient, it often significantly alters the jacket's thickness and tactile qualities. Filling losses, especially with the intention to reconstruct missing text or design, further complicates this process. Modern first edition dust jackets, manufactured with machine-made paper by commercial printers, possess physical characteristics that

Fig. 6. An after-treatment image of the interior of the lined jacket. The lining is nearly transparent but also slightly shiny.

are difficult to imitate with the more artisanal techniques of conservation and restoration.

Moreover, according to Tanselle's 2003 survey, there is growing consensus among book historians and collectors that maintaining a historically correct jacket is crucial for preserving a book's bibliographic integrity. Although difficult to detect when the book and its jacket are both in good condition, this integrity becomes more apparent with jackets in poor condition, where visible losses and damage should correspond with the book's history, emphasizing their original association (fig. 7). For the conservator, avoiding fills can be both ethical and practical.

Fig. 7. Fading and wear show that this book and its jacket have had a long association.

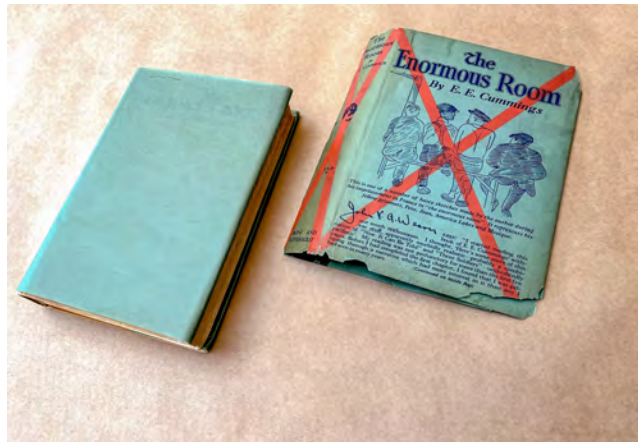

Fig. 8. The treated jacket with a toned Asian tissue "under jacket" intended to visually fill losses.

ALTERNATIVE FILLS

There are easy and reversible ways to make a dust jacket with losses appear more complete for display. For *The Enormous Room* jacket, the losses were at the edges and there was no significant text or design missing. Nonetheless, using a toned Asian paper "under jacket" (fig. 8) visually completed this graphically striking jacket so that its design rather than its condition was the initial impression in the exhibition *Sentences: Prison Writing Through the Ages*, held at Houghton Library during the summer of 2023 (fig. 9). The advantage of using an under jacket is that the dust jacket retains its authentic condition while appearing complete when viewed from a short distance on exhibit. Without an under jacket, its poor condition would be emphasized due to the contrasting binding color.

A printed under jacket may be an effective choice when displaying a dust jacket that is missing significant text and design. Here, the Internet can offer a multitude of solutions. Many modern first edition dust jackets are available as printed facsimiles from high-quality scans through Facsimile Dust Jackets LLC. These may be too "clean" compared to a damaged jacket placed overtop, so modification of some sort may be necessary. Another possibility is capturing an image of a relevant dust jacket, usually from a bookseller's listing. Often one can find a more complete jacket with similar toning or fading to download, resize, and print. The pixelation that will result from these small image files may even be an advantage in that they yield a blurry print and will be visually quieter compared to a real jacket (fig. 10).

As convenient as the Internet can be for sourcing images of dust jackets, there can be copyright concerns. The copyright expert for the Harvard Library has summarized the issue by stating that legally, there is not a blanket rule for using images of dust jackets found on the web to serve as the source for cosmetic fills. While there is a strong presumption of fair use

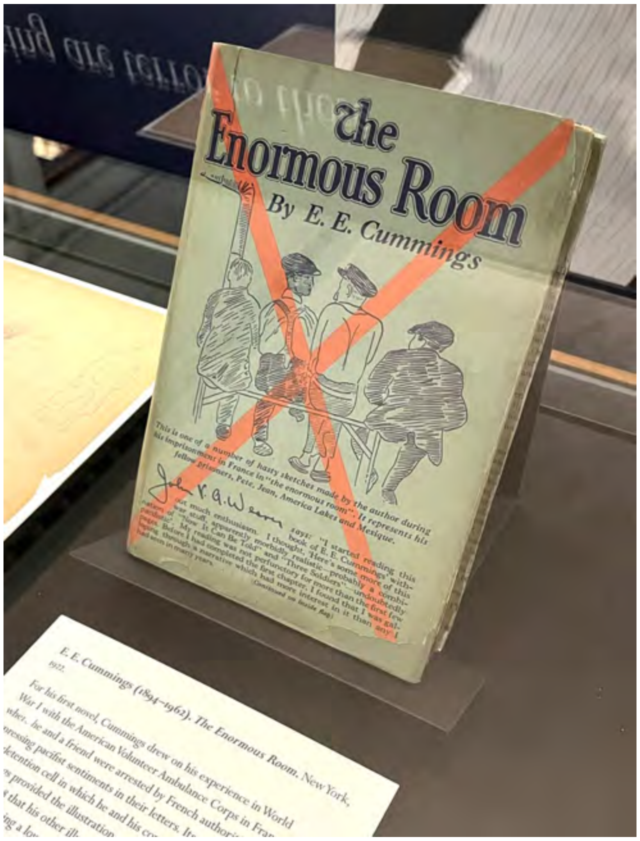

Fig. 9. *The Enormous Room* on display at Houghton Library in the summer of 2023. The under jacket disguises the losses, keeping attention on the cover design.

for cosmetic fills to repair dust jackets for nonprofit exhibition purposes, each fair use determination is fact specific to the work itself. Determining if the work is in the public domain and can be used for any purpose without permission is an important first step in minimizing the risk of copyright infringement (note 4).

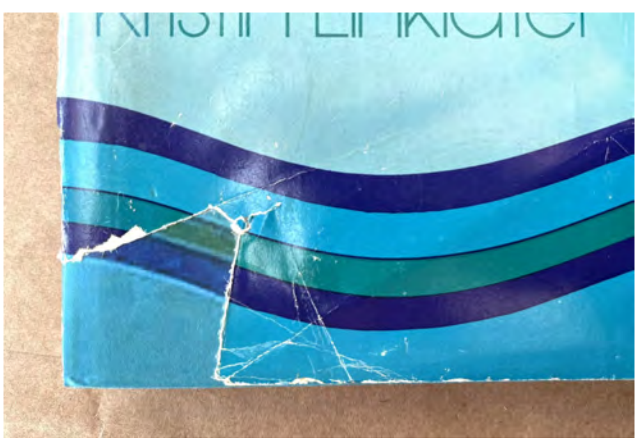

Fig. 10. Detail of a printed under jacket made from an image found on the Internet. The pixelation from small image files such as this one is an advantage in that it creates visually quieter fills.

AVOIDING INPAINTING

Clearly, some stewards and sellers of rare books view an "unrestored" dust jacket as an important sign of that book's authenticity and historical integrity. Of the various techniques that one might employ to improve the condition of a dust jacket, inpainting holds a special power to tamper with both. Perhaps it is simply too easy (and fun!) to do. Perhaps inpainting is a necessary sign in some book repair contexts that a treatment has taken place. Long ago and in a different setting, I observed cosmetic improvements being made on a rare jacket with felt-tip markers; the highest-quality watercolor paints would be no less destructive. In the end, inpainting (or retouching or coloring in) a dust jacket becomes a misrepresentation of its true condition and, in time, will negatively affect its appearance—and all other aspects of its value.

ACKNOWLEDGMENTS

I extend my gratitude for all who contributed to this project, including Erin Black of Bauman Rare Books; Kyle Courtney, Esq., director of Copyright and Information Policy, Harvard Library; staff of Peter Harrington Rare Books; Martha Kearsley, bookbinding instructor, North Bennet Street School; Leslie Morris, Gore Vidal Curator of Modern Books and Manuscripts, Houghton Library; Todd Pattison, conservator, American Ancestors; and colleagues of the Weissman Preservation Center, Harvard Library.

NOTES

1. Leslie A. Morris, e-mail message to author, May 8, 2024.
2. "John Larson's Specialist Picks," Swann Auction Galleries, posted February 22, 2023, https://www.swanngalleries.com/news/19th-20th-century-literature/2023/02/john-larsons-specialist-picks-five-to-watch-in-the-march-2-2023-sale/; "Orwell, George (1945) 'Animal Farm,' UK True First Edition With the Original and Unrestored Dust Jacket," First and Fine, accessed April 2024, https://www.firstandfine.com/product/orwell-george-1945-animal-farm-uk-true-first-edition-with-the-original-and-unrestored-dust-jacket/; New York International Antiquarian Book Fair (@nybookfair), "F. Scott Fitzgerald," Instagram post, April 7, 2022, https://www.instagram.com/nybookfair/p/CcEs9KBseM7/; "The Library of Dr. Rodney P. Swantko/Lot 15," Sotheby's, accessed July 2024, https://www.sothebys.com/en/buy/auction/2024/the-library-of-dr-rodney-p-swantko/fitzgerald-f-scott-the-great-gatsby-first-edition.
3. "The Great Gatsby Dust Jacket," *The Journal*, Peter Harrington, posted May 14, 2013, https://www.peterharrington.co.uk/blog/the-great-gatsby-dust-jacket-one-of-the-most-enigmatic-in-modern-literature/.
4. Kyle K. Courtney, e-mail message to author, February 8, 2024.

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SOURCES OF MATERIALS

NAJ Toned Tengucho by Hidaka Washi, 2.0 g/m^2 and 3.5 g/m^2 rolls

Hiromi Paper Inc.
9469 Jefferson Blvd. #117
Culver City, CA 90232
310-998-0098
https://hiromipaper.com

Klucel G (hydroxypropylcellulose), Archival polyethylene bags (2 mil)

TALAS
330 Morgan Ave.
Brooklyn, NY 11211
212-219-0770
https://www.talasonline.com

Exact-fit clear polyester book covers with nonprinted paper backing

Brodart
500 Arch St.
Williamsport, PA 17701
888-283-6087
https://www.shopbrodart.com

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Abstracts presented during the Book and Paper Group Session

POV: An Archives Conservation Laboratory's Efforts in Reaching Out and Leveling Up

Ayaka Ajiki, Sanira Beevi, and Cassandra Tang

The wheels started turning in a different direction for conservation in the National Archives of Singapore (NAS) three years ago. Tucked away in a picturesque hillside building, the conservation team operated in the shadows, as a back-of-house function. Driven by the goal to raise the profile of conservators, stoking an interest in conservation resulting in pride in and respect for the meaningful work conservators do, a progressive route was charted for the team targeting outreach, education, and engagement.

Outreach

We were eager to challenge preconceptions of conservation being deadly serious business, with no room for humor. From a dearth of conservation-related posts on our institution's social media two years ago, conservation is now front and center, gracing social media platforms such as Zoom, Instagram, YouTube, and, most recently, TikTok, making archival conservation sexy again!

Notably, Conservation in NAS, a 10-episode TikTok series, threw the spotlight on our conservation team. The series highlights behind-the-scenes conservation processes at NAS. It has garnered 1,465,200 views and is climbing (the average views per clip is 146,520). Most hearteningly, the comments section has been ripe with queries on how one can join the profession. It also won the National Library Board's Outstanding Innovation Award in 2023—a recognition for being the first conservation series from an institution in our local TikTok scene. Ultimately, it has endeavored to make conservation education accessible, eliciting wonder and reaching new audiences.

Education

It is no surprise that conservation practices are varied around the world. With limited educational institutions offering conservation training especially in Asia, such educational opportunities or professional training might be out of reach for many aspiring conservators. To tackle the issue of making conservation training accessible for our team, we created a comprehensive in-house professional training program that serves a dual purpose of being an induction program for new conservators and a progressive training model for conservators to develop their competencies at beginner, intermediate, and expert levels.

Taught by veterans in the team who have cultivated a wealth of experience training on the job, this model also serves as a means of sustainable knowledge transfer. Born during the COVID pandemic when we were sorely missing travel, it was aptly named the *Training Passport*, where conservators "travel" to new experiences and challenges and obtain a stamp when they reach their destinations. While putting together the sessions which targeted skills necessary for a paper conservator, from cooking wheat starch to cutting mat boards to sizing and lining, we also made sure to include training for operating the equipment in the laboratory. This ensured that crucial knowledge and know-how did not solely rest on one or two conservators' shoulders but are now part of the skill set of every member of team. Supplemented by a curated list of external online courses, we have been keeping abreast with the dynamic conservation landscape.

In early 2024, we extended an abridged version of this training to a group of conservators in neighboring countries, helping to raise the standard of conservation in the region.

Engagement

Necessitated by internal incidents with hazardous chemical agents and agents of deterioration, the Archives Conservation laboratory designed a first-ever internal records handling program for our library and archives staff. The National Library Board has a mandate to collect, preserve, and manage Singapore's public and private archival records of historical and national significance for their long-term preservation. As recent local and international events demonstrate, it is not enough for conservators alone to be apprised of the potential hazards in collections. Anyone who has exposure to physical records needs to be alert and informed of the signs of potential risk, and how to respond and protect oneself.

A component of our Collections Disaster Management Plan covers agents of deterioration, assessing condition of records, staff health and safety measures, best practices in records handling, how to identify health hazards, and mitigating steps to be taken. It has changed the way collections staff approach records, prioritizing their health and safety. Communication is smoother and quicker with clear

Abstracts presented during the Book and Paper Group Session, AIC's 52st Annual Meeting, May 20–24, 2024

escalation channels when the unforeseen happens. Staff and users are educated to understand the vulnerability of the materials they are handling.

Our training, which focuses on the special care required to ensure the long-term preservation of records, has also been extended to include participants beyond our organization, with external collection owners, archivists, and conservators from other local GLAM organizations to cover a wider group of users. This strengthens and cements the unifying role we play in preservation as agents of change, actively engaging an otherwise rather fragmented local conservation community.

This three-pronged approach has transformed the role we play as conservators in our organization. We are highly encouraged and motivated to do more and to do better—to make conservation accessible to all.

Starr-Crossed or Serendipitous? The Unexpected Move of Columbia University's C.V. Starr East Asian Library

Rachael Arenstein and Eugenie Milroy, A.M. Art Conservation; Alexis Hagadorn, Emily Lynch, Emily Holmes, and Morgan Adams, Columbia University Libraries

In November 2022, Columbia University Libraries' staff were notified that the entire contents of the C.V. Starr East Asian Library had to be moved off-site before the end of the academic year. Required construction to update the historic building's fire suppression system would begin in June 2023, leaving the library six months to relocate a circulating collection of roughly one million volumes, and an extensive special collection of artifacts, scrolls, rare books, and archival material. While there was ample precedent for transport and off-site storage of the circulating collection, the special collections presented a different set of challenges. Portions of the collection were not fully cataloged on an item level, creating an initial hurdle as the size and scope of the project was not clear. Another major issue was housing, as many of the 3D objects were not housed suitably for a move.

Given the tight time constraints and project scale, a team of object conservators, archivists, packers, riggers, and movers were contracted to augment in-house expertise and capacity. This collaborative group comprising more than 30 team members managed to complete the project on time and within budget. Over five months, the contract team created more than 4,000 inventory records in a custom-designed Airtable database representing more than 17,300 items. Standard- and custom-sized boxes, designed to fit on the university's library shelving, were used to pack the collection for transport in a manner and with materials designed to also be safe for long-term storage upon the return of the items after construction is complete. What initially seemed like an unexpected ordeal for the library wound up becoming a fortuitous opportunity, providing construction money for an inventory and rehousing project that would likely not have been otherwise funded.

While it is widely known that libraries hold more than books and works on paper, the depth and breadth of the 3D collections at Starr posed a challenge requiring cross-specialty collaborations and solutions. Each storage room, cabinet, and bank of shelving held surprises. The partnership between the Libraries' Preservation Division and the contractors enhanced the project as every firm contributed their expertise and experience in housing and moving artifacts, small and large. This article will focus on the collaborative tools, workflows, mistakes, and lessons that allowed the team to invent and adapt solutions throughout the fast-paced project.

The Production and Deformation of Drying Boards

Ting-Fu Fan and Yi-Chiung Lin

Drying boards are one of the most frequently used equipment in Eastern painting and calligraphy conservation and mounting studios, aiming to dry and flatten artworks. Traditional drying boards are made of wooden boards, or a combination of wooden boards and paper, or wood strips with paper such as the classic Japanese-style Karibari.

High-quality wood strips and craftsmanship can be costly, limiting the options available to some studios and conservators and reducing the likelihood of use.

In this article, I will share how to use aluminum extrusion brackets instead of wooden strips and combine them with paper to create drying boards with the same functionality. This method allows for easy production of drying boards in any desired size, offering light weight, high structural strength, and resistance to deformation. Moreover, connecting drying boards of the same size can also provide a convenient option for occasional conserving or mounting of larger artworks.

Assessing Collections at the Library of Congress: The Human Aspects for Sustainability

Beatriz Haspo

The Library of Congress is the world's largest public library, with more than 170 million items, containing 838 miles of shelving in three buildings in Washington, DC, and other facilities. Like any other institution, the Library of Congress struggles with storage space.

This article presents the integrated approach to space management and collection needs: the Space and Emergency Management Survey—the Stacks Survey, developed for the nearly 22 million books, pamphlets, and other printed of the General Collections at the Library of Congress. Besides the survey methodology and results, it will emphasize how the survey design focused on the human component, using an innovative, inclusive, and equitable approach.

This is the first time in the history of the institution that such a large-scale survey for the General Collections has been conducted. Using tablets for portability, a team of 96 people is surveying around 95,000 sections in collections areas of the Jefferson and Adams buildings, where General Collections are stored, dedicating one 90-minute shift/week/person to the project. The survey was developed with a minimum number of questions needed to gain the most possible data in key areas in a short time focusing on inventory, environmental risks, condition, and space issues, and capturing images of sections. The survey of each section takes less than 5 minutes. As part of the survey, sections are also being documented with images, constituting the first-ever comprehensive visualization of each section of the General Collections in the history of the Library of Congress.

As the project manager, I have been responsible for engineering the design, planning the logistics, staff training, and overseeing its implementation. This article will share testimonials about how the survey has been empowering staff of various backgrounds conducting the survey and impacting their understanding of the collections, storage areas, and the role they play in sustainable preservation.

The Stacks Survey is an important initiative that will provide information to support preservation actions for years to come. But the impact on the team will go much further, beyond numbers.

A New Technique for Strengthening of Naturally Degraded Acidic Paper With Cellulose Fibers Coating

Ryota Kose, Takayuki Okayama, Masazumi Seki, Naoko Sonoda, and Yuki Tanaka

From the mid-19th century until about 1990, acidic paper based materials were produced in large quantities throughout the world. Unfortunately, the use of acidic paper reduced the paper's strength due to chemical reactions during long-term storage. Although efforts have been made to mitigate this degradation through deacidification such as the Bookkeeper (BK) method, it remains difficult to restore the strength of degraded paper. The authors have developed an innovative coating method using fine cellulose fibers (FCF) as a strength-enhancing treatment after deacidification of degraded paper. FCFs are defined as nano or submicron fibers prepared from cellulose fibers by miniaturization, and are characterized by high optical transparency and chemical affinity with the cellulose. This method was patented and registered as a Japanese patent in February 2022.

Prior to FCF coating, the BK method was conducted on naturally degraded wood-free paper, after which the paper was wetted and excess of water was removed on a vacuum suction table. Until now, the FCF coating process has been done manually using a coating bar. In this study, we developed a compact coating machine that enables continuous coating on both sides of degraded paper by passing through two rolls in sequence. As optimized conditions, a coating speed of 4 m/minute and a gap of 1,500 μm between the rolls were selected for the coating of commercial FCF. Freeze drying, thermal drying, and vacuum drying were attempted as drying conditions for the paper after coating, with vacuum drying being the most appropriate. In this experiment, vacuum drying was performed at 40°C. Under this condition, the coating amount was approximately 1.2 g/m^2.

While BK treatment of degraded paper did not change the tearing strength of the paper, FCF coating treatment increased the tear strength of BK-treated paper by 1.2 times. Comparing the tear strength of papers after accelerated aging showed that BK-treated paper was 1.2 times stronger than the untreated paper, indicating that degradation was inhibited. Furthermore, BK-treated paper coated with FCF was 1.4 times stronger than untreated degraded paper. This indicates that the combination of BK treatment and FCF coating treatment can achieve both degradation suppression and strength improvement. The legibility of the original paper remained unchanged after the FCF coating treatment, and the increase in thickness due to FCF coating was about 1% of the original thickness.

Good experimental results were also obtained in the possibility of lowering the drying temperature from 40°C to 30°C and in the preparation from raw materials (bleached hardwood kraft pulp) of FCF suitable for the coating.

The Collections Won't Pack Themselves: A Preservation and Special Collections Collaboration

Mary Leverance, Amber Cooper, Sally Crutcher, and Estefani Mann, University of Arkansas

Major building renovations required the complete removal of collections, materials, and staff from two levels in Mullins Library at the University of Arkansas in 2022. Due to an accelerated timeline, library staff had an unexpectedly short timeframe to plan for the move and to pack materials. This talk will address how the Libraries Preservation Unit collaborated with Special Collections staff to prepare and pack approximately 80,000 collection items for the move out of the building. Preparations began in January 2022, with a deadline of everything moved from the building by November; renovations began mid-December.

The first steps taken by Preservation and Special Collections staff were to establish guiding principles for the project, assess collections, and identify temporary storage locations based on material usage. Preservation staff were familiar with Special Collections materials in general, but preparation of various material types for packing required a quick assessment of storage conditions and items needing preservation attention. This assessment allowed for basic triage (e.g., Mylar covers for volumes with red rot, using pre-made four-flap enclosures) while notes were taken on issues to address once collections are moved back into the refurbished space. Preservation staff provided guidance on packing procedures, trained library staff in packing, ordered appropriate supplies, and implemented easy and low-cost solutions for packing a variety of materials, including multimedia, rare books, oversize books, and objects. While there is some literature on packing collections for a move, preservation staff spoke with others in academic libraries who have recently completed a move, learned from their insights, and implemented various tips on packing.

Moving collections inherently carries a degree of uncertainty—timelines shift, or surprises are found on shelves—and this project was not an exception. Unexpected events were experienced over the course of the project: plans to make compact shelving space more accessible did not pan out, issues with the HVAC meant running portable dehumidifiers for a few months, repeated conversations about packing and moving flat files with different moving companies took place, and staff needed to take time from their regular job duties to help pack materials. Preservation and Special Collections staff managed problems as they arose and ultimately met the final deadline for the move.

Wet Recovery: The National Library of Jamaica's Perspective

Lisa-Ann Norris, National Library of Jamaica

There is no doubt that changes, uncertainties, and surprises are inevitable aspects of life. However, how we adapt and respond to them when faced with different adversities is what matters most. The field of Preservation and Conservation is one in which changes, uncertainties, and surprises occur frequently. We see changes in the different equipment used to undertake conversation works, processes, and, of course, emerging technologies, which is one of the main perpetrators of change in this 21st century. Global warming, natural disasters, and globalization are also factors to contend with in the field of Preservation and Conservation. This poster will examine how an uncertain event took us by surprise at the National Library of Jamaica. It will also examine how the event was handled and how it has allowed us to embrace the changes that came about because of this event. This event that is being referred to is a flood that took place at the National Library of Jamaica on April 16, 2016. This flood was due to a broken main connected to a cooling system from the microfilm processing laboratory. This resulted in water seeping through the roof from the fourth floor of the buildings to the ground floor. It resulted in a horrific experience for the National Library of Jamaica team, who was faced with such an uncertain event that began over the weekend (Saturday) until it was discovered the Monday on reopening the library for its usual business. There was a trail of destruction on every floor. Map cabinets filled with water and water-soaked maps, which resulted in them being discolored, soaked, and extremely fragile. Manuscripts, books, and rare books, among other paper-based items from the collection, were affected. How such a situation was handled and what changes it brought about for the organization will be discussed and analyzed thoroughly in the presentation of the poster. Finally, expecting the unexpected and embracing change, uncertainty, and surprise is a valuable mindset that can lead to personal and professional growth, enhanced resilience, and the ability to adapt effectively. By understanding the inevitability of change, embracing uncertainty, and reframing surprises as opportunities, individuals can navigate through life's unexpected twists and turns with confidence. It is also important for us to remember that change should not be seen as a deterrent but instead as an invitation to discover new possibilities.

Soluble or Not? Research Outlining Solubility and a Natural Aging Study of Water-Soluble Pencils and Pastels

Lindsay Sisson, Rosaleen Hill, Jennifer Poulin, and Scott Williams

Water-soluble pencils and pastels have been produced and utilized since the early 1900s. Water-solubility, originally developed to aid in the clean-up of waxy graphic media, soon became a desirable property for artistic practice. As such, water-soluble graphic media was integrated into the works of Jackson Pollock, Sarindar Dhaliwal, Saul Steinberg, and other artists' collections. Due to the myriad ways artists can apply this media, it can be challenging to visually distinguish it from their non-soluble pencil and pastel counterparts, as well as traditional watercolor washes. This is further impacted by the limitations of media labels, product data sheets, and the nature of artistic practice, which has made it difficult to track artworks made using water-soluble graphic media in collections. As previous studies have indicated, unlike traditional watercolor, water-soluble pencils can remain soluble long after they are applied due to their water-soluble waxy binder. The differences in their solubility behaviors paired with how easily they can be mistaken for other media can have dire consequences for artworks in collections. Additionally, there is little literature exploring the natural aging properties of these materials; therefore, the need for further exploration of these materials has been identified.

This research explores the composition, aging, and solubility behaviors of seven water-soluble graphic media: Caran d'Ache Neocolor II Aquarelle Water-Soluble Wax Pastels and Museum Aquarelle Watercolour Pencils, Brevillier's Cretacolor Aquarelle Oil Pastels, Derwent Inktense Ink Pencils, Faber-Castell Albrecht Dürer and Goldfaber Aqua Watercolour Pencils, and Gallery by Mungyo Watercolour Crayons. Fourier transform infrared (FTIR) spectroscopy, pyrolysis-gas chromatography–mass spectroscopy, and portable x-ray fluorescence were used to identify the binder, bulking agents, and colorants. Preliminary analysis has indicated the presence of polyether-polyols and other sugars instead of traditional gum binders which may contribute to the media remaining soluble over time as described previously. Thermo-aging in hybridization tubes was undertaken on media that were applied to Arches hot-pressed watercolor paper. A set of aged and unaged samples were then immersed in baths of commonly used paper treatment solvents: distilled water, ethanol, acetone, ethyl acetate, and toluene. Any color shift resulting from these baths was monitored with a Konica Minolta CM-700d color spectrophotometer, whereas the relative amount of media was tracked using ATR FTIR.

All research samples and data, in addition to pencil and pastel sets, acquired will be added to Queen's Artist Material Archive to support the development of a long-term natural aging study of these materials. An additional goal of the Artist Material Archive will focus on the creation of a database of External-Reflection FTIR spectra to help distinguish water-soluble graphic media from non-soluble pencils and pastels. This method will allow conservation professionals with access to FTIR to identify unknown media without damaging or sampling an artwork. This definitive baseline for future identification and material research will aid in the study of conservation concerns and treatment options for contemporary water-soluble pencils and pastels.

MEREDITH FRENCH AND JODIE UTTER
DISCUSSION GROUP CO-CHAIRS

Art on Paper Discussion Group 2024
Tape and Adhesives: New Techniques and Materials for an Age-Old Problem

INTRODUCTION

Tape and oxidized adhesives have long created challenges for paper conservators because of the damage they cause through staining, distortion, and the deposition of adhesive residue; in extreme cases, oxidized adhesive residues have led to the breaking apart and fragmentation of papers. Traditionally, the removal of tape carriers and adhesive has involved localized heat, erasers, and the application of organic solvents. As the field of conservation tries to move away from using toxic chemicals, other methods have been employed with varying degrees of success. This year's panel wanted to highlight practical treatment options that were innovative and less hazardous to the practitioner and the object being treated. The moderators added a discussion prompt for the attendees' consideration, asking whether heat and chemicals are actually superior treatment strategies over mechanical removal. The panelists presented two different and practical presentations, which were followed by an engaging 45-minute discussion with the audience. The first speaker, Rebecca Pollak, associate paper conservator, presented a talk co-authored by Adam Novak and Teresa Duncan, PhD, entitled "Fundamental Experiments and Applications of a Non-Aqueous Gel for Adhesive Removal on Paper." Pollak discussed the solvent gel Sylgard 184 polydimethylsiloxane (PDMS) and how it can be used to facilitate the controlled release of solvent and/or solvent vapors. Heather Hendry, senior paper conservator, offered insight into a tape and residual adhesive reduction protocol that emphasized mechanical removal options (spatulas, heat, and electric erasers), followed by limited use of solvents and non-gel poultices. During the discussion, Adam Novak joined the other speakers on stage to answer questions.

Summaries of discussion groups at the Book and Paper Group Session, AIC's 52nd Annual Meeting, May 20–24, 2024, Salt Lake City, Utah

PRESENTATION SUMMARIES

REBECCA POLLAK
ASSOCIATE PAPER CONSERVATOR, THAW CONSERVATION CENTER, MORGAN LIBRARY AND MUSEUM

Rebecca Pollak presented "Fundamental Experiments and Applications of a Non-Aqueous Gel for Adhesive Removal on Paper," a treatment using Sylgard 184, a rigid PDMS elastomer, to aid in the removal of an adhesive from an artwork on paper. Her research was undertaken with Adam Novak, paper conservator and owner of Novak Studios, and Teresa Duncan, PhD, a conservation scientist with the National Gallery of Art.

Sylgard 184 is a silicone elastomer commonly used for encapsulating electronics. It forms a continuous film that can easily be applied and removed from an object's surface, and its rigid structure does not penetrate paper fibers. Sylgard swells in a range of low-polarity solvents, making it a useful counterpart to other "rigid" hydrogels used in conservation that are optimally used with more polar solvent systems. It is sold as a two-part kit and is easily prepared by combining the elastomer base with a curing agent. Once mixed, the gel cures at room temperature over several days or more quickly at higher temperatures. The gel must be rinsed after curing to ensure that uncross-linked PDMS is removed. Pollak and the other researchers prefer rinsing in a mixture of 1:1 heptane and acetone to reduce swelling of the gel and accelerate evaporation of solvent after the final rinse. Sylgard 184 can be modified to obtain different characteristics. The manufacturer recommends mixing the elastomer base and curing agent at a ratio of 10:1; however, increasing the elastomer base to a ratio of 20:1 yields a softer, more flexible film. Thin gels conform very well to surfaces, yet they are not able to retain the solvent long enough to prevent the deformation of the gel. Gels at a thickness of 1.5 mm conform well and can be used longer with reduced deformation. Sylgard can hold a greater quantity of low-polarity solvent than higher-polarity solvent, and the gel increases in size accordingly.

The treatment object presented by Pollak was an approximately 60 × 40 inch, double-sided charcoal drawing on tracing paper made in the mid-20th century. The primary support was adhered to a paper-laminated canvas and stretched over a wooden strainer. The front of the tracing paper bore an uneven coating of spray fixative, whereas white paint had been brush applied to the back. In 2010, the object was rehoused in a sealed frame package and stored in a non-museum environment, and photographic documentation from this time indicates that the tracing paper had darkened severely since then. With the expectation that future storage environments would be unregulated, the researchers decided that removal of the drawing from the mount materials was the best solution.

The adhesive and white paint were analyzed using FTIR. Analysis indicated that the adhesive was a neoprene-based material belonging to a family of synthetic rubbers. Data showed that the paint was titanium white acrylic containing a significant amount of chalk filler. Separation of the white paint layer from the paper support was possible, although not without disturbing the charcoal media on the verso. Therefore, the goal was to remove the neoprene adhesive from the white paint layer.

Novak and Pollak determined that the ideal solvent mixture was a 2:1 ratio of acetone to ethyl acetate. However, their tested delivery methods—dampened cotton, xanthan gum, and Carbopol gels—did not provide enough dwell time and caused the adhesive to soften briefly, only to rapidly harden again. To address this problem, they turned to Sylgard 184. To tailor Sylgard to the polar solvent mixture, they prepared thicker sheets of the gel, about 1/8 to 3/8 inches. The thicker sheets hold more solvent and increase the dwell time. The gels were prepared in 5 × 7 inch Plexiglas trays and cured for approximately a week at room temperature. Rinsing followed. To remove the adhesive from the paint layer, the gels were applied, covered in Mylar and Plexiglas, and weighted for 30 minutes. This method allowed the adhesive to be effectively softened and peeled, although within a narrow window of time before rehardening. The gels were reused by soaking again in the solvent mixture.

Pollak concluded by offering some tips about Sylgard 184 and its use. The gels can be rinsed of adhesive residue, dried, and stored indefinitely. She has used two-year-old gels with success. Sylgard is available for purchase online from the manufacturer or from Amazon.

Although pricey, the efficiency of the product and the time saved during treatment made up for their cost in this case study. Pollak noted that further study has been undertaken to alter morphologies of PDMS gels to improve contact and exchange with object surfaces by preparing them with removable materials or on different surfaces. Currently, these gels do not perform better than the slab form. Future work may better characterize these pores and expand the gel's utility in conservation.

HEATHER HENDRY
SENIOR PAPER CONSERVATOR, CONSERVATION CENTER FOR ART AND HISTORIC ARTIFACTS

Heather Hendry presented "A Utilitarian Approach to Tape Removal." Hendry explained how tapes have historically been addressed by undergoing extensive solvent testing to discover the best protocol to reduce carriers and oxidized adhesives. For some conservation laboratories, this approach is not always possible or practical. Further, she questioned whether solvent use is actually necessary for most tapes and added that their use can push adhesive further into paper fibers. She followed by sharing a flowchart she developed to aid in decision making when treating pressure-sensitive tape. Hendry emphasizes the chart's simplicity: there is no mention of solvent testing or tape identification. The chart differentiates between tape adhesive that is hardened or tacky (figs. 1, 2).

If the tape is tacky, applying heat via a hot air pencil or heated spatula can aid in lifting the carrier. The adhesive can then be removed mechanically using an eraser such as crepe or vinyl. For durable papers, Hendry especially likes an electric eraser, which can be found online from stationery suppliers as battery-powered or USB-chargeable devices. The electric eraser provides speed, control, and single-direction rotation, making treatment around edges and tears easier. For tape that is hardened, Hendry suggests reducing the adhesive mechanically with micro-spatulas or scalpels. If the adhesive needs to be further reduced, Hendry then uses solvents. A consideration here is the color of the adhesive. If the adhesive is yellow or orange, acetone will likely be effective. Otherwise, a blend of 40% ethyl acetate, 40% acetone, and 20% ethanol may work. If the adhesive is clear or oily looking, she suggests trying ethyl acetate first and continuing with toluene, if necessary.

When Hendry does use solvents to reduce adhesives, it is on a suction platen with the adhesive side down. When incorporating solvents, care should be taken to choose a method that will not drive the adhesive further into the paper, as it will later oxidize and create tide lines as it ages. She emphasizes that minimizing health risks to the conservator should be a goal, and if solvents are used, the least harmful ones should be prioritized where possible.

DISCUSSION SUMMARY

The session concluded with a discussion between the presenters, moderators, and audience members. Questions and comments about the presentations were directed at Hendry, Novak, and Pollak, and a conversation about the discussion prompt followed.

The questions for Pollak and Novak centered on Sylgard 184's effectiveness when soaked in different solvents and its ability to hold them. Pollak explained that high-polarity solvents such as acetone and ethyl acetate do not swell the gel as

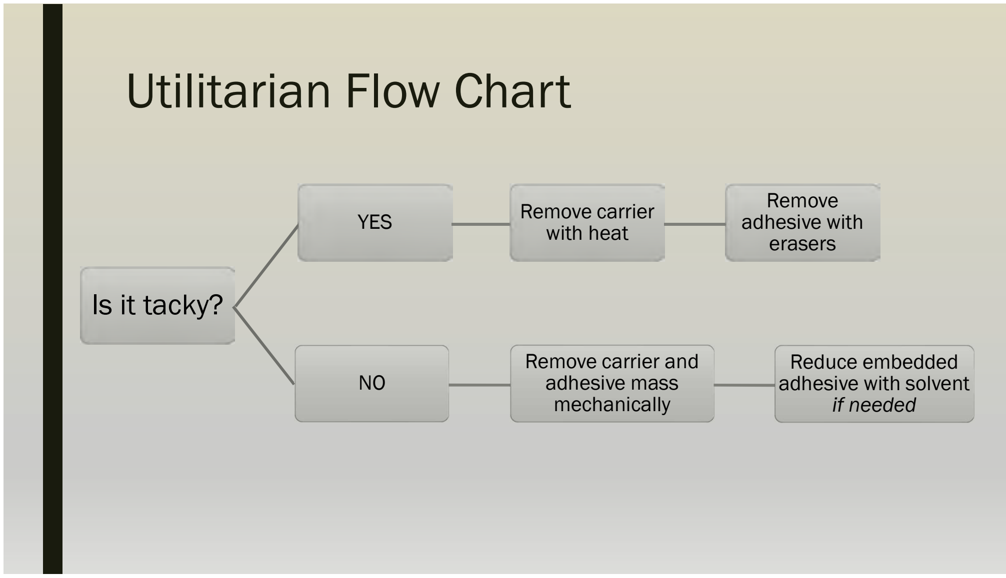

Fig 1. Tape removal decision tree. Courtesy of Heather Hendry.

much as low-polarity solvents. This can be viewed as a limitation or a benefit depending on the desired application of the gel. In the treatment presented, the Sylgard held the low-polarity solvents long enough to soften the adhesive so it could be safely removed. She added that because Sylgard is silicone, it will not absorb water; therefore, hydrogels may be more successful if aqueous blends are used. Pollak and Novak remarked how Sylgard's ability to retain solvents is advantageous in several ways. The gel does not release liquid after initial blotting, and tide lines were not observed during treatment. Additionally, the slow evaporation rate of the solvent reduced the conservators' exposure to fumes. An audience member noted that toluene has a slow evaporation rate and questioned if Sylgard could extend this rate further. While Pollak has not tried toluene with Sylgard, Novak observed that the Sylgard indeed extended the working time of the polar solvents used in the treatment, which would have otherwise evaporated quickly before the adhesive could be softened. The longer dwell times that are possible with Sylgard may indicate that lower-toxicity solvents could be used in place of toluene with success. When asked about storage, Pollak noted that it is important to keep dust from embedding in the gels. Dry storage of the gels between pieces of Mylar inside plastic bags achieves this. Sylgard can be reused with different solvents, and thorough rinsing of the

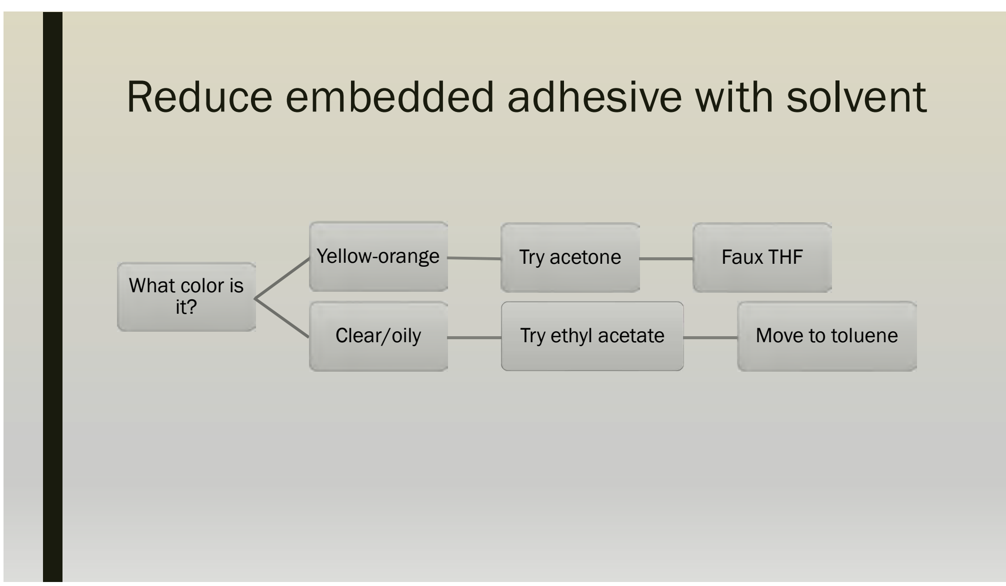

Fig 2. Solvent choice decision tree. Courtesy of Heather Hendry.

gels after casting seems to clean them of potential residues. Pollak and Novak note that more research is needed regarding the use of Sylgard directly on media, although it seems to function better as a solvent reserve than a stain reducer. When asked about the discovery of Sylgard 184, Pollak said that collaboration between herself and Duncan on several varnish and overpaint removal projects led to experimentation with the gel as a tool for adhesive removal from paper. Their protocol was developed from the manufacturer's instructions and further tailored for use in art conservation.

The questions for Hendry were mainly focused on the electric eraser. It was emphasized that soft papers are not good candidates for an electrical eraser. When a paper is too soft for the electric eraser, Hendry suggested using cellulose powder and ethanol or isopropanol. Someone asked if the electrical eraser had variable speeds. Apparently, the battery-operated models slow down as they lose their charge, but electrical erasers that plug in have only one speed.

A member of the audience mentioned the importance of considering whether the tape is original to the piece when making decisions about removal (note 1).

About halfway through the discussion period, the moderators introduced a discussion prompt: "Are heat and/or chemicals actually better for the object? Or is some fiber loss from mechanical removal acceptable to avoid subjecting paper objects to heat and chemicals?" Several people shared instances when they felt mechanical means of removal which resulted in minimal fiber loss to the object was acceptable, and they considered it less damaging to the piece in the long run than the introduction of solvents. Some such examples included removing white linen tape mechanically instead of using moisture to avoid the transfer of optical brighteners from the tape to the artifact. Another person mentioned the mechanical removal of dried PVA using a scalpel since the dried adhesive is not fully soluble in solvent, a technique that typically results in some fiber loss. Another example of accepted fiber loss was when removing tape from a tear.

An audience member shared that when working with tacky tapes, she found that using heat from a reptile heating pad added overall low-level heat and softened the adhesive enough to allow for mechanical removal. Another method of isolating tacky tape was the introduction of cellulose powder and vinyl erasers. The cellulose powder is rubbed into the tacky tape with a finger, causing it to bulk up, then a vinyl eraser is used to mechanically remove the tacky adhesive. They went on to say that they sometimes dusted cellulose powder on sticky adhesive residue and left it in place, thus reducing the chance for the tape to impact adjoining objects it came into contact with.

Finally, solvent and suction using different suction disks were discussed. The disks recommended included a fritted glass disk (which can crack under too much vacuum pressure), silicon flange, and fritted metal. Finally, an article in the *Book and Paper Group Annual* that gave instructions on how to make a fritted glass suction disk was mentioned (Varga 2007).

ACKNOWLEDGMENTS

The Art on Paper Discussion Group co-chairs wish to thank the presenters and researchers for generously sharing their work at this session. We also thank the attendees for adding depth through their questions, comments, and enthusiastic engagement. Finally, many thanks to our colleagues, BPG Chair Liz Dube, Program Chair Amy Hughes, and Assistant Program Chair Morgan Adams, for all of their support in helping organize the session.

NOTE

1. A 2020 article by Knauf and Utter discusses various ways to address the issue of tape when it is part of the final object. (Please forgive the shameless plug, it seemed relevant to the topic.)

REFERENCES

Knauf, Diane E., and Jodie Utter. 2020. "The Gentling Collection: Establishing a Treatment Protocol for Multilayered Works on Transparent Paper." *Book and Paper Group Annual* 39: 50–60.

Varga, Lauren M. 2007. "A Hand-Held Surface Suction Device: Design, Construction, and Application." *Book and Paper Group Annual* 26: 171–76.

SOURCES OF MATERIALS

Dowsil Sylgard 184 Silicone Elastomer Kit 0.5KG (1.1LB) clear
Krayden Inc.
1491 W. 124th Ave.
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KIM NORMAN AND HEATHER HAMILTON
DISCUSSION GROUP CO-CHAIRS

Library and Archives Conservation Discussion Group 2024 Managing Collection Needs and Conservation Practices in the Face of Capacity Challenges

INTRODUCTION

The Library and Archives Conservation Discussion Group (LACDG) session was held in person on Friday, May 24, 2024, at AIC's 52nd Annual Meeting. LACDG co-chairs solicited contributions on the topic of preserving collections within institutional capacity limits. Staff from the Harry Ransom Center proposed a presentation detailing their acquisitions protocols: *Preservation Challenges and Solutions in Acquisitions Workflows.* Interdepartmental collaboration has helped the Ransom Center streamline a labor-intensive task. The presenters discussed the successes and ongoing pinch points of their process. The presentation was followed by an open discussion with many session participants speaking from the floor.

PRESENTERS

Genevieve Pierce Kyle, preventive conservator, Harry Ransom Center (g.pierce@austin.utexas.edu)

Christine Bethke, accessioning archivist, Harry Ransom Center (christine.bethke@austin.utexas.edu)

Heather Hamilton, paper conservator, Harry Ransom Center (hhamilton@utexas.edu)

SUMMARY OF PRESENTATION

Preservation Challenges and Solutions in Acquisitions Workflows

Genevieve and Christine described the Harry Ransom Center's process of receiving collections. Ensuring the preservation of materials and preparing them for archival processing begins in the days before and immediately after collections are delivered. All newly acquired collections go through the following receiving process:

> acclimation and quarantine > collection inspection > accessioning > processing

Collection inspections are a collaboration between the Description and Access Department and Preservation/Conservation. For larger collections, an inspection may involve up to 10 or more staff members. Participating staff receive training to quickly but carefully inspect an entire collection for mold, insects, and stability.

The inspection allows conservation staff to get a broad overview of the condition and understand whether conservation treatments are likely to be needed. During this time, accessioning staff determine initial housing and storage needs. Care is taken to retain the original order of the materials. Special formats, such as digital materials and AV, are flagged to aid in future processing. If mold or pests are found, the affected items are separated for remediation.

Christine is a member of the National Best Practices for Archival Processing Working Group (NBPAAWG). She defined accessioning to help us understand this critical element of archives work. The NBPAAWG defines *accessioning* this way:

> *Accessioning is the basis of all archival stewardship. It is a suite of activities through which we appraise, transfer, stabilize, and document archival acquisitions. Accessioning provides pathways to access, informs future decisions, and promotes sustained resource commitment for the care of archival materials. (Archival Accessioning Work Group 2024)*

While the receiving process at the Ransom Center works well, there are pinch points and long-standing gaps in information sharing that create challenges. For example, the first

Summaries of discussion groups at the Book and Paper Group Session, AIC's 52nd Annual Meeting, May 20–24, 2024, Salt Lake City, Utah

moments after delivery of a collection can be overwhelming. While delivery drivers transport collections to the facility and unload them from the truck, Ransom Center staff are responsible for moving the boxes to the quarantine space. This task is performed by the preservation team, not by facilities staff. If the collection is large, if the boxes are in poor condition, or if the materials are unwieldy, moving them safely is difficult.

Perhaps the most challenging issue is having limited information about a collection's condition before it arrives. Materials affected by mold or insects can unexpectedly require many staff hours that have not been planned for, creating long delays in archival processing and, ultimately, delays in access for researchers.

In advance of this meeting, Heather prepared a survey to gather information about current acquisitions processes across libraries and archives. Responses were solicited from members of the Book and Paper Group and the Preservation Section of the Society of American Archivists. Responses were anonymous. There were 26 responses in all. Survey questions included the following:

1. Are conservation staff involved in the acquisition process *before* the decision is made to acquire a collection?

   Always 4% Often 15% Rarely 69% No 12%

2. Are conservation staff involved in planning to physically receive new collections?

   Always 4% Often 27% Rarely 42% No 27%

3. Are conservation staff involved on the day collections arrive?

   Always 8% Often 8% Rarely 49% No 35%

4. Is condition information provided by the donor/seller before acquisition decisions are made?

   Always 16% Often 32% Rarely 48% No 4%

5. Is the condition of a collection taken into account when considering whether to acquire materials?

   Always 4% Often 27% Rarely 42% No 27%

6. Is a quarantine process used for incoming collections?

   Always 16% Often 48% Rarely 32% No 4%

7. Are incoming collections assessed for condition right away?

   Always 28% Often 36% Rarely 20% No 16%

8. If you could choose, what are the key things you would want to know about a collection before it arrives at your loading dock?

Most common responses:

1. Where the items have been stored
2. Whether there are known mold or insect problems
3. Material types such as AV and photos
4. Inventory and descriptive information
5. Are there classified materials or ownership issues present?

After the presentation, the floor was opened for a broader discussion. Many session participants stepped forward to speak about their acquisitions experiences. Challenges that were mentioned included insufficient staffing for large-scale collection inspections, limited physical space available for these inspections, and a lack of understanding by administrators about what is involved in the process of receiving collections. Positive experiences included administrators who respect the knowledge conservators bring to acquisitions decisions and using data to support calls for process changes. But the topic that garnered the most discussion by far was mold on incoming collections. Acquisitions that arrive with mold create treatment backlogs and a bottleneck in the process of making collections accessible. As of now, there are more challenges than solutions when it comes to mold. We need to establish informed guidelines that we can use across our institutions, to educate our colleagues outside of conservation and to standardize our responses to mold.

ACKNOWLEDGMENTS

The co-chairs wish to extend their thanks to all the speakers for generously sharing their insights and experiences. They also want to thank the audience for their thoughtful questions and comments during the session.

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ABIGAIL BAINBRIDGE

Asbestos-Handled Finishing Tools: History, Risks, and Mitigation

INTRODUCTION

There is very little information online and in print about asbestos handles on finishing tools beyond passing mentions such as the pithy "asbestos handles are also found" from Fahey's 1951 *Finishing in Hand Bookbinding.* A survey created to inform this article asked bookbinders and book conservators about their level of awareness of asbestos in this context and saw that as the number of replies slowly climbed to 73, the proportion of finishing tool users reporting awareness of asbestos handles remained consistently at approximately 50%, with, as of the time of writing, 64% saying they would not feel confident identifying such a handle on their own. Those who knew about asbestos handles reported finding them in the United Kingdom (UK), United States (US), and Canada only.

This article is therefore aimed to fill a gap in knowledge and provide as much information as possible about the history and risks of these handles, as well as options once asbestos is suspected or identified. The history is pieced from printed mentions, material evidence, business records, and bookbinders who worked from the 1950s onward or their families. To understand risk and guidance on mitigation, I have interrogated the British and American regulations and (British) Health and Safety Executive (HSE) advice, and spoken to licensed asbestos contractors, asbestos testers and trainers, lawyers, expert witnesses in asbestos cases, insurance brokers, hazardous waste disposal contractors, and my local authority in London. In most cases, this was a use of asbestos for which the various experts were previously unaware, with the exception of one licensed contractor specializing in cultural heritage. Almost all of the guidance from the HSE, for instance, is more relevant to building contexts and somewhat open to interpretation or data that is hard to obtain.

The reader should note that this article is an attempt to summarize available information to raise awareness, but it is not legal or medical advice in any way. Anyone dealing with these tools should do their own research and think about compliance with the law, compliance with insurance policies, acceptance of risk, and ethics; it might be that what is technically legal is still more risk than an institution or individual is willing to (or should) assume. The focus, where there is regionally specific data or policy reflected, is on the UK, but I have also tried to point to American and Canadian policy where possible.

Independent submissions

ASBESTOS

Asbestos is a broad term that refers to a family of six naturally occurring carcinogenic minerals with similar properties: chrysotile, which is a serpentine mineral, and the five amphibole minerals actinolite, amosite, anthophyllite, crocidolite, and tremolite. Nicknames may be used colloquially: white asbestos refers to chrysotile, brown asbestos to amosite, and blue asbestos to crocidolite. Properties such as fiber length and thickness vary somewhat between them, with the result that chrysotile is generally considered to be less hazardous than the amphibole asbestos types, although the degree to which that is true is controversial. Different types of asbestos may contaminate each other in the ground, so it can also be difficult to know exactly what is present when hazards are assessed (IARC Working Group 2012a).

These fibrous silicates are found globally and have been used in small quantities at least as far back as ancient Greece. In the late 19th century, the discovery of particularly large deposits in the US and Canada came just in time to meet the massive demands of the Industrial Revolution. At the time, asbestos would have appeared as a miraculous material. It is lightweight and inexpensive, and resistant to heat, water, acid, and biological degradation. It worked also as acoustic and thermal insulation and was particularly useful near electronics, as it is nonconducting. Its fibrous nature meant that it could be woven into textiles, and it combined well with other materials to make a wide range of products: virtually anything one can imagine where these properties could be useful.

Impact of Asbestos on Health

While earlier deaths had been linked to asbestos exposure, the first one to get public attention was in 1924, of a 33-year-old woman in England who had worked in a factory for the previous seven years spinning asbestos into yarn. The discovery of this new illness, named *asbestosis*, spurned a government-commissioned study in 1930 finding that after working in the asbestos industry for at least five years, a third had asbestosis, and 80% developed it after 20 years: subsequent studies found that it had a strong correlation with high occupational exposure (UK Health Security Agency 2024). Regulations to control asbestos exposure were first introduced to the UK in 1931, including provisions for medical surveillance and compensation for illness. The first regulations in the US were not introduced until the 1970s.

While asbestos use continued to rise, researchers found more and more links to health problems. A connection to lung cancer was first made in 1935 (Bartrip 2004); by 1955, it was also understood that smoking increased the risk 10-fold of developing lung cancer among those exposed to asbestos (IARC Working Group 2012a). In 1960, a link was made to a newly recognized illness—mesothelioma: a rare cancer of the pleura (a membrane that surrounds the lungs), peritoneum (a membrane that surrounds the abdominal organs), or pericardium (a membrane that surrounds the heart) (Bartrip 2004). Mesothelioma has remained almost entirely connected only to asbestos exposure. Other cancers (of the pharynx, larynx, esophagus, stomach, colorectum, and ovary) have also been investigated for links to asbestos, but as most of the research has focused on the preceding three conditions, the evidence is not yet conclusive (IARC Working Group 2012).

Generally, asbestos-related conditions are related to the inhalation of asbestos fibers. Individual asbestos fibers range from 3 to 10 μm, not possible to see with the naked eye, and light enough to remain airborne for a substantial time, so even in situations where asbestos seems contained, there may well be dangerous levels of contamination. Fibers, especially if short, may be cleared by mucus in the upper respiratory tract, but if they are carried into the alveoli, they tend to be retained longer. Macrophages (a type of white blood cell) will try to engulf and break down the fibers, but the longer fibers associated with amphibole asbestos cannot be adequately cleared this way. Repeated failed attempts by macrophages to engulf long fibers lead to inflammation and eventually the health problems discussed here. It is also possible for asbestos to enter the skin, but it stays localized to the contact area, forming benign calluses or corns (UK Health Security Agency 2024).

Asbestosis, mesothelioma, and lung cancer are the three main diseases strongly correlated with asbestos exposure. Other cancers have weaker or less studied connections: cancer of the larynx, pharynx, trachea, sinus, esophagus, stomach, colon, and rectum (Kieffer 2006). Asbestos-related conditions are particularly understudied in women: fewer women worked in the asbestos industry historically and therefore formed a harder population to study. There may be links with ovarian cancer, for instance (Slomovitz et al. 2021).

Modes of Exposure

There are several modes of asbestos exposure, classified as occupational, secondary, and environmental. Occupational exposure occurs at work—classically in the 20th century among workers in asbestos factories but now more frequently among trades dealing with the many forms of asbestos remaining in buildings. Anyone working with asbestos without adequate personal protective equipment (PPE) can carry the fibers home undetected on their shoes, clothes, and hair, leading to secondary exposure for family members. Environmental exposure and accompanying high rates of lung cancer, asbestosis, and mesothelioma are also clearly observed among people living near asbestos mines or factories with no occupational or secondary exposure. Sources disagree on the length, but for all asbestos-related health problems, symptoms generally do not occur within the first 10 years of exposure and may still emerge after only 50 or 60 years.

Because of the long latency period and the many ways of being exposed to asbestos, it can be difficult to identify sources and levels of exposure in individuals, even though patterns on a larger scale are plainly evident. A recent case study describes a man diagnosed with mesothelioma who had a short-term high-level exposure—remarkable because it was less than was previously thought necessary to result in mesothelioma—but the authors also noted that he came from an area known for high environmental exposure, and that it could be both or even just the environmental asbestos that is to blame (Hinkamp et al. 2020). This is pertinent in considering health outcomes among bookbinders, particularly those who may have used asbestos handles in the 1950s to 1970s, as there would almost certainly have been other sources of exposure given the ubiquitousness of asbestos.

Asbestos use increased consistently from the late 19th century until it peaked in the European Union (EU) and US in the 1970s. The last US asbestos mine was closed in 2002 and in Canada in 2012, although it continues to be mined in Russia, Kazakhstan, and China. However, despite a gradual decline of use, then a complete ban on new asbestos in the EU as of 2005 and Canada in 2018 (with some exceptions for asbestos-containing materials [ACMs]), rates of mesothelioma cases have only begun to slow down in the past several years because of the long latency period. The US passed a ban on chrysotile asbestos in March 2024, but with a 12-year phase-out period, it means that chrysotile can still be in use through 2036.

Insurance and Asbestos-Related Injury Claims

In England and Wales, the Limitation Act of 1980 sets a statutory limitation of three years from diagnosis of asbestos-related illness to make a personal injury claim for compensation; however, because of the long latency period, there is no limit on the length of time between exposure and diagnosis. It is also possible for the executor to claim after a person's death. Furthermore, if the company no longer exists, its insurance provider is liable. If it is not possible to trace the employer or insurer, a small claim can be made with the government.

Employers are required by law to hold employers' liability insurance, which would need to specifically cover working with asbestos. If a policy did not cover workers to deal with asbestos and a personal injury claim was made, the employer would need to cover the claim, at £137,000 to £153,000 on average between 2007 and 2012 and likely higher now (Department for Work and Pensions 2014).

In America, the average compensation for mesothelioma claims is upward of $1 million (Jewett 2014), and asbestos-related claims led to the bankruptcy of 120 companies by 2020 (Fletcher Davis 2020).

FINISHING TOOLS

Finishing tools feature a brass or bronze tool embedded in a wooden handle and have generally been sold with the handles attached. For handle letters and decorations, the polished, engraved face bears the design, supported by the metal underneath, known as the table. From this extends a comparatively rough, tapered, square-profiled stem of metal called the *shank*, which is inserted in a hole drilled in one end of the handle—the inserted part of the shank is called the *tang* (fig. 1). Smaller decorative tools, gouges (curved lines), and pallets (straight solid or decorative lines) generally do not have *tables* but just a *face* at the end of a shank, which is flat in the case of pallets. British tools in particular have a ring between the exposed shank and the tang, known as a *cushion* or *bolster*. When the tang is fully inserted in the handle, the cushion makes a sort of cap. Decorative rolls and fillets (rolls with straight lines) are brass or bronze wheels that rotate on an axis held between a fork (double carriage) or, later on, a single carriage. As with their smaller counterparts, they also have a shank inserted into a handle, but the handles are much bigger.

The table or shank is placed over a gas flame (historically) or hot plate (in more recent times), with the handle supported by a ring around the heat source. Once hot, the tool is impressed into leather or parchment coverings, either

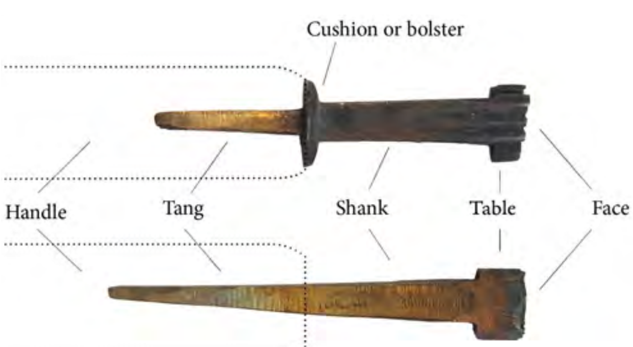

Fig. 1. Anatomy of a decorative finishing tool: English-style above and French below.

Fig. 2. A charred wooden handle that still holds onto the tool but drops unhelpful bits of charred wood onto the surface being worked.

blind or over gold leaf or metal foils. When carefully used, the wooden handle can last a long time, but if overheated or the handle is placed too close to the heat source, the wood will char (fig. 2). Too much of this and the tool will become loose and fall out of the handle, requiring replacement—an annoyance more than anything else, but particularly grating when it happens in the middle of a job. Various attempts to rectify this without making a new handle are commonly observed in old tool collections, but none are satisfactory for long (fig. 3).

It is clear that asbestos would have looked like a fantastic replacement for wood due to its thermal resistance. The mention in the Fahey book quoted in section 1 is the earliest printed reference found (1951), but it gives no detail on context. A 1964 issue of the *Guild of Bookworkers Journal* notes that Sydney (Sandy) Cockerell is "the manufacturer of . . . asbestos handles for tools" (Horton 1964). Marianne Tidcombe writes in the 1981 issue of *The New Bookbinder* that the idea came from Sandy's brother Oliver. Cockerell sold them as replacements for wooden handles, making them out of rolled-up asbestos paper glued together at the edge and sometimes with a metal tack to help hold it in place.

Asbestos handles are listed in the first four of a set of five order books from the Cockerell bindery, now at the British Library (note 1). The slim quarter leather books with marbled sides record handle sales from 1948 to 1987—a grand total of 24,230 handles over 39 years (fig. 4), peaking in the 1960s. The majority of sales were to institutions, binderies, and retailers, but there were some to individuals, and almost all in the UK. Widely recognizable names include Zaehnsdorf, Russell & Son, the London School of Printing, His Majesty's Stationer's Office, the Victoria and Albert Museum, the Royal College of Art, the Bodleian, University College London, the National Library of Wales, Tony Cains, Roger Powell, and Peter Waters (see the following).

Fig. 3. Charred wooden handles repaired with glue (left), cotton wool (middle), and paper towel (right). The latter two wiggle gently, like loose teeth. The glued tool slides out of the handle gracefully as soon as it is heated on the stove. Parchment scraps are another classic hole-stuffing material. It is unlikely that asbestos would be used for this purpose: tool stuffing is usually a makeshift, in-the-moment solution, mid-tooling when the metal drops out but the job is not finished. Cotton wool is a common material to use for a wet pad to quench hot tools against and is therefore likely to be nearby. If in any doubt, identification should be made by someone with adequate training.

Three handle sizes were available, differentiated by diameter to accommodate different sizes of tool: 5/8, 3/4, and 1 inch, often stamped with *DOUGLAS COCKERELL & SON* (fig. 5). Order quantities varied from two single handles to 1000, often in multiples of 50 or dozens, and many more for the 5/8 and 3/4 inch sizes than the 1 inch size. Prices changed yearly or more frequently, with price schedules noted in the beginning of the books; prices in February 1959, for instance, were as follows (note 2):

Handle size	Price each February 1959	Price per 100 February 1959	Price each, rough 2024 equivalent	Price per 100, rough 2024 equivalent
5/8 inch	1s 3d	£5 15s 10d	£1.70	£156.95
3/4 inch	1s 6d	£6 14s 0d	£2.04	£181.60
1 inch	1s 9d	£8 2s 9d	£2.38	£220.51

Several instruction cards tucked into the order books were presumably supplied with handles, instructing the user to enlarge a pre-existing hole in the handle to fit the tool and hammer the handle onto the tang (fig. 6). The cards proclaim this: “These will outlast numbers of wooden handles and so save time, expense, and the exasperation of loose tools.” However, James Brockman, who worked for Cockerell from 1967 to 1973 using these handles, notes that they were imperfect—they did not hold onto the tang well, and tools eventually fell out anyway, or handles broke in half.

They were made of both a whitish-gray, softer asbestos paper or a browner, harder asbestos paper. Confident identification can be made only by testing individual handles, but both chrysotile and amosite have been found (Kevin Graham and Airborne Environmental Consultants, pers. comm., 2024), and both are known to have been used (James Brockman, pers. comm., 2024). Asbestos content in these loosely bound paper handles is likely to be 85% or higher (discussion with Airborne Environmental Consultants 2024). In this article, the rolled asbestos paper handles of both colors will be referred to as Type A handles to distinguish from a second type described later.

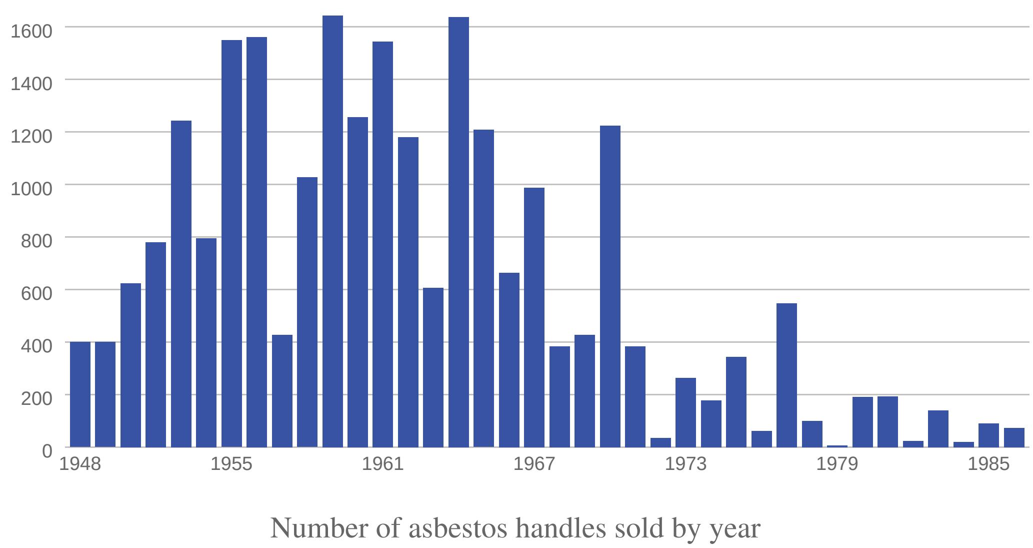

Fig. 4. The number of asbestos handles sold by Cockerell & Sons by year from 1948 to 1986 according to their order books.

Fig. 5. Stamped Cockerell asbestos handle. Courtesy of Todd Pattison.

Peter Waters, an esteemed bookbinder and conservator from the UK who later founded the conservation laboratory at the Library of Congress, worked with these handles in the 1950s, when he was in his 20s. Waters worked for Roger Powell, who had been Sandy's business partner until he established his own bindery in 1947. The Cockerell order books contain several orders from Powell and one handwritten one from Waters, dated December 3, 1955:

> *Dear Mr Cockerell,*
> *Will you please send me fifty asbestos handles—25 of each size, and perhaps too, you could let me know if you will be able to supply Farnham School of Art with 300 (150 each size) as I am making out requisitions?*
> *With best wishes, yours sincerely,*
> *Peter Waters*

According to Julian, Waters' eldest son, Waters spent several weeks using a lathe to shape factory-formed rods of asbestos into handles (pers. comm., 2024). It is hard to imagine much by way of respiratory protection for woodwork in the 1950s, but anything that would have been worn then would not be considered adequate asbestos protection now. In 2003, at age 73, Peter died of mesothelioma, which he attributed to that exposure about 50 years earlier. I found one other anecdotal report of a death resulting from asbestos exposure from finishing tools, but nothing I could confirm. Some of Powell's and Waters' tools found their way to West Dean College, where a number of asbestos handles were recently found—tapered toward the collar and rounded at the opposite ends and clearly made from rolled asbestos paper.

The goldbeater Whiley was the other known seller of asbestos handles, however, in their case, the handles—two different types—were already fitted to tools. It was not possible to determine who made them (it was not Whiley themselves) or if they were sold under any other name. The first is like the handles described earlier, but the pale gray rolled asbestos handles are capped at the business end with a dark copper alloy ferrule as if to help hold in the tang or prevent damage at this end of the handle (fig. 7).

Other Whiley tools fall under a second category that will be referred to as Type B here: wooden handles with asbestos resin ferrules (fig. 8). These ferrules appear at a glance to be metal: shiny and with a warm copper alloy coloring. However, any damaged areas will clearly show fibrous asbestos, although perhaps only with a microscope. Figure 9 shows

COCKERELL ASBESTOS HANDLES FOR FINISHING TOOLS

These will outlast numbers of wooden handles and so save time, expense, and the exasperation of loose tools. The following points should be noted when fitting the handles:

(1) Square ended tangs should be filed to a taper
(2) There should be a shoulder or washer on the tool for the handle to butt against.
(3) A suitable size of handle should be used and the hole in it enlarged with a bodkin or file tang to fit the tool.
(4) The tool should be held in a vice and the handle tapped on with a hammer.

Fig. 6. Reproduction of the small card found in one of the Cockerell order books with instructions for attaching asbestos handles.

Fig. 7. Whiley handle letters with white-gray asbestos handles and brass ferrules. Courtesy of Paul Welters.

tools from a set in bad condition where the fibers were easily apparent at a distance. The use of this material combination makes sense if there was a strength/longevity issue with the asbestos handle holding up—use the stronger wood, but protect the edge that gets warm with the thermal insulation properties of asbestos. It is unclear how the tang is held in the tool; the asbestos ferrule is about 2 mm thick with air space inside. It appears that the tool is wedged into the wooden handle as normal and that the wood has been carved away to accommodate the thickness of the ferrule over it.

Although there were still some orders trickling in through the Cockerell bindery in the first half of the 1980s, James Brockman recalled that the alarm had been sounded about asbestos handles in the 1970s and binders were already replacing them for wood—or attempting to coat them with paint or tape to save the effort. However, Doug Mitchell remembered using asbestos handles at the Foreign Office up to the late 1990s and at the British Museum/British Library during his time there in the 1980s, saying that the latter replaced them only around 2007 when the British Library Centre for Conservation opened (pers. corr., 2024). It is still common now to find these handles among collections of old tools or even in secondhand sales.

Fig. 8. Whiley Type B tools with wooden handles and asbestos resin ferrules.

Fig. 9. Whiley Type B handles, of which the asbestos resin ferrules are damaged on the left and center tools.

IDENTIFICATION

Identification of asbestos is done by an asbestos surveyor under the microscope fitted with filtered extraction using various stains that interact with the different types of fibers. In the UK, it is only legal for someone with the right level of training to purposefully go looking for asbestos (as opposed to experiencing an accidental exposure), so if any professionals—including self-employed people—suspect that there may be asbestos handles among their tools, they need to ensure that training and insurance are in place for existing staff or bring in trained asbestos contractors. In the US, Occupational Safety and Health Administration (OSHA) Standard 29 CFR 1910.1001 also requires training and air sampling for anyone exposed to asbestos at work (OSHA 1994). Canadian Occupational Health and Safety Regulations SOR/86-304 10.4–5 requires a risk assessment by a "qualified person" to be kept for 30 years and air sampling during work with ACMs. Therefore, in all of these countries, someone with specific training in work with asbestos needs to be involved at least in the planning stages.

The following section is intended as a visual guide for when it is reasonable to suspect asbestos presence on finishing tool handles, but not a replacement for definitive identification. That said, it is reasonable to note that there are only a few other options for handle materials, and they are likely materials that conservators and bookbinders would be able to identify: the traditional wood, and some institutions, including the British

Library and Parliamentary Archives, also experimented with nylon on all sizes of tools, including rolls. Nylon (likely nylon 666) handles are a milky white or yellow-white, very smooth and uniform, and may be discolored near the tool end from heat. They are very clearly plastic and unlikely to be mistaken for anything else.

Any collections with tools made before 2005, when asbestos use was banned in the EU, should be suspected for possible inclusion of asbestos handles or prior contamination of wooden handles by neighboring asbestos (explained in the next section) (note 3).

Any sets of tools that have not yet been inspected for asbestos should be signposted as possibly containing asbestos and noting health hazards—wording is available from the HSE website on asbestos—and blocked off from access until an inspection can be carried out. If during inspection there is any doubt, asbestos should be assumed until testing can be carried out.

Wood

Wooden handles (fig. 10) were traditionally predominantly made from beech wood, left bare or finished (stained, waxed, varnished). They vary in size and shape as well: some are relatively shapeless dowels, whereas others are shaped at the ends for aesthetics and comfort. They may have shiny metal ferrules at the ends; look for signs that this is actually metal rather than varnished asbestos (see the following), such as dents or scratches on the surface where the shine is maintained. Each one I have seen has plainly apparent wood grain. Splits from a badly inserted tool or charring from an overly hot stove are obvious giveaways as well. If the cut edge of the wood is visible, it will look like end grain and not the tight spiral of something rolled. There may be a small hole in the end of the handle opposite the tool, from holding it in a lathe or an abandoned attempt at inserting a tool on that end. It will not be a regular hole that runs the length of the handle (see the following). It is unlikely that wood would be mistaken for asbestos, but assume asbestos in case of any uncertainty.

Fig. 10. Finishing tools with wooden handles.

Type A (Asbestos)

Type A asbestos handles can look like wood in color (likely made from amosite in this case) or like pale gray cardboard (likely made from chrysotile); they might have a mottled tone but nothing that looks like wood grain (fig. 11). Every one I have come across has a visible seam parallel to its length where the asbestos paper roll ends. The ends may or may not be shaped; if they are, there are likely visible fibers protruding from the sanded areas. Many tools show a tight spiral at each end from the rolling of the asbestos paper (fig. 12), but this is not always visible. There may be an air space or hole in the center of the roll or not. Some also have a metal nail or tack about halfway down the length of the handle. Even in handles that appear in good condition, there are usually fibers visibly protruding from the edges of the white-gray ones. Handles made by Cockerell may be stamped *DOUGLAS COCKERELL & SON* along the length (see fig. 5).

Fig. 11. A collection of asbestos-handled tools, many with corrosion on the cushions. They are all the white-gray type handles, except for the brown one second from right. Courtesy of Bronwen Glover.

Fig. 12. Cockerell handles viewed from the end away from the tool: on the left, the asbestos handle appears sawn, and on the right, the uneven rolling is visible. Also note the large hole in the center on the left. Courtesy of Todd Pattison.

Brown-colored asbestos handles can easily be mistaken for wood at first glance.

Survey respondents were asked to report the type of tools on which they had seen asbestos handles: the majority said decorative tools, handle letters, and pallets, and one person added in type holders (all smaller handles); only a couple had seen them on fillets or rolls, which would have much larger handles. Orders in the Cockerell order books suggested that the 1 inch handles were used for type holders.

If a handle is entirely coated in tape or paint, it may be wood, but asbestos should be suspected; there is not an established tradition of painting wooden handles, and this may be an attempt at encapsulation. Another feature that is not at all definitive but can be an indication is green corrosion only on the cushion (i.e., the part of the metal touching the handle), which is visible on many asbestos-handled tools (see figs. 5–8).

Type B (Asbestos and Wood)

Type B handles have wooden handles and asbestos resin ferrules, and I have only seen them on tools sold by Whiley. The majority of the handles bear all of the features of the wooden handles noted previously. The ferrule is a dark, shiny, warm brown and gives the impression of a copper alloy with a patina; it is roughly 14 mm wide × 2 mm thick. The wood touching the ferrule may have a slightly darker wash of color from sloppy varnishing of the ferrule, visible on the tool on the left in figure 9 and on the right in figure 10. From the edge, tight concentric circles are visible. When the tang is not centered perfectly, a gap is visible behind the cushion. Pale gray fraying fibers may not be easily visible on undamaged tools but can often be found by microscope at the edges of the ferrule.

SAFETY OF ASBESTOS TOOL HANDLES

There is no solid information available on the specific impact of these tools on the health of their users, and as in many other areas, men have been more studied than women, so the data is not necessarily universally applicable (IARC Working Group 2012a). There are some studies linking bookbinders (alongside other printing industry workers) with increased rates of asbestos-related cancers (Il'icheva and Zaridze 2004; Seyyedsalehi and Boffetta 2024), but this is a broad category of workers who would likely be exposed to other sources of asbestos as well as other carcinogens. It might be illuminating to collate data on causes of death since about 1960 for people whose profession is listed as bookbinder in areas where asbestos handles are known to have been used. However, when I contacted the British Office of National Statistics for this data, I was told it was too small a population to release the information under General Data Protection Regulations. This would not give a conclusive picture of exposure just from finishing tools, however, as asbestos was also in other equipment such as blocking presses and cooling mats for finishing tools, as well as papers and boards—and in many other products around the home and other buildings.

Asbestos risk is related to the particular type of asbestos itself, how high a content of asbestos to binder or other material is present, and how tightly it is bound in the matrix (or how friable it is—defined by the US as "crumbled, pulverized, or reduced to powder by hand pressure" (US Environmental Protection Agency 2020) and by the UK as "easily crumbled or reduced to a powder" (Health and Safety Executive, n.d.). Kadec reported an 85% asbestos content in Type A tool handles they have analyzed, both amphibole and serpentine asbestos, and note that anything used for insulation purposes should be considered friable. Finishing tools are often dropped handle down into a box for storage, with some shaking of the box to align the tools and fit the last several in. There is also pressure applied on the tool during use that would put a strain on its secure hold in the handle, so at both ends through normal use, the handle would be subjected to the type of wear that would release fibers and cannot be considered a safe thing to continue using. Individuals tempted to make their own decisions about what personal risk they want to assume should remember the environmental and secondary exposure routes for asbestos; that without adequate PPE and training, they are likely exposing others around them; and for those in the UK, it is illegal to use ACMs.

Unfortunately, any wooden handles not fully and perfectly lacquered, stored alongside asbestos handles, would be at risk of cross-contamination: asbestos fibers from neighboring tools can be lodged in the wood grain. Boxes with no tools should be carefully assessed for the likelihood that they may have had asbestos handles in them at one point—for instance, a set of wooden handle letters in its original box is unlikely to have been used to store other tools with asbestos handles, as it would not make sense to put them together, but decorative tools, pallets, gouges, and so on may have moved around in storage boxes over time. The boxes themselves would also have the same risk.

Tool handles made after 2005 (when asbestos was fully banned in the EU) and never stored with old tools would not be a risk.

MITIGATION

Regulations on Working With Asbestos

In the UK, work with ACMs is regulated and categorized into three tiers. Nonlicensed work can be carried out by anyone with training following the requirements listed in the Control of Asbestos Regulations 2012, which include specifications for training, risk assessment, safe systems of work, and so forth. Notifiable nonlicensed work can also be carried out as mentioned previously, but the relevant enforcing authority (local authority or the HSE) must be notified in advance, with medical examinations carried out and records kept. Training is required under the legislation for anyone undertaking either nonlicensed or notifiable nonlicensed work on asbestos. The final category, notifiable licensed work, is to be carried out only by a licensed contractor who has notified the enforcing authority at least 14 days in advance. It is illegal to carry out licensed work without a license.

Training for work with asbestos falls under three categories: asbestos awareness training, which is intended only for incidental contact with asbestos (not for any work on it); nonlicensed asbestos training, which would be adequate for nonlicensed and notifiable nonlicensed work on asbestos; and licensed asbestos training required for the higher-risk licensed work. Asbestos awareness training is on the order of £15 to £20, and nonlicensed asbestos training is around £250.

The HSE website states that "the employer of anyone whose work might involve asbestos has the responsibility for deciding how much risk the proposed work presents" (Health and Safety Executive, n.d.). (The 2012 regulations define a self-employed individual as both employer and employee for the purposes of following the guidance.) This risk then determines whether the risk is nonlicensed, notifiable nonlicensed, or licensed. Detailed guidance for meeting each category is given, and too exhaustive to repeat here, but it is all based broadly on how likely the ACM is to release fibers, on how many fibers are likely to be released, and how often the work is carried out and for how long. The HSE also provides specific examples for each category, but all relate to the building trade, so some interpretation is required for our context; the HSE and local authority both declined to give advice about finishing tools when asked. Trained asbestos contractors and educators consulted for this article all reported an opinion that removing Type A tool handles would count as licensed work. Type B handles have not, to my knowledge, been assessed, and therefore no removal should take place before an assessment occurs. This would involve attempting to remove the handle under controlled conditions, using a tent to contain the area, negative air pressure to extract and filter the air, and monitoring of how much fiber is released into the air. The results of how much fiber is released would then categorize it as nonlicensed, notifiable nonlicensed, or licensed. Kevin Graham, a licensed asbestos contractor who has removed Type I handles, reported the results of his monitoring in these circumstances, finding a release of 5.5 fibers per cubic centimeter of air, which would certainly exceed the legal UK limit of 20 fibers per cubic centimeter of air if the control measures were not in place (pers. corr.).

While the focus here is on the UK for reasons of scale, as the US is the other main place these tools are found, a quick overview of the legislation is worth including. In 1989, the Environmental Protection Agency (EPA) banned most ACMs, but in 1991, the ban was overturned by the Fifth Circuit Court of Appeals. Trump-era restriction of the EPA's powers curtailed recent attempts until the Biden administration finally restored its ability to regulate in this way, and in March 2024, the ban on chrysotile asbestos was passed—although with a 12-year grace period and no ban of other asbestos types. However, all asbestos is still regulated as a hazardous substance, notably for this context, by OSHA. The permissible exposure limit (PEL) of an average of 0.5 fibers per cubic centimeter over 8 hours is half as low as the UK's limit, but a short-term exposure limit of 2.5 fibers/cm^3 for 30 minutes is also given. The US specifies in Standard 29 CFR 1910.1001 the regulations for training, air quality/exposure monitoring, PPE, labeling, and cleanup, among others (OSHA 1994).

Asbestos waste disposal in the US is covered by the federal Toxic Substances Control Act 40 CFR 173 as well as state air quality legislation, so regulations will vary by state. California's Department of Toxic Substances Control website has a general minimum guidance, but local legislation should also be consulted. Waste should be wetted and double bagged, labeled in a specified way, and disposed of as hazardous waste. Less than 50 pounds of household or business asbestos waste can be delivered by the household or business to a hazardous waste collection facility, with some further requirements for businesses (State of California, n.d.).

Encapsulation

Encapsulation is the term used for covering or coating asbestos in a material to contain it. Several people asked through the survey if the handles could be covered with tape, paint, or something similar, or noted that they knew people who did this. It is illegal to use asbestos in the UK, and so even if it were safe, it would not be allowed. However, it is still quite possible for the tang to become loose and the tool to drop out, releasing fibers, so encapsulation does not make the handle safe for use.

It is possible to coat historically important, contaminated wooden handles for tools that will not continue to be used, but this is a more expensive option than removal. This has been done for tools in museum collections. Anyone wanting to retain examples of asbestos handles could also construct a sealed Perspex/Plexiglas box that would permanently enclose the handle.

Bagging and Removal

The easiest and least expensive way to solve the problem of the asbestos handles is to get rid of the entire tool. It is common practice to double bag asbestos waste and label it as such before disposal in line with local asbestos regulations. Some jurisdictions specify the thickness of plastic bag, the wording on the label, and wetting of the asbestos, so it is worth consulting local regulations first.

Untrained people should only be in the position of doing this if there is an accidental exposure. Employers (including the self-employed) should not ask or allow untrained staff to look through tool collections trying to find any asbestos handles, as this would invite exposure. Bagging by an asbestos contractor might cost on the order of £500 at the time of this writing.

If asbestos is accidentally discovered in the course of work, such as a sudden recognition of an asbestos handle among a collection in use on a finishing stove or opening a box of second-hand bookbinding tools to find an asbestos handle inside, work should stop in that area until all appropriate measures can be taken. Put up a warning sign and close off the space to anyone who might pass through. Clean small amounts of dust/debris by wiping down surfaces with damp rags; *do not use a standard vacuum*, as there are particular filters that must be in place for asbestos. Dispose of the rags as asbestos waste (double bagged and labeled) and record the event in the appropriate health and safety logs, then decide whether a licensed contractor is required to further assess or clean up the area. Detailed emergency procedures can be found in Equipment and Method Sheet 1 on the HSE asbestos website.

In many areas, asbestos waste can be disposed of free of charge at local authority hazardous waste disposal centers. However, it must never be placed in normal rubbish streams.

Tools can also be bagged and labeled for safer, longer-term storage while a decision is made about disposal or replacement. They should be placed in a low-traffic area, and their presence should be recorded by the person responsible for the health and safety of the institution.

Replacement

In the case of important or expensive tools, it might be preferable to remove the handles, clean the brass, and replace the handles with wood. For a sense of scale, a recent quote obtained from one asbestos specialist added up to £3500 for this work for the first 50 tools, plus £1000 for each set of 50 after that, based on costs for setting up a tent to work on-site, the number of tools a contractor could manage in a day, and cost of independent certification afterward that the space is safe for resuming work.

Decontamination

Any wooden, board, or cloth-covered boxes in which asbestos-handled tools were stored should also be disposed of as asbestos waste; asbestos fibers can be lodged invisibly in the grain or fiber matrix and cross-contaminate wooden tool handles later stored in those boxes. Best practice would also include having a licensed contractor clean any remaining wooden tool handles, particularly in collections where tools may have been moved around in various storage areas rather than always kept in the same place. A contractor can also assess whether decontamination of the surrounding area is also necessary.

CONCLUSIONS

In researching this work, I very much wanted to find a solution to the removal and replacement of asbestos handles that is affordable (i.e., nonspecialist) and safe. Many readers will be dismayed that the advice essentially boils down to either spending a lot of money, throwing away the tools (and possibly both if a storage or work area needs to be decontaminated), or keeping but never using them. There may be a temptation to downplay the risks of asbestos exposure or consider that if tools have been in use already, a little more use is not going to hurt, but it must be stressed that there is no safe amount of asbestos exposure. The individual fibers are invisible to the naked eye, linger for years, and can get easily transferred to other people, so any risks taken are not localized to the individual taking the risks but also to family members and colleagues. Even if the use or removal of these handles by a nonspecialist is legal in a given country, people ought to consider these risks as well as whether they have adequate insurance and protective measures in place.

This information is important, particularly as it relates to our tiny field and its niche tools, but I am concerned that upon reading this article, people unaware of asbestos handles might go looking for them among tool collections that may be little used, creating an opportunity for a health hazard that did not exist otherwise. Please exercise caution.

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APPENDIX

A decision tree is shown in figure 13.

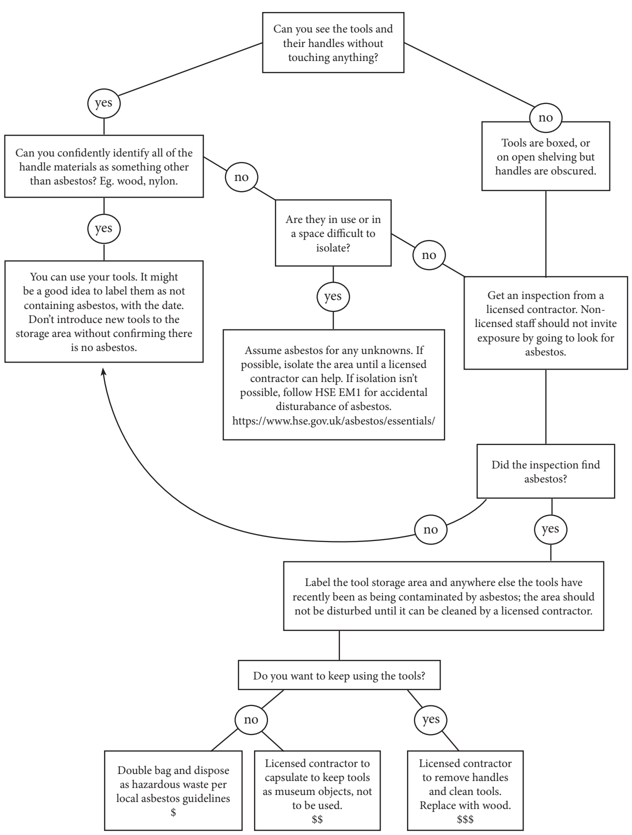

Fig. 13. Decision tree for employers, employees, and the self-employed.

NOTES

1. Add. MS 84227–84231, "Cockerell Bindery Papers. Orders for asbestos handles for finishing tools; finishing stoves; sewing frames; 1948–1988. Five volumes."

2. Inflation figures from the Bank of England Inflation Calculator available at https://www.bankofengland.co.uk/monetary-policy/inflation/inflation-calculator.

3. More photographs are available at http://www.bainbridgeconservation.com/asbestos.

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