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Edited by

Kira Eng-Wilmot
Alison Casteneda
Nora Frankel
Anne Getts
Emma Schmitt
Jessica Urick

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CONTENTS

GENERAL SESSION

TIPS SESSION

POSTER SESSION

PREFACE

The 28th volume of POSTPRINTS contains papers, tips, and posters presented at the Textile Specialty Group (TSG) session and the General session of the annual meeting of the American Institute for Conservation of Historic and Artistic Works, Houston, Texas, in May and June 2018.

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A LOT OF NITPICKING: DOCUMENTATION OF TOM WELTER'S PAINTED SILK BATTLE FLAG ENCAPSULATION METHOD AND MATERIALS

ANN FRISINA

ABSTRACT— Reconsidering the history of conservation is not solely about how things have been treated. Instead, by examining the decision-making process, which forms and informs future conservation treatments, we can gain context to fully understand and assess previous work. Thomas Robert Welter, born in 1919 (died 1991), began to develop a method to encapsulate fragile silk battle flags in 1964 after a three-day tutorial with conservator Katherine Scott. While Welter was very talented as an artist and mechanic, he had no prior experience in textile conservation. The encapsulation treatment that he developed, while invasive by today's standards, was performed on more than 100 painted silk battle flags throughout the United States by Welter and his daughter, Nancy Cyr. Innovative in application, Welter's ultimate goal of treatment was not just to consolidate but to make the flags available for use. Within this paper, a detailed documentation of the procedure developed by Welter is revealed. Materials such as surfactants and adhesives are identified. All information documenting the treatment procedure is based on Welter's personal journal entries, written treatment documentation, physical evidence, and an oral history provided by Cyr. It is hoped that by documenting Welter's encapsulation method, conservators and curators will be better informed to preserve these fragile silk battle flags.

DOCUMENTANDO MÉTODOS Y MATERIALES RELACIONADOS CON LA BANDERA DE BATALLA EN SEDA DE TOM WELTER

RESUMEN—Reconsiderar la historia de conservación no incluye solamente cómo los artefactos se han tratado. En cambio, por medio del examen del proceso de decisiones, que informa futuros tratamientos de conservación, podemos comprender e informar futuros trabajos. Thomas Robert Welter, nacido en 1919 (muerto en 1991), empezó a desarrollar un método para encapsular de banderas de batalla, hechas en seda, que datan de 1964, tras tres días de un tutorial con la conservadora Katherine Scott. Aunque Welter era muy talentoso como artista y mecánico, no tenía experiencia en conservación de textiles. El tratamiento de encapsulación que desarrolló, pese a ser considerado sumamente invasivo hoy en día, se aplicó a más de 100 banderas de batalla hechas en seda pintada, a largo y ancho del país, por Welter y su hija, Nancy Cyr. De innovadora aplicación, el fin último del tratamiento de Welter era tanto consolidar como mantener en uso las banderas. En este artículo, la documentación del proceso desarrollado por Welter será revelado. Materiales como surfactantes y adhesivos serán identificados. Toda la información documentando el método de encapsulación de Welter se basa en los diarios personales de Welter. documentación escrita del tratamiento, evidencia física, e historia oral obtenida de Cyr. Se espera que a través de la documentación del método de encapsulación de Welter, conservadores y curadores estén mejor informados para preservar estas frágiles banderas de seda.

1. INTRODUCTION

In 1964, a project was initiated to preserve 57 silk battle flags used by Minnesota regiments in the Civil War and Spanish American War. The flag collection had been displayed on their poles and stored within the state capitol rotunda cases since 1905. A 1960 image of the case shows the flags in a jumbled state (fig. 1). A procedure to

Fig. 1. The Battle Flags, Capitol Rotunda, ca. 1960 (Courtesy of Minnesota Historical Society).

stabilize and secure these fragile textiles was created by Lieutenant Thomas Welter. This paper documents the history and conservation procedure that Welter created and executed. Welter's method of treatment, its evolution over time, and materials used are documented in his business records and by his daughter/business partner, Nancy Cyr. Flags treated with this singular method can be found throughout the United States. Many conservators are asked to reverse this invasive treatment. It is hoped that this review of his procedure will better inform future conservation treatments of the flags as well as archive an early part of textile conservation history.

2. DESCRIPTION OF THE TREATMENT PROCEDURE AS INSTRUCTED BY KATHERINE SCOTT AND DEVELOPED BY TOM WELTER

In January of 1964 Kathryn Scott, a New York textile conservator, was hired to visit Minnesota for three days and consult on the battle flag project. This three-day tutorial was developed by Welter into a methodology to consolidate painted silk flags (fig. 2). Welter's resulting treatment would not be considered acceptable today. Its use of certain materials and its invasiveness does not meet current standards. However, Welter's consolidation method did save flags that were rapidly deteriorating.

2.1 INITIAL DOCUMENTATION

Welter's documentation of the flags is found in three primary sources: his daily journal, index cards, and a task log kept in a three-ring binder (figs. 3, 4). Reviewing the first index card reveals a brief assessment of the first flag's condition, number one, Tenth Regiment Infantry Civil War flag (Welter Index Card, flag no. 1). A three-ring binder holds what appears to be Welter's conservation time log. A matching conservation tracking number is noted on both the index card and conservation time log. The index cards lack detailed condition issues. Also missing is any description of ropes, tassels, flag pole, or finial. In contrast to the index card, the conservation time log verifies treatments, dates, and hours for procedures. Missing from the conservation log are procedures, materials, and treatment results.

Fig. 2. Tom Welter handling flag, 1963 (Courtesy of Nancy Cyr).

Fig. 3. Daily Journals (Courtesy of Nancy Cyr).

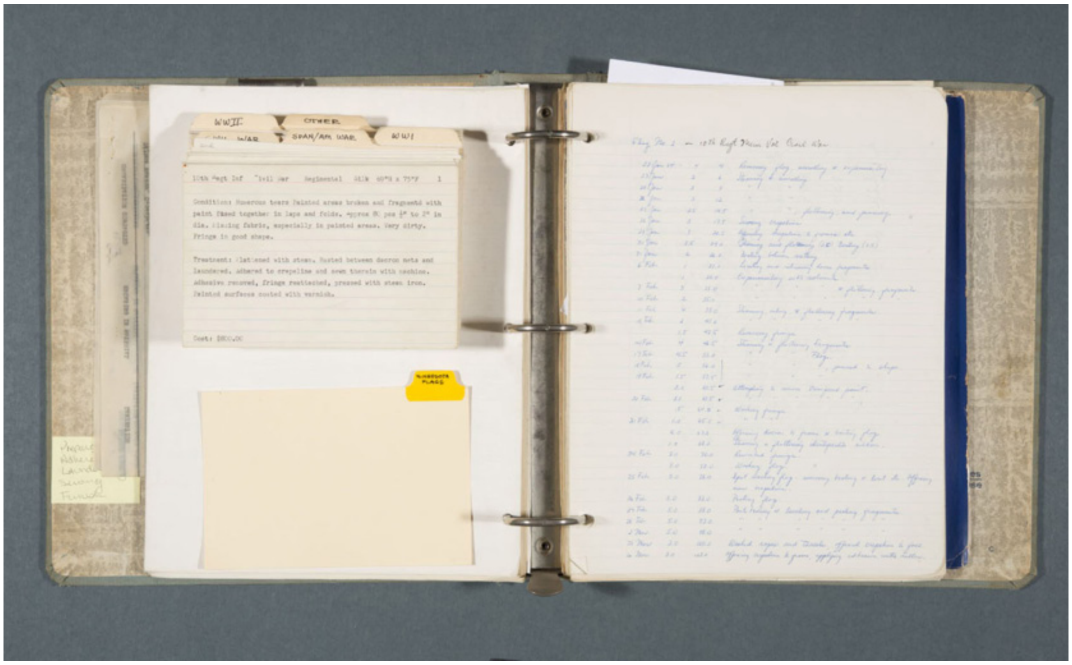

Fig. 4. Index Card and Conservation Time Log (Courtesy of Nancy Cyr).

Fortunately, because Welter was teaching himself, procedural details are noted in his daily journal. No post-treatment reports or photography have been found, though it is probable that they were submitted with final billing.

2.2 HUMIDIFY AND DISASSEMBLE

Unrolling painted silk flags was a delicate process. Welter describes his first day humidifying with Scott: "Spent the afternoon assisting Kay and discussing methods and procedures with her. Haven't learned much and feel she does a lot of nitpicking" (Welter Daily Journal 1964–1966, 112). Condition issues confronted while unrolling included fragile silk, large areas of loss, brittle paint, and fused paint. Unrolling and separating fused paint was achieved with the aid of steam created by a teapot and a bathtub shower hose (Welter Daily Journal 1964–1966, 2). Welter's second iteration was to modify a croup pot to provide directed steam. This piece of equipment, dubbed the "Steam Jenny," stayed with him for the remainder of his career (Welter Index Card, flag no. 1).

Once unrolled, the flags were disassembled for wet cleaning. The pole sleeve was opened and the cotton lining removed and discarded. All fringe was disengaged by clipping threads and "removing short threads," small pieces of thread left behind (Welter Daily Journal 1964–1966, 42). Treating the flags' components independently allowed for careful handling of each element. Unfortunately, removing original materials, fabrication techniques, and field repairs that document the flags' history of use all eliminate important historical voices.

2.3. DISTORTED PAINT

Welter's first goal in treating the painted areas was to impart flexibility and to flatten them. A formula created by Welter was tested. It is unknown where this formula came from. "Approx[imately] 4 parts O PR [oil paint restorer], 1 part linseed oil, 1 part poppy-seed oil and 1 part B[utyl]/S[cellusolve]. Applied to small area of flag" (Welter Daily Journal 1964–1966, 15; fig. 5). The next day, the treated test area was examined and thought to be in good shape. (Welter Daily Journal 1964–1966, 15). Unfortunately, the formula wicked into surrounding areas of the 10th Minnesota Regimental flag (fig. 6). This oil deposit will be addressed in the wet cleaning section.

Fig. 5. Oil paint restorative, Salamander Inc. (Courtesy of Nancy Cyr).

2.4 ENCAPSULATING FOR WET CLEANING

The fragile silk battle flags were encapsulated between screens stretched with fabric for wet cleaning. To do this, a shellacked set of 7' x 8' wooden frames were fabricated, which nest one inside the other. The first flag treated was sandwiched between a layer of stretched silk crepeline and nylon netting: "…attached crepeline to frame with staple gun. I don't like working with this crepeline material. Feel that Dacron would be

Fig. 6. 8th Minnesota regimental battle flag (Courtesy of Minnesota Historical Society).

better" (Welter Daily Journal 1964–1966, 6). It is likely that the silk crepeline suffered from weave deformation or tears due to stretching and attachment to the frames. Welter's ingenuity solved the issue of working with delicate silk crepeline. His answer was to replace silk crepeline with Dacron curtains, a polyester open weave fabric. Dacron curtains were inexpensive, available, and could be reused multiple times, minimizing the process of preparing frames for wet cleaning. The silk crepeline was applied to the flag after wet cleaning. After the first flag, Welter used only Dacron frames to wet clean.

Unfortunately, by eliminating the application of silk crepeline at the beginning, which Scott's treatment plan had applied as a consolidating overlay prior to wet cleaning, an additional procedure to transfer the flags following wet cleaning and unsupported to screens stretched with silk crepeline was required. The development of his new procedure was time-consuming and required basting the flag twice (Welter Time Log, flag no. 9). Scott's original procedure of applying crepeline to one side prepared the flag for final consolidation stitching and minimized handling.

2.5 WET CLEANING

Welter's wet cleaning system started with a series of trial-and-error experiments performed on small fragments of flags. Scott advised that Orvus W.A. paste be used as an appropriate surfactant. Testing a solution of Orvus W.A. paste on small fragments was done to prove whether the colors were fast. In January of 1964, Welter wrote in his journal: "Put a gob of Orvus in the water and submerged the flag" (Welter Daily Journal 1964–1966, 16). No exact concentrations of surfactant or mention of purified water has been found.

Wet cleaning the first flag, the 10th Minnesota Regimental battle flag, took a total of seven hours and two separate baths (Welter Time Log ca. 1964–1966, flag no. 1). Welter describes the flag prior to wet cleaning: "It is quite dirty and all my steaming and oiling has left filmy residue. It could possibly be stains, although I've checked a small area with Orvus and water which seems to clean it quite well" (Welter Daily Journal 1964–1966, 15; fig. 6). The flag was submerged in a solution of Orvus W.A. paste and water, then soaked in clean water for two hours, rinsed with a gentle spray, and blotted to remove excess water. Once the flag began to dry, discoloration around the designation ribbon was noted: "There is some oil staining around the ribbon especially at the right edge" (Welter Daily Journal 1964–1966, 17). His response was to immediately lay the flag back in the sink and scrub the oil-stained area with a toothbrush and solution of Orvus and water (Welter Daily Journal 1964–1966, 17). Over time, Welter would describe scrubbing flags with the flat part of his hand against the bottom of the sink when submerged in Orvus to facilitate the removal of dirt and grime.

Dye bleeding was sometimes an issue. Welter's response was to apply a salt solution to set the dye (Welter Daily Journal 1964–1966, 24). Cyr believes that Welter used table salt. More than once he notes, "I had obtained a very slight color bleed while testing and feel a salt solution will remedy this" (Welter Daily Journal 1964–1966, 15). Fugitive dyes were again an issue with a very stable World War II service flag. Welter's resolution this time took him to a coin laundry, where he put the flag in a dry-cleaning machine (Welter Daily Journal 1964–1966, 159). None of the civil war flags was dry cleaned, likely owing to their fragility.

Fringe, tassels, and ropes were also submerged and washed separately from the flag (fig. 7). The fringe was then rinsed and combed straight with a bent fork (Welter Daily Journal 1964–1966, 118). When washing tassels with their wooden molds in situ, Welter submerged them in water.

Fig. 7. Cyr combing out fringe (Courtesy of Nancy Cyr).

2.6 STAIN REMOVAL

Welter did not focus on stain removal, with the exception of transferred paint (fig. 8). Testing different solvents and procedures noted in Welter's journal, "I tried removing paint which had transferred while the flag was rolled, using steam and Butyl-cellusolv[e]. Seems to work OK. Brush on with a blotter on reverse side" (Welter Daily Journal 1964–1966, 13). Two days later, the treated areas "looked quite faded and bleached out" (Welter Daily Journal 1964–1966, 14). It is unknown what was left behind on the surface of the flag. Fortunately, his response to spot clean the area with Orvus W.A. paste and water removed the white discoloration.

2.7 SILK CREPELINE ENCAPSULATION

Encapsulating a battle flag required joining two pieces of silk crepeline along the selvedge (fig. 9). Welter would cut, align, and apply water-soluble adhesive, 699-B-3 purchased from Adhesive Corp, "to keep from fraying and keep stiff when I sew two pieces together" (Welter Daily Journal 1964–1966, 86). The joined crepeline would then be stapled to a set of wooden frames and submerged in water to preshrink. This resulted in a taut overall substrate on which to align and encapsulate the silk flags. Cyr described 699-b-3 as a solvent-based, mold release adhesive that turned plastic when dry. A search is underway to learn more about this product.

As noted in the original procedure, Welter encapsulated the flag between silk crepeline and nylon bridal net. Once wet cleaned, the nylon bridal net was removed and replaced with a layer of crepeline. However, the

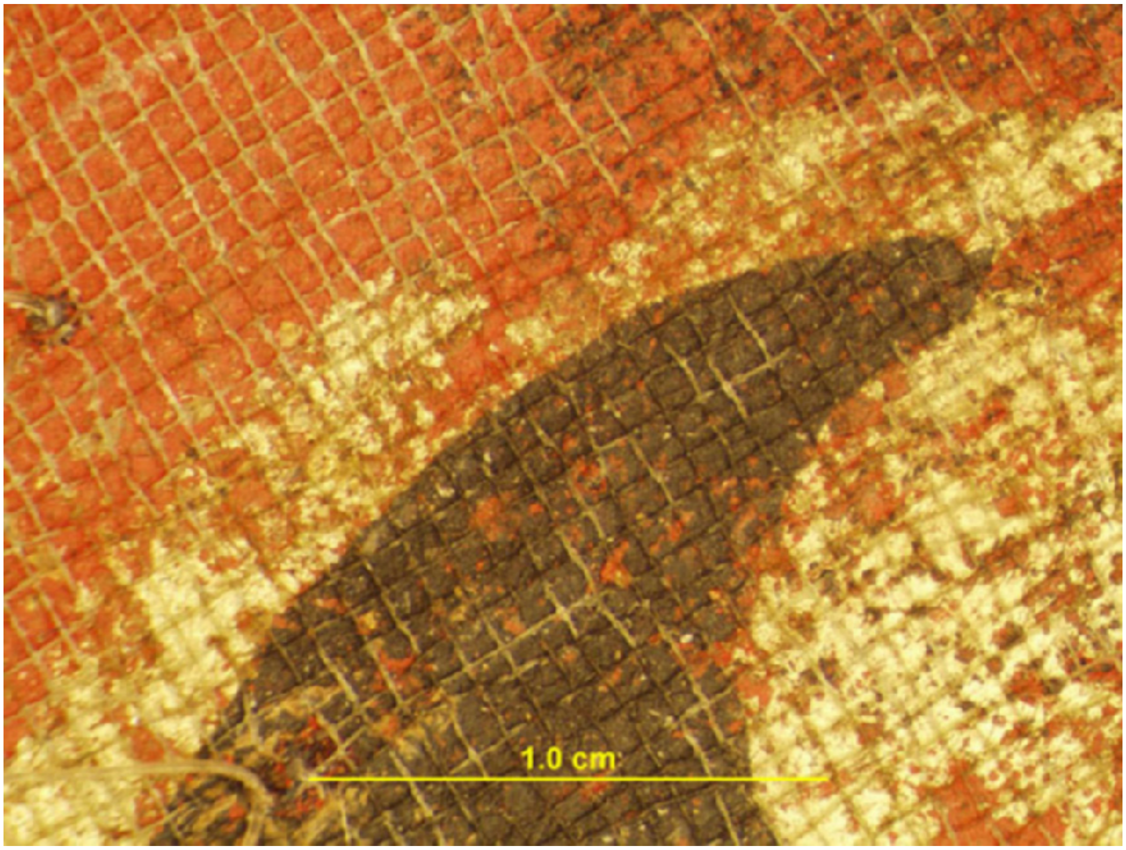

Fig. 8. Detail of 3rd Minnesota Regimental Battle Flag (Courtesy of Minnesota Historical Society).

Fig. 9. Detail of 11th Minnesota National Battle Flag (Courtesy of Minnesota Historical Society).

second procedure, using temporary Dacron frames for wet cleaning, required an additional step transferring the fragile flag to a new set of silk crepeline screens once wet cleaned (Welter Daily Journal 1964–1966, 103). Welter would remove the bottom Dacron, replace it with crepeline, and baste the whole package so that it could be safely turned over. The basting would be removed again and the Dacron replaced with silk crepeline. In order to minimize the damage in basting the flag three times, ceramic magnets from Edmond Scientific Co. were employed to secure the fragile silk fragments from moving. "The magnets I wanted to use when I have a flag laid out on netting and want to turn it over…This is time consuming, and sometimes makes elongated holes in the netting. I've tried pinning and this is not satisfactory either…It's surprising the pull they have" (Welter Daily Journal 1964–1966, 118).

Once the flag was between crepeline, it was secured with "paste basting," using a mold release adhesive called 699-B-3 to prevent shifting of fragments between silk crepeline and to stiffen it for stability while sewing (Welter Time Log , flag no. 1; fig. 10). Once pasted with 699-b-3, the flag was stiff like paper. The prepared flag was now ready for consolidation stitching. Next, lines in chalk were marked across the width of the flag as stitching guides.

2.8 CONSOLIDATION STITCHING

The fragile painted silk flags were consolidated with machine stitching (fig. 11). It is unknown where Welter came up with the idea to use a sewing machine. Welter designed a long-neck sewing machine for consolidation stitching. Fabricated with a 48"-long neck, it allowed for a flag to pass under the machine's needle

Fig. 10. Tom Welter applying 699-b-3 (Courtesy of Nancy Cyr).

Fig. 11. Tom Welter sewing flag (Courtesy of Nancy Cyr).

without being crumpled (fig. 12). Half of a flag would be sewn in one direction. Then the flag would be turned around and sewn in the opposite direction. The machine has only one stitch, zig-zag, which was threaded with a thin nylon monofilament thread.

A sewing table to house the long-arm sewing machine was designed and fabricated by Welter. The table was designed to support the flag entirely while it was on the machine. Two rollers, both in front and back, supported the flag as it was stitched. The flag was basted to a denim header and wound around the front roller. As the flag passed through the machine, it would extend over the back roller. It took nine hours for the first flag to be fully stitched. As Welter's expertise progressed, a common stitching time was three to four hours (Conservation Time log, flag no. 1).

2.9 RINSE ADHESIVE

The flags were submerged a second time to remove the 699-B-3 adhesive. However, Welter changed his wet-cleaning procedure after the ninth flag. Cyr identified this change to the procedure. The task log notes that the 10th flag was treated differently. Paste basting was executed before the flag was wet cleaned while it was still dirty. Wet-cleaning results were reviewed: "flag came out of the laundering in good shape, just a slight trace of color bleed into the shield. Removed it from the frames, and trimmed off excess crepeline" (Welter Daily Journal 1964–1966, 126). Streamlining his procedure eliminated the stress of handling, basting, and submerging the flags twice. At this point, the Dacron frames were used solely to encapsulate the flag for wet cleaning after the consolidation stitching. Any flattening needed after wet cleaning was achieved with an iron on low heat.

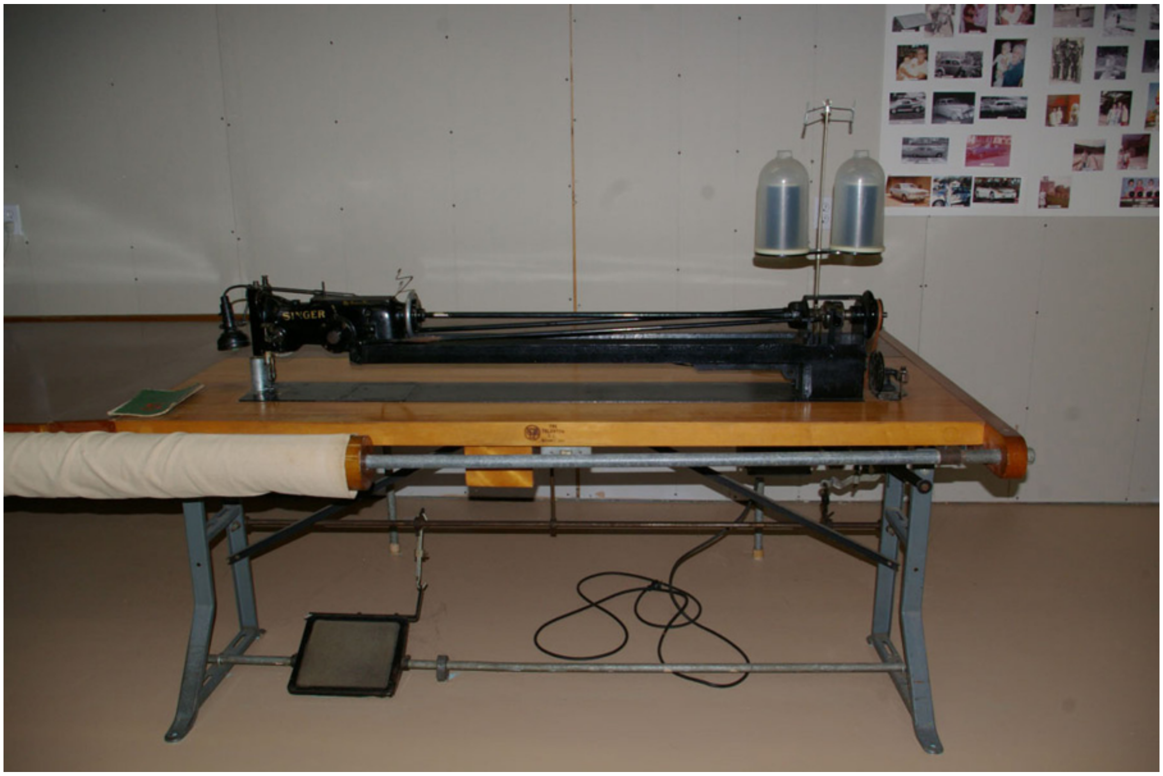

Fig. 12. Sewing machine with 48" long neck (Courtesy of Nancy Cyr).

2.10 PAINT CONSOLIDATION

Painted areas were often coated with varnish. Welter tested with three off-the-shelf varnishes purchased at an art supply store: "…inspection of pieces done yesterday show Damar Varnish and Picture Varnish have a very high gloss—not at all satisfactory. Matte-varnish much better… Finally developed method where I steamed and flattened using OPR [oil paint restorer] during the process. After water has evaporated, apply M-V [matte-varnish]" (Welter Daily Journal 1964–1966, 11). Varnish was applied directly over the silk crepeline and stitching. It can be seen on the silk crepeline surface with close examination (Welter Daily Journal 1964–1966, 41; fig. 13). Welter questioned whether coating the flag with varnish was appropriate: "Started varnishing the painted area... Am not certain that this is the best thing for the flag, and don't suppose anyone will know until many years have passed" (Welter Daily Journal 1964–1966, 97).

2.11 AMELIORATING AREAS OF LOSS

Many of the Civil War flags had large areas of loss due to damage on the battlefield or souvenirs being taken. Some of the flags were so devoid of their painted emblems and designation that little was left. Welter's previous training included sign painting. Using this skill, Welter would make a diagram of the flag and fill this loss with dry brush painting on the crepeline to complete the image (Welter Daily Journal 1964–1966, 205 and 208). Cyr informed the author that Welter used oil paints and that while a gap between the fill and flag was left, slight migration of the oil can be found (fig. 14). It took Welter 13 hours to prepare and hand paint the missing state seal and designation ribbon of the 4th Minnesota Infantry battle flag. No other methods of ameliorating areas of loss are noted.

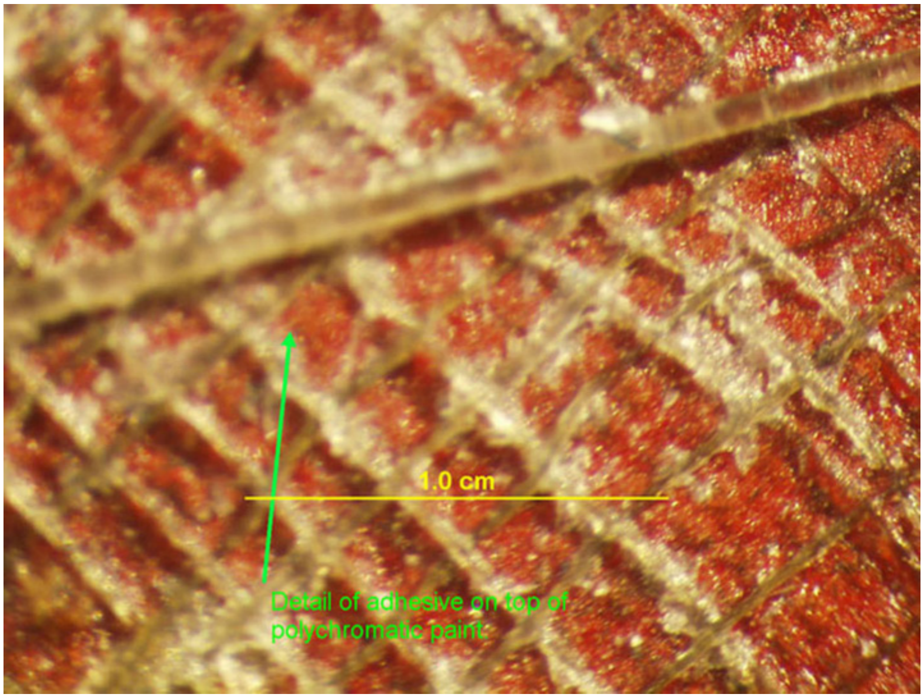

Fig. 13. Detail of 3rd Minnesota Regimental Battle Flag (Courtesy of Minnesota Historical Society).

Fig. 14. Detail of 8th Minnesota Regimental Battle Flag (Courtesy of Minnesota Historical Society).

2.12 FLAG REASSEMBLY

Once consolidated, each flag was reassembled and returned to its staff. Welter replaced the sleeve lining with cotton material that he identified as tarpon. The sleeve was folded over and machine stitched. A new leather tab, positioned at the top and bottom of the sleeve, was secured with machine stitching. The fringe was machine sewn around the perimeter of the flag. Areas of lost fringe were left bare. Cyr stated in an informal conversation that machine stitching of the fringe created an unexpected result. The tension of the pressure foot on the machine stretched out the fringe as the sewing progressed. This resulted in excess fringe on many of the flags, which was trimmed. Welter saved excess fringe and used it as a reference.

3. CONCLUSIONS

Welter's work has been examined by many conservators. The common question conservators are asked is whether his invasive treatment should be reversed. However, the larger question is whether Welter's use of unknown and untested materials is deteriorating the structural stability of the flags. Is the oil staining that bleeds out from the painted areas, a mixture of multiple components, something that should be treated? What

Fig. 15. 8th Minnesota Regimental Battle Flag (Courtesy of Minnesota Historical Society).

exactly is mold release adhesive 699-B-3, and has it been completely removed from the textile? The first step to answer these questions was to document Welter's methods and materials.

It is easy to pass judgment on Welter's treatment as a complete failure. However, it is important to remember that Welter's work was a reaction to the imminent danger and loss of flags. Cyr, Welter's daughter, states in an oral history interview: "...that was one of the things that came up, you know. These flags are falling apart in the Capitol Rotunda, and what do you do with them?" (Nancy Cyr interview transcript, 7). A battle flag's demise was often considered inevitable owing to its use on the field and its fragile materials. Battle flags were replaced as existing ones deteriorated during war. Sometimes, battle flags were disassembled into small souvenirs. It is in this transitory state that a battle flag exists between use, symbol, and ephemera. This issue is identified by Welter:

> *"In flag preservation a person is usually faced with the dilemma common to other aspects of museum work, that is, whether to stress conservation or utilization—or both, and in what ratio? In considering this problem one must bear in mind that flags tend to retain their original symbolism and thus are unlike other historical artifacts...."* (Welter "Flag Preservation by Netting", 1)

Welter's use of the word "utilization" suggests that he believed that these flags should be used. His goal to consolidate was not just to preserve but to make usable. The completed flags are displayed unfurled in the Minnesota State Capitol as if ready for parade (fig. 15). As a former World War II reconnaissance pilot who flew behind enemy lines, it is likely that Lieutenant Tom Welter's desire to consolidate flags was more than just an act of preservation.

ACKNOWLEDGMENTS

The importance of physical files and treatment reports cannot be understated here. No archive that documents the treatment described in this paper has been found at Minnesota Historical Society (MNHS). Fortunately, Welter's business history was saved by his daughter. Reviewing Welter's index cards, task logs, and journals documents and informs our understanding of exactly what was done as well as what materials and media were used. I'd like to thank Nancy Cyr for sharing her father's business archive and participating in clarifying the procedure. Finally, I'd like to thank the Minnesota Historical Society for funding my participation in this year's conference.

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AUTHOR BIOGRAPHY

ANN FRISINA began her career at the Textile Conservation Workshop in 1989 under the guidance of senior conservator, Karen Clark. While at the TCW, her work focused on flat textiles, such as samplers and quilts. Moving to the Cathedral of St. John the Divine Textile Conservation Lab, the focus was European tapestries and rugs. Next, Ann worked for the Historic New England on upholstery conservation. Moving to the Midwest 18 years ago, Ann became the textile conservator for the Minnesota Historical Society (MNHS), where she remains today working to preserve a broad-based textile collection in both historic houses and the MNHS museum. Address: 345 W. Kellogg Boulevard, St. Paul, MN 55102; E-mail: ann.frisina@mnhs.org.

THE MORTLAKE HORSES: A COLLABORATIVE APPROACH TO THE CONSERVATION OF A SEVENTEENTH-CENTURY BRITISH TAPESTRY AT THE METROPOLITAN MUSEUM OF ART

OLHA YAREMA-WYNAR AND ALEXANDRA BARLOW

ABSTRACT—In preparation for the opening of The Metropolitan Museum of Art's renovated British Galleries, associate conservator Olha Yarema-Wynar and assistant conservator Alexandra Barlow completed the long-term conservation treatment of the 17th century tapestry, *The Destruction of the Children of Niobe* (36.149.1), from the English Mortlake workshop. This tapestry is one of two in The Met's collection from *The Horses*, a set depicting riding horses described in Ovid's *Metamorphoses*. *The Destruction of the Children of Niobe*, measuring approximately 4 by 6 m, is impressive in size and image. Past efforts at restoration of this large work of art are visible throughout the piece; within this one tapestry are numerous examples of techniques used during the long history of tapestry preservation. The most recent treatment was informed by an understanding of these historic techniques as well as by the skill and experience of its conservators. Stimulating conversations with curators at The Metropolitan Museum of Art also influenced the treatment by helping to determine an aesthetic vision for the tapestry. These discussions focused on the challenge of balancing the curatorial vision with the stabilization needs of the tapestry, while working within the tenets of current conservation philosophy.

LOS CABALLOS DE MORTLAKE: UNA PERSPECTIVA COLABORATIVA DE LA CONSERVACIÓN DE TAPICERÍA BRITÁNICA DEL SIGLO DIECISIETE EN EL MUSEO METROPOLITANO DE ARTE

RESUMEN—En preparación para la inauguración de las Galerías Británicas del Museo Metropolitano de Nueva York, la conservadora asociada Olha Yarema-Wynar y la conservadora asistente Alexandra Barlowc completaron un tratamiento de largo plazo en un tapete del siglo diecisiete la Destrucción del los Niños de Niobe (36.149.1), proveniente del taller del británico Mortlake. este tapete es uno de dos en la colección de "Caballos" del Met. El par de tapetes muestra caballos a galope, haciendo referencia a la Metamorfosis de Ovidio. La Destrucción de los Niños de Niobe, que mide aproximadamente 4x6 metros, es impresionante tanto en imagen como tamaño. La pieza muestra signos de restauraciones anteriores en numerosos sitios. El tapiz tiene ejemplos numerosos de técnicas usadas durante la historia larga de la preservación de tapicería. El tratamiento más reciente fue informado por medio del entendimiento de estas técnicas históricas, en paralelo con la experience y la habilidad de sus conservadores. Conversaciones estimulantes con curadores en el Museo Metropolitano de Arte también incluyeron el tratamiento por medio de ayudar a determinar una visión estética de la tapería. Estas discusiones presentaron un reto en cuanto a cómo acomodar tanto la visión de los curadores como las decisiones de los conservadores, basada en necesidades de estabilidad y los la filosofía de conservación hoy en día.

1. INTRODUCTION

As part of the preparation and planning for the renovation of the British Galleries at The Metropolitan Museum of Art, associate conservator Olha Yarema-Wynar and assistant conservator, Alexandra Barlow completed the conservation treatment of the 17th century tapestry, *The Destruction of the Children of Niobe*, from the English

Mortlake Workshop (fig. 1.) This tapestry is one of two in The Met's collection from *The Horses*, a set that depicts horses found in Ovid's *Metamorphoses*. The second tapestry from this series in the collection of The Met is *The Seizure of Cassandra by Ajax* (37.85). This tapestry is currently in the process of undergoing conservation treatment.

Curators from the European Sculpture and Decorative Arts department and conservators in the Department of Textile Conservation made the decision to conserve both tapestries as part of the same project. This was planned to allow for rotation of the two tapestries in the future, thus avoiding the stress of long-term hanging. These Mortlake tapestries entered The Met's collection in the 1930s but have not been on display since the middle of the 20th century. Prior to their exhibition, the pieces needed stabilization of weak, fragile areas and the hanging systems required updating. The tapestries' large size meant that the treatment would be time-consuming. For the conservation treatment of *The Destruction of the Children of Niobe* tapestry, one conservator worked on the project full time, the other did so part time. The conservation treatment was scheduled for one year, but ultimately took one and a half years to complete.

2. THE MORTLAKE TAPESTRY WORKSHOP

The Mortlake Tapestry Workshop was established in 1619 during the reign of James I in Mortlake, a village west of London. Flemish weavers were hired and brought to England to create a fine weaving workshop comparable to those in other parts of Europe (Hefford 2007). Another tapestry from the Mortlake Tapestry

Fig. 1. *The Destruction of the Children of Niobe* tapestry from a set of *The Horses* before treatment. Mortlake Tapestry Manufactory, designed by Francis Cleyn. Silk, wool. England; 1650–70. Gift of Christian A. Zabriskie. Metropolitan Museum of Art (36.149.1).

Workshop, *News of the Stag*, from the series known as the *Hunters' Chase* (57.127), is also in the collection of The Met. This tapestry was previously on display in the British Galleries, but de-installed and stored prior to the start of the Galleries' renovation.

2.1 THE HORSES SERIES

The *Horses* series was designed in the 1630s by Francis Clein for Charles I. The original version was woven with silk, wool, and luxurious silver gilt threads. The series, a set of six tapestries, depicts stories from Ovid's *Metamorphoses* with riding horses from those stories featured as the dominant subject of the scene (Hefford 2007). Only a fragment of one of the tapestries from this original series exists today in the collection of the Victoria and Albert Museum (T.228-1989).

Based on the coat of arms woven into both tapestries, it has been determined that the two *Horses* tapestries now found in The Met's collection are from a series woven some years later, in the 1650s or 1660s, for Henry Mordaunt, second Earl of Peterborough, and his wife, Penelope O'Brien.

2.1.1 The Horses Woven at Lambeth

Cartoons for *The Horses* were used multiple times to weave the same series for various clients. In the collection of Simon Franses in London, another version of *The Destruction of the Children of Niobe* tapestry exists but was instead made by the Lambeth Workshop (Laffan and Monkhouse 2015), established in London by William Benood, a weaver formerly at Mortlake (Marillier 1927). The Lambeth workshop, along with others in 18th century England, used Mortlake's designs after their 17th century inception at Mortlake.

The *Niobe* tapestry woven at Lambeth was displayed as part of the 2015 Art Institute of Chicago exhibition, *Ireland: Crossroads of Art and Design, 1690–1840*, and published in the accompanying catalog. From this, the conservators recognized variations in the design and condition of these two tapestries. The bottom border of the Lambeth version is intact, with the floral design extending to the ends of both sides of the tapestry. In The Met's version, the bottom border has two missing sections, removed and replaced by commercially woven fabric at some earlier point in the tapestry's history (see fig. 1).

Visible in the *Niobe* tapestry woven at Lambeth is an additional figure that does not appear in the Mortlake version at The Met. In The Met's version, the corresponding area where the figure exists in the Lambeth version is empty space. However, this empty space is filled with insertions from other tapestries, making it unclear if a figure originally existed in The Met's version (fig. 2.)

3. CONDITION

At the start of the tapestry conservation treatment, curators and conservators met to discuss defining goals for the artwork. The large tapestry was determined to be in fair condition. It measures approximately 4 by 6 m with a warp count of 6 warps per centimeter. It is composed of silk and wool wefts on a wool warp. One of the most immediately apparent condition issues was that the object had many areas of deterioration with exposed warps and missing wefts. In addition, there were large slit closures that needed securing and splattered paint on some edges. It was also quite evident from its appearance that the tapestry was previously restored more than once, using a variety of techniques. One of these earlier preservation campaigns had left faded, commercially woven fabric insertions within the bottom border. Others were visibly causing tension to the original material as it aged.

Fig. 2. Detail from *The Destruction of the Children of Niobe* tapestry in the collection of The Metropolitan Museum of Art. The insertion of multiple tapestry fragments can be seen. This was possibly done replacing an additional figure that can be seen in the tapestry woven at Lambeth.

4. TREATMENT GOALS

Working within the targeted period of a year, the agreed upon treatment goal was to preserve both the tapestry's original weaving and its preservation history. The conservators planned to address or adjust past restorations only when they caused structural tension that compromised its integrity. The decision to use minimally invasive conservation methods seemed straightforward; however, the reality of such a project was much more complex. The conservators found that they first had to consider options that best addressed the needs of the project overall, then each area individually.

A determination was made that choosing a single conservation method and using it for the entire project would be limiting. Because *The Destruction of the Children of Niobe* tapestry has a layered history of past restoration campaigns, over time these restorations have had very different effects on the textile. As a result, the conservators concluded that the conservation project would be most successfully achieved by using a wide range of conservation techniques.

5. A REVIEW OF PREVIOUS TECHNIQUES

This paper focuses on the conservation treatment of *The Destruction of the Children of Niobe* tapestry, but both of the Mortlake *Horses* tapestries in the collection of The Met present a valuable document of prior methods of tapestry preservation. Repairs and stabilization seen on the textiles are not only from their time in The Met's collection but also from their previous existence outside of a museum. These past techniques provide a record of the evolution in conservation philosophy, changes in technical skill, long-term effects of restorations, and response to shifting views of the value of tapestries. The conservators on this project were able to survey these previous techniques and treatments in great detail.

One of the first techniques observed during the initial condition report of *The Horses* was the use of insertions. This technique used fragments of other tapestries, sewn into the original weaving of the textile, to compensate for areas of loss (fig. 3). In many areas of the tapestry, this work was quite skillfully performed. The new fragments had been placed in a way so that their colors and warp density matched the original design and materials well. Some of these fragments were pieces of other pictorial tapestries, reclaimed to repair *The Horses* tapestries.

Fig. 3. Detail from the top proper right of the *Niobe* tapestry in the collection of The Metropolitan Museum of Art. A previous technique of using insertions is visible upon closer examination.

In addition, there were areas where plain blue gallon was inserted to compensate for fragile areas, present on much of the top border area on both tapestries. These insertions were attached with contrasting white stitches. Evenly incorporating new materials into an original tapestry is difficult; the considerable skill of the previous restorers working on this tapestry is apparent. Many of these insertions are strong and lie flat. From a distance, the tapestry looks to be complete. However, on closer examination, conservators found a collage of unrelated tapestry fragments incorporated into the original material.

In other areas of the tapestries, past preservation work was not as successful. In the *Destruction of the Children of Niobe* tapestry, for instance, some areas with darning stitches used to mend holes have caused additional condition issues over time (fig. 4). These areas had issues of structural tension that created distortions in the original material and design. Other previous techniques observed included the support of fragile areas to an underlay of net, the covering of missing areas of warp and weft with a series of stitches, as well as the use of combined techniques, such as the use of patches with overpainting (fig. 5).

6. WORK BEGINS

Work was guided first by considerations of structural instability and visual distortions. The conservators reviewed and determined which previous repairs would remain and which required attention. The consolidation process started with closing the slits. As conservators worked on the slits, they moved the object from one side to the other by rolling it on a tension table (fig. 6). Rolling the tapestry from side to side allowed for close examination of the original weaving and techniques used in previous repairs. Despite time constraints,

Fig. 4. Detail of one of *Niobe*'s daughters where a previous technique used darning stitches to mend a hole. This has caused additional condition issues over time.

Fig. 5. Detail of a previous technique that used both an insertion of a tapestry fragment and overpainting to compensate for loss in design.

Fig. 6. Conservators working on the tension table in the Department of Textile Conservation.

the conservators worked to examine and stabilize all areas of the tapestry. However, this meant not concentrating too long on any area, but instead prioritizing the most essential treatments necessary to preserve the integrity of the entire tapestry, ensuring that it would safely hang on the wall and endure.

6.1 CONSIDERING THE OVERALL PIECE

Information from this rolling practice (performed four times during treatment) allowed conservators to study each section in greater detail. Every new detail they uncovered provided a deeper understanding of the conservation work needed, which was crucial for determining each next step.

6.2 SLIT CLOSURES

Consolidation work on the slits was divided into several different types of treatment. Conservators removed all weak and large stitches with mismatching color threads and closed the slits with compatible discrete threads (figs. 7a, 7b).

In some places, the left side of the slit did not align well with its counterpart on the right side owing to small tapestry fragments inserted during a previous repair that caused the one side to become longer than the other. Conservators had to take great care to absorb this extra material.

Some areas had many original well-preserved wool threads; however, they were not sufficiently strong. Rather than replace them, new stitches were added using matching color DMC floss, which would make the slits strong.

6.3 CONSOLIDATION OF SILK AND/OR WEFT WOOL LOSS

After completing work on the slits, the team members turned their attention to places with fragile silk and missing brown wool, both of which they stabilized with a spaced plain weave method. For deteriorated silk, because the original colors were off-white and light yellow, either matching or half-tone-darker DMC floss was used. For the areas with missing brown weft—frequently seen on historic tapestries resulting from the use of a mordant containing iron salt during dyeing—neutral-colored threads were used, matching the color of the exposed warps (fig. 8). Matching the warp color while stabilizing the remains of brown wefts with the spaced plain weave method helped avoid the added texture that using new yarns with contrasting colors would have created.

6.4 TOP AND BOTTOM BORDERS

Next came the heavily damaged borders—especially the top one. In the past, several different methods had been used to repair these areas. Within the insertions, many of the connecting stitches were done in light-colored sewing threads. Some of the most visually and structurally distracting threads were removed; new warps were inserted between small pieces to keep them in place. The result was a more stable structure and a clearer view of the original design.

6.5 SUPPORT TO TOP BORDER

In other fragile areas along this top border, stabilization was achieved by using the couching technique (fig. 9). To strengthen the upper part of the border, a partial support of Pima cotton fabric was attached underneath. Pima cotton is light and would not add much weight to the tapestry. This was an important

Fig. 7a. Detail of slit closure before treatment.

Fig. 7b. Detail of slit closure after treatment.

consideration because the tapestry will be displayed hanging vertically. Additionally, partial supports were placed under all areas treated by either couching or spaced weaving. These Pima underlay supports were attached to the tapestry's reverse with even tension using zigzag stitches.

6.6 REWEAVING

In two areas, a reweaving method was used for stabilization. These areas had been repaired in the past with darning stitches, which pulled the fabric where the wefts and warps were missing, causing structural and visual distortion (fig. 10). Once the darning stitches were removed, it was necessary to compensate for the resulting holes. The areas bordering the holes were determined to be strong enough to withstand new inserted warps. Based on the Textile Conservation Department's considerable expertise in reweaving, we were confident that the approach would be successful; this turned out to be the case (fig. 11). Introduction of new yarns resulted in regained structural integrity for the tapestry.

6.7 ATTACHMENTS OF NEWLY WOVEN GALLOON AND INSERTIONS

Next, it was time to address the tapestry's corners and galloon. To prepare for this work, a sample was readied for submission to a weaver. The sample was made of "blending wefts": two or more similar colors combined in a single yarn to better match the original. In the sample, it was critical to maintain the original tapestry's warp count. To subtly create the appearance of old patina, randomly exposed warps were left bare.

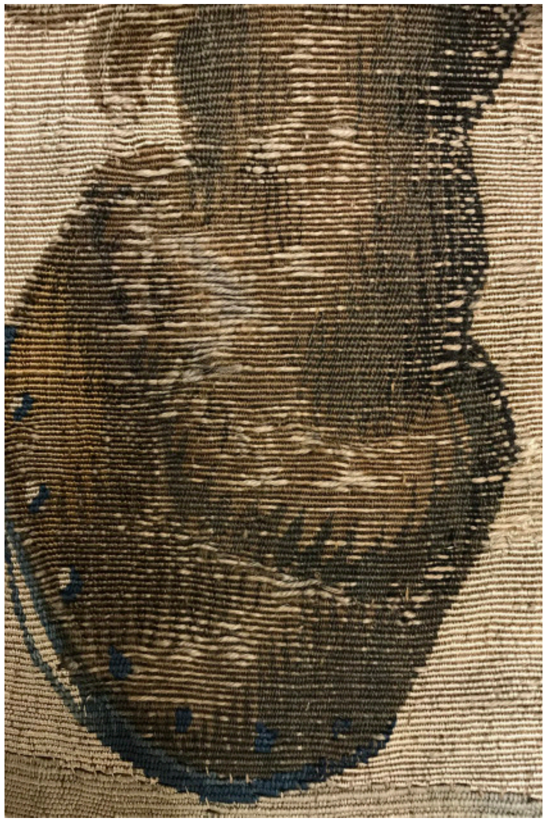

Fig. 8. After stabilization using a spaced plain-weave method.

Fig. 9. Couching along the top border.

Fig. 10. Area with darning stitches causing distortion before treatment.

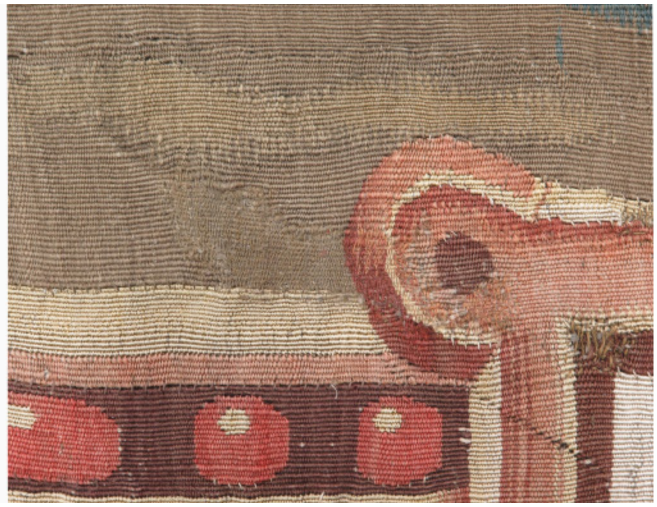

Fig. 11. Area with darning stitches causing distortion after reweaving treatment.

In a previous restoration, the two lower corners and one small piece at the top had been cut off and replaced by commercially made fabric. The fabric originally was a dark-blue color to match the background of the border and galloon. As often happens over time, the once well-matched color faded, making these areas visually very different from the original tapestry. In addition, the fabric used in the previous restoration was much thinner than the tapestry, giving it an appearance quite unlike the original.

In order for this work to be accomplished, the tapestry was moved to tables and opened completely so that the entire piece could lay flat. The faded repairs were removed in preparation for the newly woven fabric produced by a weaver with guidance from the conservator's sample. In some places, this was incorporated in to the missing areas as an underlay support. At the top and bottom of the tapestry, new galloon was attached with overcast stitches. Everything worked well. The newly woven fabric blended excellently with the tapestry and, in addition to making the tapestry stronger, it gave a more finished look to the entire object.

7. HORSES' LEGS AND COMPENSATION FOR LOSS

The final stage of conservation would ordinarily be when a new lining and hanging system are attached (Kajitani 1979). In this case, however, before this last stage began, something became apparent: the border, with its new, dark-blue galloon, now dominated the composition, especially in comparison with the central portion where some of the original color had been lost. Because tapestries are pictorial objects that tell stories, viewers should be guided toward the center, the most significant part, where the story unfolds. If the observer's eye is attracted first to the border, the story that the artist wants to tell becomes fragmented, less obvious. After several detailed discussions with curators, the decision was made to strengthen the brown color on the horses' legs by reweaving with additional brown wefts, bringing more attention to the center of the tapestry (fig. 12).

Fig. 12. After treatment to compensate for loss in the design.

It was a decision not reached lightly, as it came at a point when the conservation process seemed nearly complete. Reweaving the horses' legs meant retracing many steps, requiring considerably more time in sustained effort. However, with so much work having already been spent on this project, it did not make sense to leave it a less than perfect effort. The conservators returned to the project.

The original warps were well preserved and in good condition. Only a partial support had to be removed to achieve free access to the areas woven in brown-colored wool. The missing weft was compensated for by reweaving with brown yarn (fig. 13). In the end, it was well worth the additional effort. The *Niobe* tapestry is now visually stronger, with more focus on its central section as the artist of the original cartoon had intended.

8. CONCLUSIONS

What was learned from this experience? By sharing parts of our decision-making process during the complicated large-scale *Niobe* project, the conservators hope to have presented a view into some of the many challenges that one faces when working on historic textiles. It is not only about the choice of the most appropriate treatments; the importance of being creative and flexible cannot be emphasized enough, as well as the great value of collaboration between conservators and curators. Conservation work requires balance between the curators' vision and understanding of the object and the conservators' knowledge and experience.

Fig. 13. Partial view of *The Destruction of the Children of Niobe* after treatment.

Decisions are made based on each individual object and informed by current conservation philosophy. If something seems amiss, conservators must have the courage, vision, and often the stamina to "return to the drawing board." This way, in the end, they will feel comfortable knowing that everything possible has been accomplished to preserve the art for future generations.

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AUTHOR BIOGRAPHIES

OLHA YAREMA-WYNAR, associate conservator, is responsible for the conservation of textiles from the Department of Arms and Armor and the Department of European Sculpture and Decorative Art's tapestries collection. She holds an MFA in decorative and applied arts from the Lviv National Academy of Arts and an MA in Digital Media Studies from the University of Denver. In 2012, Olha was awarded her PhD in museology and cultural studies at the National Academy of Sciences of Ukraine, Kyiv. Her thesis topic was "Western European Tapestries of the 16th–19th Centuries from the Collection of the Bohdan and Varvara Khanenko Museum of Art: Manufacturing Technology and Methods of Conservation, Preservation, and Museumification." As of 2017, she is a Fulbright Specialist in museology with a concentration in textiles. Address: The Metropolitan Museum of Art, 1000 Fifth Avenue, New York, NY 10028. E-mail: olha.yarema-wynar@metmuseum.org.

ALEXANDRA BARLOW, assistant conservator, is currently working with Olha Yarema-Wynar on the treatment of three large tapestries in preparation for the renovation of the British Galleries. She received her MA in Fashion and Textile Studies with a focus on conservation from the Fashion Institute of Technology and her BA in Anthropology from San Francisco State University. While completing her master's degree, Alexandra held a graduate internship position in the conservation laboratory of The Costume Institute. Address: The Metropolitan Museum of Art, 1000 Fifth Avenue, New York, NY 10028. E-mail: alexandra.barlow@metmuseum.org.

CONFRONTING CHALLENGES AND CONSIDERING CONSENSUS IN THE CONSERVATION OF 18TH-CENTURY FASHION

MARINA KASTAN HAYS

ABSTRACT—The subject of this paper is the conservation and mounting of a ca. 1775 French court dress and associated qualitative research. The research included literature review; a survey of other 18th-century dresses; and a series of informal interviews with conservators in the United States, United Kingdom, and France. These inquiries focused on the best ways to address the types of degradation most common in 18th-century womenswear, the appropriateness of attempting to reverse alterations made to garments before they entered museum collections, and the various possibilities for exhibiting garments that are missing components. Guided by this research and discussions with curatorial staff, the author developed a treatment plan for the court dress, decided not to attempt to reverse alterations made to its petticoat, and constructed a reproduction stomacher to stand in for the missing original. The process of making the stomacher by painting fabric to match the dress and recreating the original 18th-century trim is described. Finally, the author considers what this study revealed about the degree of consensus in fashion conservation practice today, concluding that conservators approach historic fashion relatively consistently, even in the context of different institutions and geographic regions.

HACIENDO FRENTE A LOS RETOS Y CONSIDERANDO EL CONSENSO EN LA CONSERVACIÓN DE LA MODA DEL SIGLO DIECIOCHO

RESUMEN—Este artículo versa sobre la conservación y el montaje de un vestido Francés de corte, ca. 1773, asociado con investigación cualitativa. La investigación incluye una revisión literaria, y una revisión, por medio de encuestas a través de entrevistas informales, de otros vestidos del siglo dieciocho. Las entrevistas incluyeron conservadores de los Estados Unidos, el Reino Unido, y Francia. El cuestionario incluyó las mejores opciones para tratar degradación característica de vestido femenino del siglo dieciocho, cuán adecuado es intentar deshacer modificaciones al vestido realizadas previo a su acceso a museos, y distintas opciones para exhibición de vestuario con faltantes. Esta investigación, aunada a discusiones con personal de curaduría, permitió a la autora desarrollar un plan de tratamiento para el vestido de corte. Se optó por no revertir las alteraciones al fondo (petticoat), y se cosió la reproducción de una pechera que ocupó un faltante. Este artículo describe el proceso asociado a la creación de la pechera por tiñendo la tela para una lectura homogénea, y recreación de un vestido original del siglo dieciocho. Por último, la autora considera que este estudio reveló el nivel de consenso relacionado con la práctica de la conservación asociada a moda, concluyendo que los conservadores tratan a la moda de manera relativamente consistente entre instituciones y áreas geográficas.

1. INTRODUCTION

As a Fellow in the conservation lab of the Metropolitan Museum of Art's Costume Institute, the author conserved and mounted a ca. 1775 French court dress (C.I.61.13.1a, b; fig. 1) in preparation for the exhibition *Visitors to Versailles (1682–1789)*, April 16 to July 29, 2018. The project spurred several associated research initiatives on the topic of the conservation of 18th-century fashion. The conservation of garments from that century is not fundamentally different from the conservation of garments from other eras; the same code of

Fig. 1. The court dress (C.I.61.13.1a, b), a robe à la Française, France, ca. 1775 (purchase, Irene Lewisonhn Bequest, 1961), as exhibited in *Visitors to Versailles (1862–1789).*

ethics and best practices would be applied to a dress from 1750 and one from 1950. There are, however, common issues relating to both treatment and display of fashion from the 18th century. This paper focuses on three such topics: possibilities for addressing the types of damage most common in womenswear from this time, altered garments, and garments that are missing components.

The research conducted in connection with the treatment of the court dress included literature review; an object survey; and informal interviews with other conservators, focusing on their experiences treating similar garments. The knowledge shared by these professionals informed the treatment of the court dress and served as a means to assess broader patterns in fashion conservation. Of particular interest was the question of how much consistency there is in current practice and whether differences in approach tend to lie along personal, institutional, or geographic lines.

Interviews were conducted with eight conservators from seven institutions in the United States, United Kingdom, and France. These conservators were selected primarily on the basis of their experience working with historic fashion, though the author's own language abilities and institutional connections were also a factor. The study was, by design, more qualitative than quantitative, focused on collecting detailed anecdotal information from a small number of handpicked subjects rather than statistical data from a larger, randomized group. Though all of the discussions were guided by the same list of questions, they were not strictly structured; interview subjects were encouraged to focus on whatever aspects of the topic were most interesting to them or to turn the conversation to other related subjects as they saw fit.

Table 1. Objects Included in Survey of 18th-Century Women's Garments from the Collection of the Costume Institute

Accession Number	Title	Date	Culture
1996.374a-c	Robe à la Française	ca. 1760	British
2001.472a, b	Robe à la Française	ca. 1765	European
50.168.2a, b	Robe à la Française	1760s	French
C.I.59.29.1a, b	Robe à la Française	1750–1775	French
1999.41a, b	Robe à la Française	ca. 1770	French
C.I.61.34a, b	Robe à la Française	ca. 1770	French
2005.61a, b	Robe à la Française	ca. 1775	French
2009.300.855	Robe à la Française	ca. 1780	French
C.I.65.13.2a-c	Robe à la Française	ca. 1778–85	French
C.I.66.39a, b	Robe à l'Anglaise	ca. 1785–87	French
32.35.8a-c	Robe à la Française	1774–93	French

2. PATTERNS OF DEGRADATION AND STABILIZATION

The project began with a survey of 10 mid- to late 18th-century European dresses from the Costume Institute's collection (table 1). Examination of these garments revealed certain patterns of degradation specific to womenswear from this time. Because the fashionable silhouette changed very little over a period of several decades, the construction of women's dresses is relatively consistent, as are the associated condition issues—notably, damage at the waistline where the side seam of the bodice meets the skirt and horizontal splitting at the upper sleeves.

2.1 DEGRADATION AND STABILIZATION OF THE WAISTLINE

The side waist of an 18th-century dress is the intersection of multiple seams, and bears the majority of the weight of the wide, oversized skirts that were fashionable during this period. Furthermore, the area sustained significant stress from wear since the waist was the only point from which a woman in 18th-century undergarments could bend. Eight of the 10 objects in the survey were damaged at this point, with weave distortions, broken threads, tears, and/or losses (fig. 2). Most had been reinforced with whipstitches bridging the side and waist seams. In many cases, these repair stitches had also broken, further evidence of the stress that the area must sustain.

All of the conservators interviewed said that they would use a combination of support fabrics and conservation stitching to stabilize this type of damage, though one specified that she would prefer to use a thoughtfully designed mount to support the area rather than intervening in the object itself, if possible. There was agreement that the use of adhesives was not an appropriate solution. At a concentration that would allow the treatment to be reversible, adhesives would not hold up under stress from gravity unless the garment could be dismantled, fully lined with an adhesive-coated support, and reassembled. Unsurprisingly, there was also consensus that removing original stitches to more effectively stabilize a garment should be, at most, a last resort. Two of the conservators interviewed said that they had not and probably would never do such a thing. Those conservators

Fig. 2. Damage at the side waist on three robes à la Française, ranging in date from ca. 1760s to 1775, all in the collection of the Metropolitan Museum of Art. From left to right: 50.168.2a (Gift of Fédération de la Soirie, 1950), 2005.61a (Isabel Shults Fund, 2005), and C.I.61.34a (purchase, Irene Lewisohn Bequest, 1961).

who had or might have done so explained that a decision to remove stitches would be determined primarily by necessity but also by how intact a garment was. Removing stitches from a "pure" historical example would be more problematic than it would be for a garment that was already otherwise compromised.

Fortunately, it was not necessary to make such a decision in the treatment of the court dress. It was damaged at both sides of the waist and had been repaired with whipstitches and darning in thick cotton thread. The repair had held strong on the proper right side (fig. 3). Though it was aesthetically less than ideal, removing the repair stitches would likely have caused further damage; thus, as many as possible were left in place. A few stitches were clipped so that a support patch could be inserted; the ethics of doing this were relatively straightforward since they were not original to the garment. On the proper left side, which had more extensive damage, the repair stitches had all broken. As a result, the skirt was already separated from the bodice and its pleats released so that the fabric lay flat (fig. 4). This made it possible to fully underlay the damaged area with a support fabric and join it to the textile with laid and couched stitches (fig. 5). The skirt was then repleated and the seams restitched.

Though a combination of support fabrics and conservation stitching is widely considered to be the best option for stabilizing this kind of structural damage, it may not be a simple task to figure out how exactly to execute such a treatment. The complex geometry of the waist of an 18th-century dress can necessitate an equally complex geometry of support. The court dress required three separate underlays on each side of the waist (fig. 6). One follows the horizontal waist seam and pleat pattern of the garment. The second extends from the front to the back skirt, folding over at the seam connecting the two. The third underlays the point where the side and waist seams intersect. Overlays of silk crepeline were also added where there were loose wefts and splits along pleat lines to prevent abrasion in these particularly vulnerable areas.

2.2 DEGRADATION AND STABILIZATION OF THE SLEEVES

Observation of extant objects suggests that figured silks from the 1700s are prone to splitting in the warp direction, especially in areas subject to gravitational or mechanical stress, such as close-fitting sleeves that would

Fig. 3. Proper right waist of the court dress (C.I.61.13.1a) before treatment.

have been strained by the flexing of the wearer's arms. Because women's sleeves in this era were usually cut on the cross grain (Arnold 1964), they tend to have splits that are horizontal in relation to the body (fig. 7). Again, there was agreement among the conservators interviewed that stitching with localized supports was the best option for stabilization. However, the bodices and sleeves of most 18th-century dresses are lined in linen, and there is generally no access between the layers. If a split is large enough, a patch may be inserted through the opening and the garment stitched to this interstitial fabric using a curved needle, without catching the lining. If the opening is small, though, or if the dress fabric is weakened but still structurally intact, inserting an underlay is impossible. In these cases, it may be tempting to use the linen lining as a support for the silk, but there was agreement among the conservators interviewed that this is not an ideal approach. They reasoned that the differing responses of silk and linen to changes in temperature and humidity would likely cause tension between the two layers if joined, especially at the perimeter of the stitched area.

However, three of the dresses included in the survey *had* been stabilized with stitches joining the silk to the linen, evidence that this is an approach some conservators do take. These garments did not display damage

Fig. 4. Proper left waist of the court dress (C.I.61.13.1a) before treatment.

obviously resulting from this treatment, perhaps because they have been stored in a museum environment with minimal fluctuation in environmental conditions. Furthermore, certain objects that had been stabilized in the preferred way—with support patches inserted between the layers—had deteriorated further because the lightweight underlays used did not prevent the dress fabrics from bending and flexing at their weak points. This is a useful reminder that even when there is consensus as to best practice, it is worth considering alternative possibilities.

On one sleeve of the court dress was a set-in crease along which many wefts had broken. Because a full split had not yet developed, a support could not be inserted between the silk and the sleeve lining. Though the object survey provided some evidence that joining the two layers might be a viable method for stabilization,

Fig. 5. Proper left waist of the court dress (C.I.61.13.1a) after treatment.

the decision was made to follow advice offered by working conservators and avoid this approach. Instead, the silk alone was stitched, without any added support. This was a compromise; while stitching without the addition of a support did not fully stabilize the silk, it might keep the splitting from progressing further by limiting the movement of the fabric on either side of the existing crease.

3. ALTERED GARMENTS

An 18th-century dress that has not been altered in some way is a rare find. Silk textiles in that century were extremely valuable, but labor was cheap, making it worthwhile to update garments to keep up

Fig. 6. Interior of proper right waist of the court dress (C.I.61.13.1a) after treatment (underlays numbered in the order in which they are referred to in the text).

with changes in fashion or resize them for other wearers. In the 19th and 20th centuries, revival styles and a vogue for fancy dress parties led to garments being cut up and remade in less reverential ways. The result is that many extant objects are poor representations of the fashionable ideal that they originally represented.

The existing body of conservation literature includes several accounts of attempts by conservators to restore altered garments to their original forms (Lawrence and Cavallo 1971; Doré 1978; Arnold 1980; Mailand 1980). The number of articles on the topic may give a false impression of how common this kind of

Fig. 7. Horizontal splitting at the upper sleeves on three robes à la Française, ranging in date from ca. 1774 to 1793, all in the collection of the Metropolitan Museum of Art. From left to right: 2005.61a, C.I.61.13.1a, and 32.35.8a (Rogers Fund, 1932).

treatment really is. In fact, few institutions have the resources to dedicate to such extensive projects. In addition, altered garments may lack the evidence of their initial shape necessary to guide a reconstruction or be missing too much original material to be restored. Finally, some conservators feel that all such interventions are ethically questionable.

When a reconstruction is carried out, it is generally because a garment is of an extremely rare type, as in the case of a ca. 1700 mantua in the Los Angeles County Museum of Art's collection (Knutson 1991), or because it cannot be exhibited as is. This was true of a mid-18th-century mantua that was not only altered but was in pieces when it arrived at the Victoria and Albert Museum (Hackett 2009). Crucially, the existing literature shows that it is easy to go wrong in reconstructing an altered garment; more than one article describes revisiting a previous reconstruction effort in order to correct misinterpretations of the available evidence of a garment's earliest incarnation (Kite and Cogram 2006; McLean, Rosenbaum, and Schmalz 2014).

3.1 ALTERED ASPECTS OF THE COURT DRESS

In the case of the court dress, the robe appears to be completely unaltered. However, both museum documents and object-based evidence suggest that the petticoat (fig. 8) is not in its original form. Accession records refer not to a petticoat but rather to a "length of material" that could be "used for the petticoat" (Weissman 1961). While the five widths of silk may have been stitched together to form a large rectangle before they entered the collection, it seems that they were pleated after arriving at the museum.

The current form of the petticoat is inconsistent in a number of ways with comparable contemporary examples included in the author's object survey as well as those diagrammed by Arnold (1964) and Waugh (1968). The waistline of the court dress's petticoat is straight, while other 18th-century petticoats have shaped waistlines, lower at the center front (and sometimes also center back) than at the sides (fig. 9). Though most 18th-century petticoats have openings at the sides or center back roughly 9 to 14 in. long, the

Fig. 8. Petticoat of the court dress (C.I.61.13.1b).

Fig. 9. Petticoat, France, ca. 1775 (2005.61b).

court dress's petticoat is totally open at the back, like an apron. It has only two pleats per panel, each with a pleat depth of 5 to 6 in. In contrast, other 18th-century petticoats have many more and shallower pleats or are gathered by a drawstring.

Test-dressing the petticoat seemed to confirm that it has been altered. Like other petticoats of this era, the waistline of the garment sits away from the body, supported by and following the perimeter of the paniers worn beneath. However, for the front to hang correctly, this petticoat must be tied with a wide gap at the center back (fig. 10). The opening is about the width of the silk fabric from selvedge to selvedge, evidence that an entire panel of silk may be missing.

This spurred discussion with conservators and curators at the Costume Institute about whether an attempt should be made to restore the petticoat to a more historically accurate form. Doing so would involve removing the existing stitches holding the pleats in place, which were not original, and repleating or gathering the fabric in a configuration suggested by other, apparently unaltered, petticoats from the same period. As it was, the waistline was under strain when the petticoat was on a mannequin, apparently due to the unorthodox arrangement of the pleats; however, it had to be acknowledged that the process of restoration would itself stress the object. Also considered was the fact that only the center front of the petticoat would be visible when dressed with the gown on top, and this section appears more or less historically correct. Furthermore, there was little evidence of the petticoat's original form—such as creases, soiling or fading patterns, or stitch holes—to inform a reconstruction. Weighing these factors, the decision was made to leave the petticoat as is. To

Fig. 10. Test dressing the court dress petticoat (C.I.61.13.1b).

Fig. 11. Waist tapes added to the court dress petticoat (C.I.61.13.1b) for additional support.

prevent additional damage to the silk fabric at the waistline, cotton tapes were added at either side of the center front (fig. 11). These can be tied around the mannequin's waist to better distribute the weight of the petticoat and provide additional support.

4. MISSING COMPONENTS

The question of how to exhibit objects that are missing essential components may arise with fashion from any period, but it is particularly pertinent for 18th-century garments, since what are called "gowns" or "dresses" are, in fact, ensembles composed of multiple elements. Petticoats made from uncut widths of fabric were easily and often deconstructed and repurposed. Stomachers—triangular pieces pinned or stitched to the fronts of gowns to fill in open bodices—are small and detachable; more often than not, they have been separated from the dresses with which they were originally worn. Indeed, the court dress was accessioned by the Costume Institute without a stomacher, a problem that must be solved anew each time it is exhibited. Five decades of installation photographs are evidence that opinions on how best to do so have evolved over time.

4.1 OPTIONS FOR DISPLAY

In most cases, the decision of how to display an incomplete ensemble will be made by a curator, but execution may fall to the conservator. One possibility is to make a stand-in from fabric of a complementary or neutral solid color. Another is to use an accessioned object associated with another ensemble. A final alternative is to create a reproduction that suggests or approximates what the missing piece might actually have looked like. Conversations with other conservators suggest that the choice depends primarily on the preferences of individual curators. At the Costume Institute, the current curatorial philosophy is that fashion objects must "appear as close as possible to what the designer or maker intended" (Scaturro and Fung 2017, 162). This ultimately guided the approach to exhibiting the court dress in *Visitors to Versailles (1682–1789)*.

Three-dimensional ornamentation was an essential element of the rococo aesthetic (Ribeiro 2002) and surface decoration was heavily concentrated on stomachers; some surviving examples are so covered in trimmings that their base fabric is barely visible. In addition, extant objects and portraiture are evidence that most stomachers in the second half of the century were made from the same fabric as the robe and petticoat with which they were worn, with matching trims. Therefore, neither a "blank" prop nor a mismatched contemporaneous piece would be an accurate representation of the 18th-century fashionable ideal. It was decided that a reproduction stomacher should be made to give the exhibition audience a full and accurate understanding of the court dress and the fashions that it reflects.

Fig. 12. Reproduction fabric (hand-painted silk taffeta) next to the court dress (C.I.61.13.1a).

Fig. 13. Original fly fringe trim on the court dress (C.I.61.13.1a).

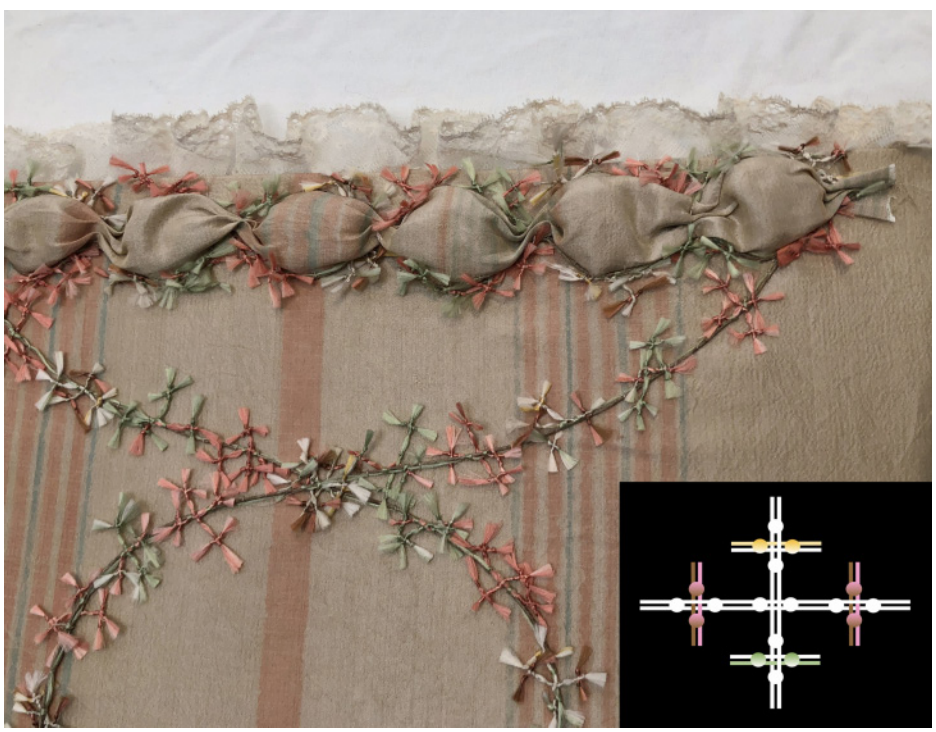

Fig. 14. Reproduction fly fringe trim, with inset diagram of arrangement of silk strands and knots.

Fig. 15. Completed reproduction stomacher.

4.2 CREATING A REPRODUCTION STOMACHER

To create the reproduction stomacher, a color-matched silk taffeta was painted with stripes using Jacquard Textile Colors.[1] This process was relatively quick and inexpensive, gave a great deal of control, and yielded a finished product with slight imperfections that help it to blend visually with the centuries-old garment (fig. 12). The stripe pattern was first laid out with painter's tape, which served as a guide for the application of Jacquard Resistad, a water-based gutta resist. Once the resist was dry, paint was applied by brush. The painted fabric was wrapped around a piece of buckram, which is light and flexible but stiff enough to mimic the smooth, conical shape of a body molded by stays, the 18th-century version of a corset.

The court dress is ornamented with a kind of passementerie trim called fly fringe, consisting of tufts of knotted silk floss secured to a thicker gimp thread (fig. 13). This trim was precisely recreated using untwisted filament silk embroidery floss, taking care to match the color combinations, lengths of individual pieces of floss, and distances between knots (fig. 14). In arranging the finished trim on the stomacher, the goal was for the reproduction to be historically appropriate and to fit in visually with the gown without becoming the center of focus. Contemporary pictorial sources and extant objects provided inspiration for a suitable but relatively restrained application of ornament (fig. 15).

5. CONCLUSIONS

Information gleaned from published literature, interviews with conservators, and examination of surviving 18th-century objects was synthesized in the plan for treating and mounting the court dress. Adhesives and joining layers of the garment were avoided; instead, laid and couched stitching and localized supports were used to stabilize all structural damage. Understanding the reasons why other conservators might or might not elect to restore an altered garment to its original form led to a decision to leave the petticoat as it was. Finally, following an exploration of the various approaches to exhibiting incomplete 18th-century ensembles and guided by curatorial vision, a reproduction stomacher was made for the court dress's appearance in *Visitors to Versailles (1682–1789)*.

The research that informed the treatment of this dress also served, more generally, as a lens through which to view the question of consistency in costume conservation—or, more specifically, consistency in the conservation of fashion, which is costume that represents the aesthetic ideal of a particular time, place, and people. Because this is not generally considered or taught as a distinct specialty within the field of conservation, the author wondered whether there might not be more variation in practice than in other areas.

Of course, all conservation decisions depend on the needs of particular objects and the realities of logistical factors, such as budget and available time. It is, however, still possible to identify patterns in conservators' approaches to solving certain types of problems. The author hypothesized that there would be clear divisions along geographic and institutional lines, assuming that conservators trained in different countries would act accordingly, and that the focus of particular institutions would, to some extent, dictate the decisions made by the conservators working there. For example, a social history museum might be more concerned with preserving historical evidence and a museum with a focus on fashion might privilege aesthetics. This turned out not to be the case. The interviews indicated that variations in approach were dictated primarily by the individual personalities and preferences of conservators and the curators they work with. The variations, however, are minimal. This study, though not exhaustive, suggests that there is a high degree of consensus on most issues, from how to stabilize degraded fabrics in garments with complex construction to whether it is appropriate to endeavor to reverse alterations made to garments in the past. Fashion conservators seem to be surprisingly consistent in their convictions, a more or less united front against the ravages of time.

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NOTE

[1] Jacquard Textiles Colors have been tested by other conservators (Kaldany, Sigurdardottir, and Berman 1997) and deemed appropriate for conservation applications, being sufficiently colorfast and nonreactive.

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SOURCES OF MATERIALS

Au Ver à Soie Soie Ovale untwisted silk floss
Needle in a Haystack
2433 Mariner Square Loop, Suite 102
Alameda, CA 94501
510-522-0404
www.needlestack.com

Jacquard Textile Colors and Resistad Water-Based Gutta resist
Dharma Trading Co.
1604 Fourth St.
San Rafael, CA 94901
800-542-5227
www.dharmatrading.com

Silk taffeta
JRB Silks
375-G Winkler Drive
Alpharetta, GA 30004
678-661-1781
www.jrbsilks.com

AUTHOR BIOGRAPHY

MARINA KASTAN HAYS is the Polaire Weissman Fund Fellow in conservation at the Metropolitan Museum of Art's Costume Institute, where she has researched the conservation of 18th-century fashion and tecniques for conserving leather and fur garments. She previously completed internships at the Costume Institute and at the Textile Conservation Laboratory at The Cathedral of Saint John the Divine. She holds a Master of Arts in Fashion and Textile Studies with a concentration in conservation from the Fashion Institute of Technology and a Master of Library and Information Science from Pratt Institute. Address: 1000 5th Avenue, New York, NY 10028. E-mail: marinakhays@gmail.com.

THE USE OF PAPER-BASED MATERIALS FOR THE TREATMENT OF PLANT FIBERS

ANOEK DE PAEPE, SISKA GENBRUGGE, AND MARIEKE VAN ES

ABSTRACT—The collection of the Royal Museum for Central Africa (RMCA) in Belgium encompasses a broad range of objects that contain plant fibers. Those plant fibers are sensitive materials that damage easily owing to handling, light exposure, and fluctuations in relative humidity and temperature. Consequently, the fibers of the objects are often discolored, deformed, or broken; multiple objects are actively shedding fibers or suffer from "baldness." Some plant-fiber objects selected for exhibition in the RMCA were too degraded to be displayed. These plant fibers were treated with paper-based materials in order to stabilize the objects and improve their readability. Multiple products can be grouped under the term *paper-based materials*, such as Japanese tissue, archival grade paper, and cellulose pulp. These products have specific sets of characteristics that can be used for diverse treatments of objects, ranging from thin protective coatings to structural fills. The versatility of the paper-based materials will be demonstrated through a discussion of several treatments that straddle the disciplines of textile, object, and paper conservation.

EL USO DE MATERIALES DERIVADOS DEL PAPEL PARA EL TRATAMIENTO DE FIBRAS DE MADERA

RESUMEN—La colección del Museo Real de África Central (RMCA por sus siglas en inglés) en Bélgica incluye una gran variedad de objetos hechos a base de fibras vegetales. Dichas fibras vegetales son materiales sensibles, fácilmente dañables como consecuencia de manejo, exposición a la luz, y fluctuaciones de humedad relativa y temperatura. Algunos de dichos objetos de fibras vegetales seleccionados para exhibición en el RMCA estaban demasiado degradados para exhibirse. Dichas fibras vegetales fueron tratadas con materiales a base de papel con el fin de estabilizar los objetos y mejorar su lectura. Múltiples productos pueden agruparse bajo el término materiales derivados del papel, tales como el papel Japonés, papel de grado archivo, y pulpa de papel. Dichos productos tienen propiedades características que pueden usarse de manera diversa en varios objetos, e incluyen desde cubiertas de protección hasta rellenos para soporte estructural. La versatilidad de los materiales derivados del papel será demostrada a través de varios tratamientos que incluyen disciplinas como la conservación de textiles, objetos y papel.

1. INTRODUCTION

The RMCA is a research institute and an encyclopedic museum that comprises a diverse collection with a strong focus on objects from the geographic region of Central Africa. The museum was closed between 2013 and 2018 for a major renovation. During its closure, the conservators treated a large number of objects that were predominantly made from organic materials, especially plant fibers. Certain objects that were selected by the curators for exhibition on the reopening were too degraded to be displayed. Japanese tissue, cellulose pulp, and archival grade paper were used as loss-compensation materials during those treatments.

2. RELAXATION OF PLANT FIBERS

The majority of the objects containing plant fibers were deformed due to improper storage, handling, and display. The objects needed to be reshaped using humidity treatments prior to any loss compensation. The

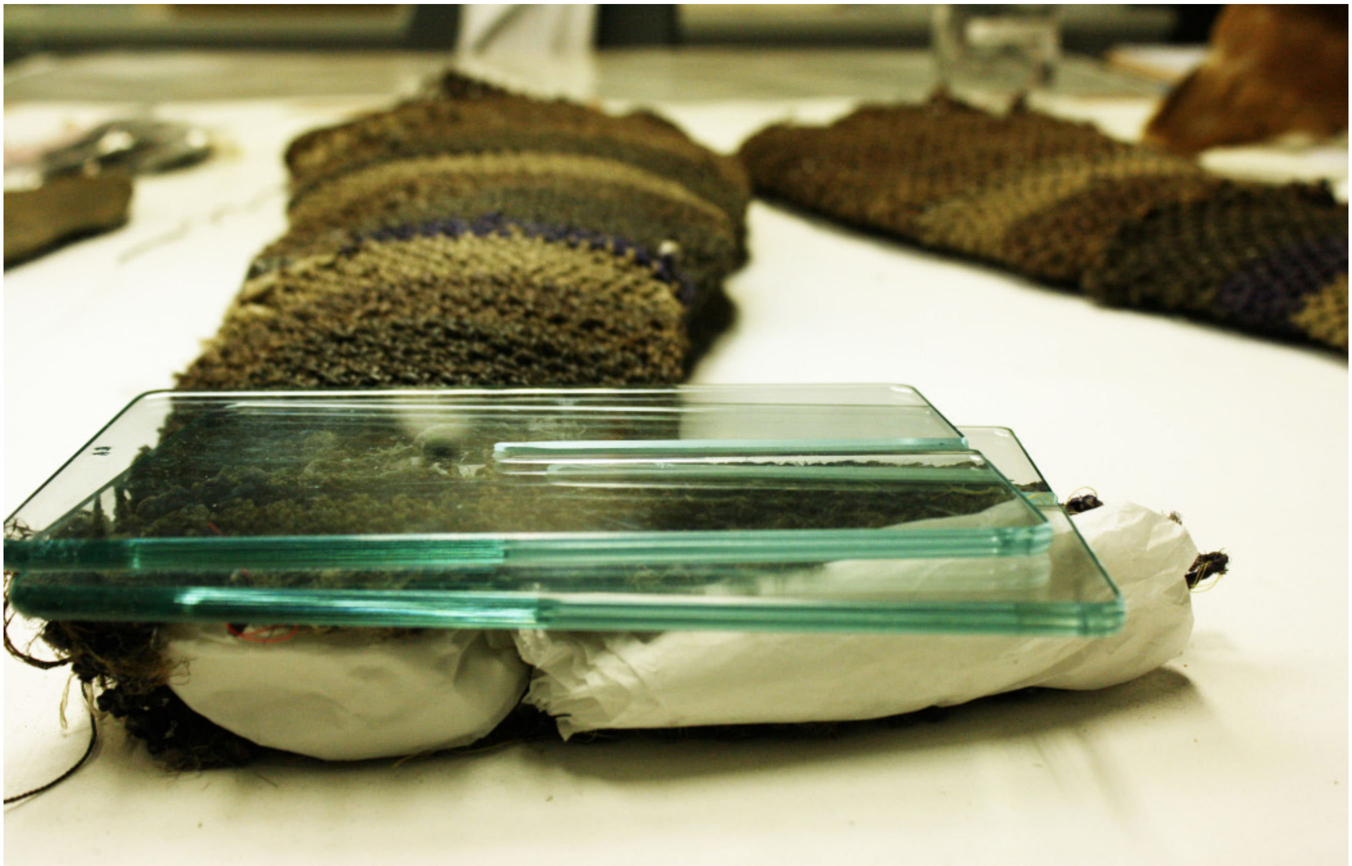

Fig. 1. Local humidification, EO.1998.14.24-2 (Courtesy of A. De Paepe, Collection of Royal Museum for Central Africa, Tervuren©).

addition of humidity can make a dry and brittle plant fiber flexible again. Once flexible, the fibers can be formed into their original shape using gentle pressure. Two fiber relaxation and reshaping methods are used in the conservation laboratory at the RMCA: the ultrasonic cold steam method and the Gore-Tex method.

2.1 ULTRASONIC COLD STEAM

Ultrasonic cold steam is steam that is generated by ultrasonic vibrations (Tímár-Balázsy and Eastop 2011). When an object is made from different materials or if just part of the object is distorted, local humidification with ultrasonic cold steam is recommended. The cold steam can be directly applied with the ultrasonic humidifier onto the plant fiber. Once the fibers are humid, weight is placed on the fibers in order to gently manipulate them back to their original form (fig. 1).

A humidification chamber, during which the whole object is submitted to ultrasonic cold steam, can be used when an object is completely deformed. The conservation crew of the RMCA made a humidification chamber using a clothing rack and plastic sheeting for the treatment of a Matadi dance skirt. A tube with a nozzle leading from a humidifier was inserted through a small gap in the humidification chamber. The relative humidity was slowly increased to approximately 80%. This humidity level was maintained for three weeks in the chamber (fig. 2). Any increase in humidity means a higher risk of mold formation; thus, it is crucial to monitor this humidification process very closely.

Fig. 2. Humidification chamber, EO.0.0.17317 (Courtesy of S. Genbrugge, Collection of Royal Museum for Central Africa, Tervuren©).

2.2 GORE-TEX METHOD

The Gore-Tex method is a safe and more controlled way to humidify plant fibers because there is no direct contact between the object and water (Tímár-Balázsy and Eastop 2011). Gore-Tex is the brand name of a semi-permeable membrane used in the textile and shoe industry [1]. During this method, a sandwich of blotting paper, plant fibers, Gore-Tex, and moist blotting paper is created between two sheets of Mylar [2] (fig. 3). This sandwich is then weighted with lead weights or glass plates. This humidification and reshaping

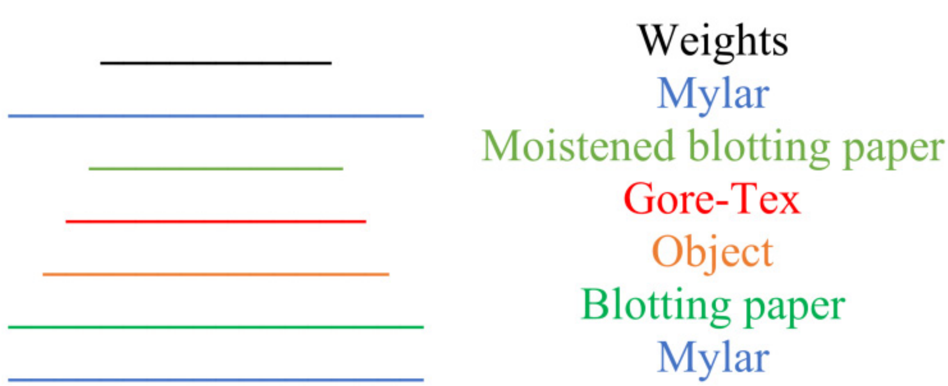

Fig. 3. Diagram of Gore-Tex method.

method is very effective on flat textiles and was used to flatten a woven burial mat, which will be discussed in more detail later (see fig. 6a).

3. LOSS COMPENSATION METHODS FOR OBJECTS CONTAINING PLANT FIBERS

Lost and broken fibers were restored using paper-based materials in order to stabilize the object and/or improve its readability.

Following the guidelines of the ICOM Code of Ethics for museums, the conservation treatments should be as reversible as possible and the added materials should be easily distinguishable from the original material (International Council of Museums 2013). The added materials may not cause more damage to the object. Additionally, the newly introduced materials should be softer than the original material, may not emit hazardous gasses, must have good aging properties, and the pH value should be compatible with the original material (Ledoux 2012).

Therefore, each of the paper-based materials as well as the paints, dyes, and adhesives were Oddy tested following the guidelines of the British Museum (Thickett and Lee 2004). The samples were kept in a sample vial with a small tube filled with deionized water, and a copper, silver, and lead coupon. The sample vial was then placed in an oven for 28 days at of 60°C. The results are shown in tables 1 and 2 in the appendix.

3.1 JAPANESE TISSUE

Japanese tissue can be used for a wide array of different treatments of plant fibers because it is a flexible material that can easily be toned with well-known conservation-grade paints and dyes. The paper is handmade and can be produced from three types of bast fibers: Kozo, Mitsumata, and Gampi, which each have different properties (Soleymani 2015).

Kozo is made from the inner bark of the mulberry tree; it is a strong tissue due to its long fiber length and the high percentage of alpha cellulose. The Mitsumata is produced from the bast of the shrub, *Edgeworthia gardineri*. The fibers are shorter than Kozo fibers, which results in a weaker, less absorbent, and softer tissue. Gampi paper is made from the bark of the shrub *Wikstroemia canescens*, and is also short-fibered. Gampi tissue is fine, transparent, smooth, and strong (Roberts and Etherington 1982; Shiraiwa 2015; Soleymani 2015). All four treatments described below were carried out using the Japanese tissue Kozo K-37 [3].

The choice of color medium to tone the Japanese tissue fills depended on the appearance of the original fiber and the adhesive used. The color medium was not to be affected by the adhesive used, in particular by the solvent (Norton 2001).

Solophenyl is a synthetic textile dye that is commonly used in textile conservation. It is a direct dye that penetrates directly into the fibers. This dye is predominantly used to stain cellulose fibers and can therefore be used on Japanese tissue (Boersma et al. 2000). The biggest advantage of dyed tissue over other toning methods is that the properties of the paper remain the same. The paper stays soft, absorbs water, and remains more fibrous (Norton 2001). The disadvantage of dyed tissue is that the direct dyes remains water soluble even after dying (Tímár-Balázsy and Eastop 2011). A good alternative, but unavailable in the laboratory at the RCMA, are fiber-reactive dyes, which are known for their excellent wash fastness (Norton 2001; Tímár-Balázsy and Eastop 2011).

Some Japanese tissue fills were toned using GOLDEN Fluid Acrylic paint. The application of a layer of acrylic paint onto the Japanese tissue alters the appearance and characteristics of the paper. The tissue can become stiffer, shinier, or more elastic. The color is also more intense, whereas a dyed tissue gives a more translucent result.

The last color medium that was tested was the Derwent Artist colored pencils. The advantage of colored pencils is that they work more precisely in comparison to dyes or acrylic paints. It is easy to make different color shades or to imitate structure. On the other hand, they give a glossy look to the paper.

Woven and knotted textiles and costumes were treated with Japanese tissue in the conservation laboratory, as well as a large variety of other objects ranging from musical instruments to masks, in order to compensate losses in various materials, from leather to wood. The following examples will demonstrate that Japanese tissue is a very versatile material that can be used to stabilize all kinds of plant fibers. The appearances of paper can be easily adjusted with the addition of dyes or paints and adhesives.

3.1.1 Dance Costume

A Central African dance costume (EO.1998.14.24-2) was selected for display. The costume was worn by boys of the Chokwe culture during their initiation rituals (Bouttiaux 2009). Figure 4 shows this exact dance costume worn by a young man in 1931. The object was collected by the herpetologist and collector Gaston De

Fig. 4. Dance costume, EP.0.0.5759 photo G. De Witte (Courtesy of Royal Museum for Central Africa, Collection of Royal Museum for Central Africa, Tervuren©).

Fig. 5. (a) Detail of dance costume before treatment, EO.1998.14.24-2; (b) detail picture dance costume after treatment, EO.1998.14.24-2; (c) top dance costume after treatment, EO.1998.14.24-2 (Courtesy of A. De Paepe, Collection of Royal Museum for Central Africa, Tervuren©).

Witte (1897–1980), who is also the photographer of the picture. His images are an invaluable source for the conservator because they give a notion of how the costume was worn and therefore how it can be displayed. The costume is made with an open structure knotting technique from twisted plant fibers.

When the costume was taken out of the storage area, it became clear that it had lost much of its former glory. The costume had several large losses (fig. 5a). Displaying the costume on a bust while in such bad shape was not an option, because it would cause further tearing. After a thorough examination and a discussion with the curator, it was decided to stabilize the costume and fill the losses to improve readability of the piece.

The creases in the costume were flattened using local humidification with ultrasonic cold steam. A fill was made from Japanese tissue colored with Solophenyl dye by dipping the tissue twice in the dyebath for 30 seconds. Subsequently, the tissue was twisted, twined, and multiple pieces were knotted, imitating the technique that was used to create the costume. This fill was sewn onto a support of silk crepeline with polyester yarn (fig. 5b). As a final step, the fill was attached to the dance costume by sewing the crepeline onto the edges of the gap (fig. 5c).

3.1.2 Burial Mat

Japanese tissue was also used to stabilize a burial mat (EO.0.0.29227) that is made from stiffer, flat strips of yellow and red plant fibers woven into intricate patterns. The iconography on the burial mat refers to the burial rituals of the Bwende people in the northern region of the Democratic Republic of Congo. Pictures show the condition of the mat when it was registered in the museum in 1926 (fig. 6a). Years of improper storage (the mat was tightly rolled onto itself in a very dry environment) has resulted in an extremely dry, brittle,

Fig. 6. (a) Burial mat in 1926, EO.0.0.29227 (Collection of Royal Museum for Central Africa, Tervuren©); (b) burial mat, EO.0.0.29227 (Courtesy of Jo Van de Vyver, Collection of Royal Museum for Central Africa, Tervuren©).

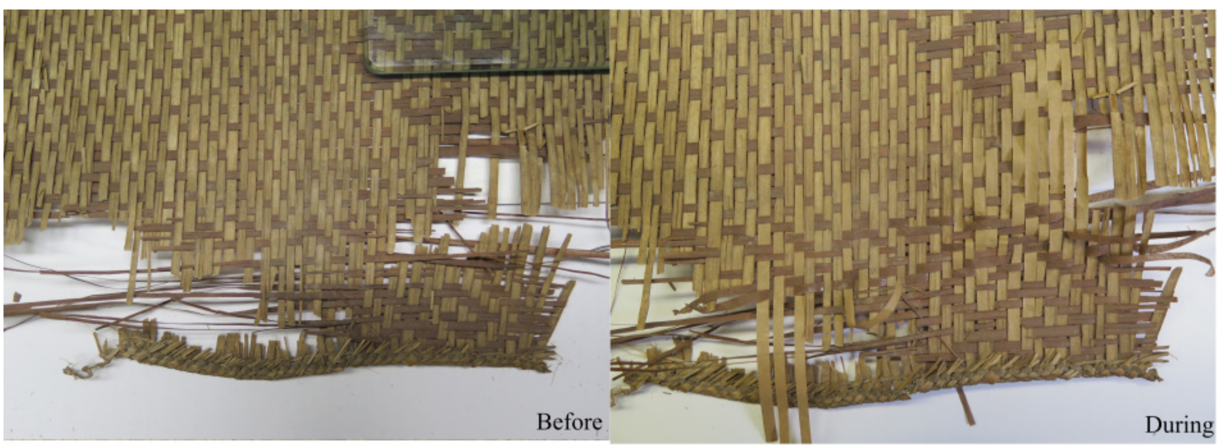

Fig. 7. (a) Burial mat before treatment, EO.0.0.29227; (b) burial mat during retreatment, EO.0.0.29227 (Courtesy of A. De Paepe, Collection of Royal Museum for Central Africa, Tervuren©).

and deformed object from which several fibers were broken or lost (fig. 6b). The extant fibers were cleaned with a vacuum cleaner and latex sponge, after which the mat was flattened with the Gore-Tex humidification method. Once the mat was relaxed, strips of Kozo Japanese tissue were colored with GOLDEN Fluid acrylic paint. Two strips were adhered with wheat starch paste to mimic the thickness of the original plant fiber. These strips were then woven into the burial mat to bridge the edges of the lost material. The most labor-intensive and time-consuming task was the weaving of the strips. The woven pattern was complicated; therefore, it was not always easy to find the correct placement of the completely detached pieces of the burial mat, especially along the edges (fig. 7). After treatment, the mat was mounted on a board (made out of a wooden frame, foamboard, polyester fiber, and a textile layer) for exhibition.

3.1.3 Yaka Mask

A mask (SJ.1327) worn by the Yaka people in the southwest region of the Democratic Republic of the Congo was a second object that received treatment involving a weaving technique with Japanese tissue (fig. 8). Unlike

Fig. 8. Yaka mask, SJ.1324 (Courtesy of A. De Paepe, Collection of Royal Museum for Central Africa, Tervuren©).

the burial mat, this mask is made from a very fine woven structure, which has the appearance of a flexible cloth. The mask had losses and damage in the frontal area and needed to be stabilized before it could be displayed on a mount.

The area where the mask was damaged was made of woven plant fibers. Small irregular strips of Solophenyl-dyed Japanese tissue were created, which were used to weave a plain-woven fill. Unfortunately, the resulting tissue turned out to be too weak to be used as a structural fill. A stronger fill was created by using a combination of Japanese tissue and cotton. Very fine irregular strips of Japanese tissue were integrated into a support fabric of toned, pure cotton medical gauze, mimicking a woven textile. This combination of woven materials resulted in an extremely lightweight and flexible tissue. This woven fill was placed inside the mask and all remaining loose plant fibers were attached to this tissue with a highly diluted wheat starch paste (fig. 9a). The fill was further reinforced with small "Frankenstein" mends, which are twined strips of Japanese tissue (fig. 9b) (Florian, Kronkright, and Norton 1990). These Japanese tissue mends were also adhered with wheat starch paste.

3.1.4 Drum

The next object that received a treatment with Japanese tissue is a trapezoidal wooden split drum (MO.0.0.27782), also known as an idiophone drum (fig. 10). This type of drum is called a *lukumbi* or a *nkumvi* and appears in different places in the Democratic Republic of the Congo (Central Basin, Maniema, Kasai, Katanga, Kivu and Kwango). The drum is composed of a piece of wood, probably one single hollow tree trunk. A narrow slit carved along the top of the drum acts as the sound opening. The drum is struck with two drumsticks on the left and right side ends of the drum. This instrument was used as a tool for communication in tone language cultures and as an entertaining musical instrument.

The drum arrived at the conservation laboratory with a broken shoulder strap. The strap is composed of a long, strong and wide, but flat plant fiber (fig. 11a). The strap was broken into several pieces and was splitting. Since the damage was old, the broken fibers were deformed and needed to be relaxed. A topical treatment with ultrasonic cold steam brought the fibers back to their original shape. Subsequently, in order to stabilize the plant fibers and to unify the piece, a supporting layer of Kozo was applied to the back of the existing fibers using wheat starch paste. To mimic the appearance of original plant fiber, the Kozo tissue was first toned with GOLDEN acrylics before application (fig. 11b).

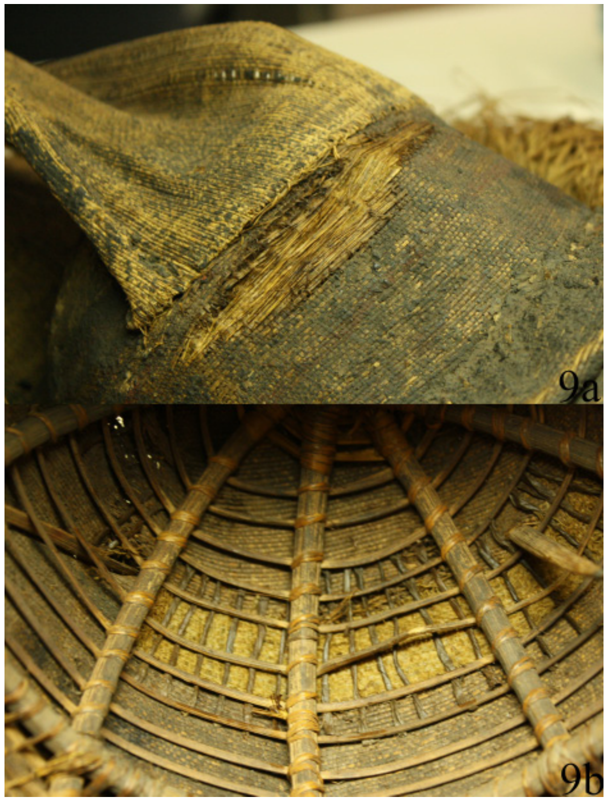

Fig. 9. (a) Detail of filling Yaka mask, SJ.1324; (b) detail of Frankenstein mends Yaka mask, SJ.1324 (Courtesy of A. De Paepe, Collection of Royal Museum for Central Africa, Tervuren©).

Fig. 10. Drum, MO.0.0.27782 (Courtesy of A. De Paepe, Collection of Royal Museum for Central Africa, Tervuren©).

Fig. 11. (a) Drum before the treatment, MO.0.0.27782; (b) drum after the treatment, MO.0.0.27782 (Courtesy of A. De Paepe, Collection of Royal Museum for Central Africa, Tervuren©).

3.2 CELLULOSE PULP

A group of objects were treated with cellulose pulp from the brand Arbocel. Arbocel is a powdery material made from 100% cellulose. It exists in different varieties, but in the conservation laboratory of the RMCA, Arbocel BWW 40, PWC 500 and BC 1000 are used. The differences between these types of cellulose pulp can be found in their fiber length and their pH value. The PWC 500 is a fairly neutral cellulose powder with a pH of 7. The pH value of the BWW 40 and BC 1000, on the other hand, is slightly acidic. The full outcome of the Oddy test can be found in table 2. In brief, the lead coupon of the Arbocel BWW 40 oxidized slightly but no powdery white corrosion was observed. This result was expected since Arbocel BWW 40 is the most acidic cellulose powder, with a pH value of 4.

3.2.1 Gitenga Mask

The Arbocel cellulose powder was used to fill a gap on a Gitenga mask (EO.1980.2.1162) that was worn at the Mukanda rituals by the Pende people (fig. 12). The mask is made from a skeleton of branches covered with a woven textile made from plant fibers. At the bottom of the front of this woven sheet, there was a large gap. The mask has two protruding eyes that are made from woven twigs and are attached to the woven textile with cord. Around the right eye was another gap that caused the eye to sag (fig. 13). To stabilize the mask and to improve the readability, a support fabric for the entire front of the mask needed to be made. A linen fabric was selected, because it fit the best with the original material. The linen was dyed with Solophenyl and was sewn with cotton thread onto the round branch on the inside of the mask. To visually compensate for the losses, however, a flexible material with a similar structure needed to be made.

Fig. 12. Gitenga mask, EP.0.0.11531 photo A. Scohy (Courtesy of Royal Museum for Central Africa , Collection of Royal Museum for Central Africa, Tervuren©).

Fig. 13. Gitenga mask, EO.1980.2.1162 (Courtesy of J. Van de Vyver, Collection of Royal Museum for Central Africa, Tervuren©).

Fig. 14. Detail of the fill (Courtesy of A. De Paepe, Collection of Royal Museum for Central Africa, Tervuren©).

After careful testing, it was decided that using a casting material and a silicone mold was the best option to create a fill with the desired properties. Consequently, a new piece of woven plant fiber with a similar structure as the woven textile of the mask was impregnated with Paraloid B72 to avoid sticking to the mold material. Silicone rubber was spread out over the impregnated textile. Once cured, the silicone mold could be released from the textile.

A conservation-grade casting material was made from a mixture of Arbocel PWC 500, two varieties of Lascaux acrylic emulsion adhesives [303 and 498HV (1:1)], and pigments. After testing different types of Arbocel cellulose powder, Arbocel PWC 500 was chosen. This type had good results in the Oddy test and it has a neutral pH value. Furthermore, it gave the best result when used in combination with the mixture of Lascaux. The two Lascaux adhesives are commonly used in textile conservation, mostly in a mixture. They are thermoplastic acryl adhesives that are created from a vinyl polymerization (Tímár-Balázsy and Eastop 2011).

This mixture was spread over the previously made silicone mold. When cured, the mold was removed. The outcome was a thin, flexible, and lightweight sheet with a similar structure to the front of the mask. The color was further adjusted by using raw pigments dispersed in Lascaux adhesive as binder. The filling was attached to the dyed linen backing fabric using a mixture of the two Lascaux adhesives (1:2). The textile of the mask was secured to the support with a few stitches of silk thread (fig. 14).

3.3 ARCHIVAL-GRADE PAPER

Archival-grade paper is a paper made from 100% cellulose with a neutral or slightly basic pH. This paper is often used to create passe-partouts and backings for fragile paper artworks, but the paper can also be used to compensate losses in flat branches and to support thick plant fibers that need a stronger support. There is a large variety of different archival-grade papers on the market. The RMCA laboratory uses Renaissance paper and Moorman paper for this type of treatment.

Fig. 15. (a) Skirt, EO.0.0.17317 (Courtesy of J. Van de Vyver, Collection of Royal Museum for Central Africa, Tervuren©); (b) detail of skirt after the treatment, EO.0.0.17317 (Courtesy of S. Genbrugge, Collection of Royal Museum for Central Africa, Tervuren©).

3.3.1 Matadi Dance Costume

A skirt from a dance costume (EO.0.0.17317), is originated from the region of Matadi, a seaport on the Congo river. The skirt, which dates from the early twentieth century, was used during dances performed by boys from Mayombe who were trained in the *Khimba* initiation school. The skirt is made from raffia fibers that are attached to a thicker waistband made from plant stems. The skirt was stored flat on a shelf for many years. As a result, all of the raffia fibers were deformed, and the waistband of the skirt was broken and had a substantial loss (fig. 15a). The skirt was to be displayed with a hidden mount; therefore, it was important to restore the waistband of the skirt so that it could be used to attach the mount.

The skirt was placed in a humidification tent until the lighter-weight fibers relaxed. Once the fibers were reshaped, the waistband of the skirt was treated. Strips made from thick Moorman 400 g paper were cut into bands of the same width as the existing plant fibers of the waistband. The strands were toned with GOLDEN Fluid acrylics to match the color of the existing fibers. The strips were then attached to the existing fibers using Paraloid B72 in a 20% solution with acetone-ethanol (fig. 15b).

4. CONCLUSIONS

Japanese tissue, cellulose powder, and conservation-grade archival paper have become staple materials in the conservation laboratory at the RMCA. The variety of papers and cellulose pulp available on the market makes these materials ideal resources for loss compensation on ethnographic objects. Their appearance and characteristics can be further adjusted by the application of a dye, paint, or adhesive coating to the surface or through the integration of other materials such as medical gauze into the paper-based material.

Paper-based materials have often proven to be an excellent solution for the treatment in the diverse collection of the Royal Museum for Central Africa, where conservation is truly cross-disciplinary between object, textile, and paper conservation.

ACKNOWLEDGMENTS

We would like to thank the American Institute for Conservation for giving us the opportunity to present our findings at the 46th Annual Meeting in Houston, Texas. Furthermore, we would like to express our gratitude to the Foundation of the American Institute for Conservation for their generous grant to travel to Houston. Last, but not least, we would love to thank our colleagues for their help and support, especially An Cardoen, Anne Welschen, and Jo Van De Vyver for providing the photographs and to Marijke de Bruijne for the work that she accomplished on the burial mat during her internship at the RMCA.

APPENDIX

Table 1. Materials Analyzed with the “3-in-1” Oddy Test

		Results			
Japanese Tissue	**Dye/Paint + Adhesive**	**Ag**	**Pb**	**Cu**	**Samples**
Control	C	P	P	T	N/A
KOZO K37	N/A	P	P	T	No change
KOZO K37	Solophenyl	P	P	T	The color has faded
KOZO K37	GOLDEN Acrylics Fluid	P	P	P	Sample was stuck in the test tube
KOZO K37	Derwent Artists color pencils	P	F	T	No change
KOZO K37	GOLDEN Acrylics Fluid + wheat starch paste	P	P	T	The sample was curling
KOZO K37	Solophenyl + Klucel G	P	P	T	The color has faded

Table 2. Materials Analyzed with the "3-in-1" Oddy Test

		Results			
Cellulose pulp	**Adhesive + Additives**	**Ag**	**Pb**	**Cu**	**Samples**
Control	C	P	P	T	N/A
Arbocel BC 1000	N/A	P	P	T	No change
Arbocel PWC 500	N/A	P	P	T	No change
Arbocel BWW 40	N/A	P	T	P	No change
N/A	Lascaux 303 HV	P	P	T	Very tacky, less transparent
N/A	Lascaux 498 HV	P	P	T	Yellowed
N/A	Lascaux 303 and 498 HV (1:1)	P	P	T	Yellowed, tacky
Arbocel BC 1000	Lascaux 303 and 498 HV (1:1)	P	P	T	Yellowed
Arbocel PWC 500	Lascaux 303 and 498 HV (1:1)	P	P	T	No change
Arbocel BWW 40	Lascaux 303 and 498 HV (1:1)	P	P	T	No change
Arbocel PWC 500	Lascaux 303 and 498 HV (1:1) + pigments	P	P	T	No change

NOTES

[1] Gore-Tex is made out of a membrane that is composed of polytetrafluoroethlylene (CAMEO 2016).
[2] Mylar is a transparent sheet, made of polyethylene terephthalate. It is chemically inert without plasticizers (Boersma et al. 2000).
[3] KOZO K-37 has a weight of 19 g/m^2 and a pH value of 8.1. To create the paper, calcium hydroxide ($Ca(OH)_2$) was used and it was dried on stainless steel (La Route du Papier 2018)

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SOURCES OF MATERIALS

Arbocel BWW 40, PWC 500, and BC 1000; GOLDEN Fluid Acrylics; Klucel G; Lascaux HV 303 & 498; Silikonabformmasse Mblau; Paraloid B72

Kremer Pigmente GmbH & Co.KG
Haptstr. 41 – 47
DE 88371 Aichstetten
Tel: +49 7565 91448 0
Fax: +49 7565 1606
www.kremer-pigmente.com/en

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https://www.laroutedupapier.com/catalogue

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Pampuslaan 125
NL 1382 JM Weesp
Tel: +31 294 41 39 51
Fax: +31 294 41 42 57

AUTHOR BIOGRAPHIES

ANOEK DE PAEPE is an object conservator at the Royal Museum for Central Africa (RMCA) in Tervuren, Belgium. As the museum was being renovated, she was working on preparing the objects for the reopening of the museum. In 2016, she received her master's degree in conservation and restoration of textiles from the University of Antwerp. During her studies, she did internships at the Fashion Museum of Antwerp and at the Design Museum of Ghent. Furthermore, she has researched the degradation of white glass beads on African objects. Address: Leuvensesteenweg 13 Tervuren, BE-3080. Email: anoek.depaepe@africamuseum.be.

SISKA GENBRUGGE is head of conservation at the Royal Museum for Central Africa (RMCA) in Tervuren, Belgium. Prior to her appointment at the RMCA, she was assistant objects conservator at the Los Angeles County Museum of Art (LACMA). Siska completed her master's degree in conservation as a Fulbright scholar at the University of California, Los Angeles (UCLA)/Getty Conservation Program. She also holds a master's degree in art history from the Katholieke Universiteit Leuven (KUL), Belgium. Address: Leuvensesteenweg 13 Tervuren, BE-3080. Email: siska.genbrugge@africamuseum.be.

MARIEKE VAN ES graduated from the University of Antwerp, where she received her master's degree in conservation and restoration. After graduating, she worked at the Fashion Museum in Antwerp. Since 2014, she has been working at the RMCA, where she prepared objects for the renovated museum. Address: Leuvensesteenweg 13 Tervuren, BE-3080. Email: Marieke.vanes@africamuseum.be.

THE HIDDEN CODEX: AN INTRODUCTION TO TEZCATLIPOCA'S SMOKING MIRROR

KELLY H. GROSS

ABSTRACT—This paper discusses the loss of cultural heritage, including the history and religion of the indigenous Mixtec people and its impact on Mesoamerican studies, through the examination of a newly introduced original Mixtec codex, named the Hidden Codex. Historically significant artifacts are being overlooked and their cultural heritage lost—the Hidden Codex is a case in point. This artifact has largely been discounted as a reproduction and has been only recently studied historically and analytically. It now represents the only Mixtec divinatory almanac, referred to as a Tonalamatl, known to exist. This paper explores the Hidden Codex research and presents an objective picture of the evidence, including provenance documents of source location and history. Opposing viewpoints are also presented. Insight is provided into the codex's cultural use of pictorial calendar-based events and rituals. Finally, the results of energy-dispersive X-ray spectroscopy and other forms of analytical testing are presented along with a discussion of the indigenous construction and its importance historically. The significance of this research is that it presents what possibly could be the only known codex that was never in the hands of the Spanish as well as presenting the possibility that the indigenous people continued to practice their religion under Spanish occupation, contrary to popular opinion.

EL CÓDICE ESCONDIDO: UNA INTRODUCCIÓN AL ESPEJO DE HUMO DE TEZCATLIPOCA

RESUMEN—Este trabajo versa sobre la pérdida de patrimonio cultural, incluida la historia y religión de la la gente Mixteca, población indígena, y su impacto en los estudios Mesoamericanos, a través del examen de un documento recientemente revelado, el Códice Secreto, de origen Mixteca. Un problema es que artefactos con relevancia histórica han sido históricamente ignorados, y como consecuencia, tal patrimonio cultural se está perdiendo. El Códice Secreto se incluye entre tales artefactos, en riesgo de perderse. Dicho Códice ha sido ignorado previamente, al ser considerado una reproducción, y sólo en fechas recientes se han hecho análisis históricos y científicos. Es, a la fecha, el único ejemplo conocido de almanaque adivinatorio, o Tonálamatl. La presente investigación relacionada con el Códice Secreto muestra evidencia objetiva, incluyendo datos relacionados con su origen e historia. También se presenta evidencia que contrasta con dichos datos. Incluida en esta investigación está la investigación de pictogramas conectados con el uso cultural del Códice así como eventos calendáricos y rituales. Por último, los resultados de Espectroscopía de Dispersión de Rayos-X (EDS, por sus siglas en inglés), y otras formas de análisis instrumental se presentan en conjunto con la construcción indígena y su importancia histórica. La importancia de esta investigación radica en que éste, es probablemente el único códice que jamás estuvo en manos españolas. Asimismo, es posible que el documento haya sido usado por la población mixteca, incluso durante la ocupación española, contrario a la creencia popular.

1. INTRODUCTION

The Hidden Codex, seen in figure 1, was named by the author to focus on the importance placed on it by its creators since it is the only codex that was concealed from the Spanish. This is illustrated by the fact that it was never confiscated and remained in the hands of the Mixtec until 1913 (Smithsonian 1913). The original Mixtec title is likely "Tezcatlipoca's Smoking Mirror."

Fig. 1. The Hidden Codex composite image of pigment testing sample sites (Courtesy of McCrone Associates).

This artifact is a single work on plaster and fiber mat, measuring 122cm by 30.5cm. The codex has been carbon dated between 1630 and 1680 CE (Beta Analytic 2003). It is fully illustrated in vivid color. The pigments were made from natural materials in the La Mixteca region of Oaxaca in Mexico (McCrone 2012). Since its recent discovery, it has been well researched and is being submitted here for further study and analysis.

The Mixtec people of Oaxaca established a dynasty around the city of Tilantango (Terraciano 2001). They were known for their works of art and colorful pictorial record documents known as codices. At the height of their influence prior to the Spanish conquest, they numbered over 1.8 million.

From the period of 200 BCE to the eighth century CE, the Zapotec people flourished in their largely agrarian society in the central region of Oaxaca and may have some shared cultural influences with the ancient Olmec and Maya civilizations. The Mixtecs migrated south from what is currently southern Guerrero to the central valley of Oaxaca. Their influence expanded to the point that they began displacing Zapotecs. From 1100 to the 15th century, they gained preeminence in the Oaxaca Valley. In the mid-15th century, the Aztecs invaded and made vassal states of the Mixtecs and Zapotecs. Both the Mixtecs and Zapotecs resisted; by 1486, however, they were required to pay tributes to the Aztec. This situation endured until the arrival of the Spanish in 1521 (Schmal 2006).

A Mixtec codex is rare, as there are only eight known Mixtec codex artifacts in the world, all in European museums. The Hidden Codex, however, represents the *only* Mixtec divinatory almanac, or cultural religious document, known to exist.

Extant authenticated Mixtec codices comprise genealogic information, property records, or event recording. The codices were also used to present religious and cosmological information, including myths, ceremonies, and beliefs passed down from one generation to the next (Terraciano 2001).

A divinatory almanac codex is used in religious practice and is referred to as a Tonalamatl (pronounced *tow-NAAL-a-mot*). The Tonalamatl is a religious manual used by a priest like a horoscope to predict futures and preside over holiday rituals. There are known Aztec examples of a Tonalamatl, but none from the Mixtec culture is currently known to exist.

The Hidden Codex portrays five deities in the major festivals. The four major festivals are related to the 365-day solar calendar and fall on the equinox and solstice periods. The fifth deity is portrayed conducting the New Fire Ceremony marking the completion of the 52-year Maya Calendar Round cycle synchronizing the 365-day solar calendar with the 260-day ritual calendar.

The borders are segmented with the traditional 13-day pictorial sequencing seen similarly in many of the other eight known Mixtec codex examples. The Mixtecs divided their 260-day years into 20 weeks of 13 days each. There are 20 valid Mixtec day signs to populate each of the available 13-day slots on each page. The Aztecs also have 20-day signs but are different in design and difficult to compare to the Mixtecs.

Ideally, other researchers would continue to expand on the initial research contained in this paper. Instead, adherence to a traditional orthodoxy that no new codex artifacts can be discovered has led to a doctrine that risks the loss of cultural heritage.

2. THE HIDDEN CODEX DESCRIPTION

The Hidden Codex contains five panels of major deities and their actions. Four are panels relating to the four seasons of the year surrounded by cells containing individual day signs in the traditional 13-day trecena pattern. The fifth scene depicts the 52-year New Fire Ceremony and is also outlined with a 13-day trecena border.

The first panel in the Hidden Codex, figure 2, is replicated in other codices—notably, the Aubin Tonalamatl and Borbonicus. This panel depicts the Spring Equinox ritual called the Festival of Flayed Men in honor of Xipe Totec (Our Lord the Flayed One), the Red Aspect Tezcatlipoca seated on the step fret throne platform. The step fret is a familiar motif in pre-Columbian culture signifying power (Frassani 2017). The main subject of panel 2, seen in figure 3, portrays the Mixtec Quetzalcoatl wind deity named Nine Wind Flint Helmet. The deity is in the aspect of the White Tezcatlipoca for the festival of the autumnal equinox. Panel 3, seen in figure 4, portrays the festival held in honor of the rain deity Tlaloc, performed at the winter solstice. Panel 4 in figure 5 shows the Blue Aspect Tezcatlipoca aspect named Huitzilopochtli, representing the Festival of the Banners held during the summer solstice.

The first page of the double-wide panel 5, figure 6, depicts the Smoking Mirror, the Black Tezcatlipoca, performing the 52-year New Fire Ceremony, which includes a sacrificial ritual. The second page of the double-wide panel 5, figure 7, portrays individual sacrifices with eyes closed, signifying death. Close inspection shows that the sacrifices are pictured not as identical but, instead, some care was taken in painting so that each bears some individual feature.

Fig. 2. The Hidden Codex, panel 1.

Fig. 3. The Hidden Codex, panel 2.

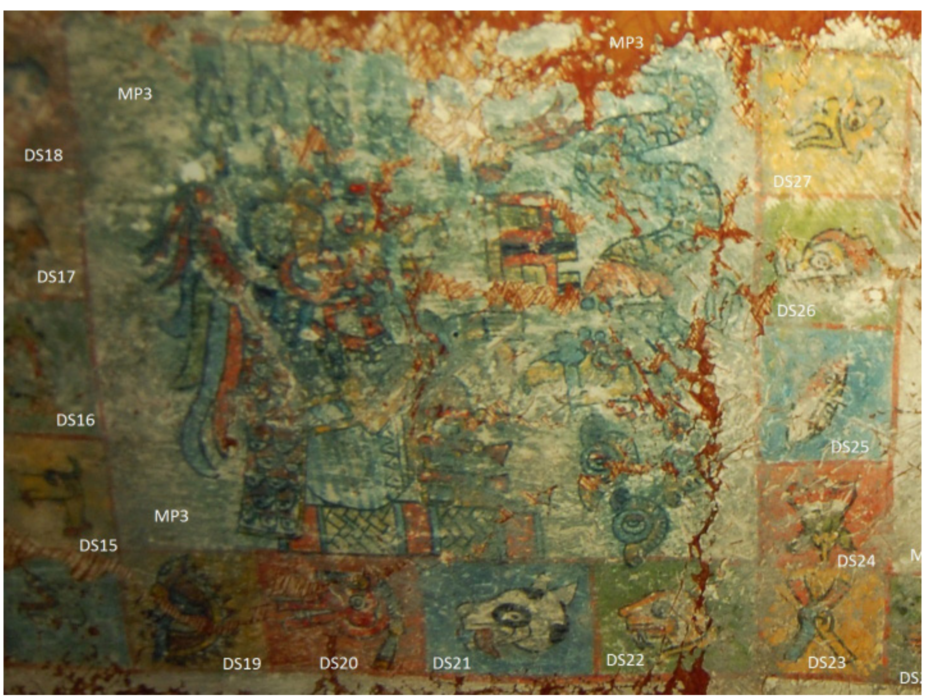


Fig. 4. The Hidden Codex, panel 3.

Fig. 5. The Hidden Codex, panel 4.

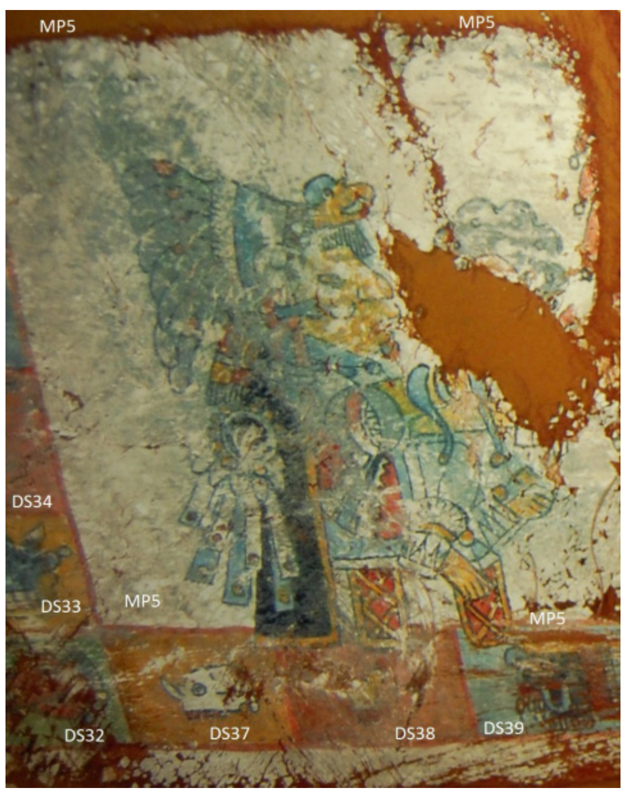


Fig. 6. The Hidden Codex, panel 5a.

Fig. 7. The Hidden Codex, panel 5b.

It is useful to make approximate comparisons to the extant historical and genealogical Mixtec codices, for there are similarities in the day signs. Some panels and deities portrayed in Aztec codices bear a resemblance to Mixtec codices, including the Hidden Codex, suggesting a common origin to many components of the Mesoamerican belief system.

There is evidence to suggest that the indigenous people of Mesoamerica continued to practice their religion past 1700 CE and even well into the colonial period. Divinatory almanacs were still being used by the K'iche' Maya people of highland Guatemala after the conquest, ca. 1700, as suggested by Francisco Ximénez (Vail and Aveni 2009), who describes books with divinatory calendars as having "signs corresponding to each day."

The mountainous land in Oaxaca has contributed to the cultural diversity of the Mixtec. As a result, many towns were isolated for long periods and developed and maintained their languages and ancestral traditions intact well into the colonial era and, to some extent, to the present day (Schmal 2006).

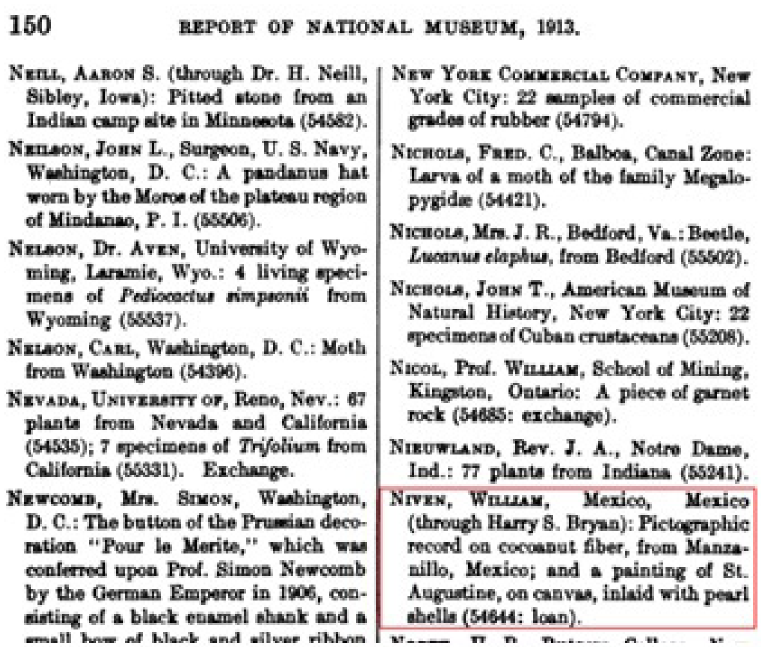
3. HIDDEN CODEX HISTORY

The history of the Hidden Codex begins in the Central Highlands of Mexico. The indigenous Mixtec people who mainly inhabited the region known as La Mixteca of Oaxaca were well known for their pictographic writing and artisans who created gold objects along with other works of art. The Hidden Codex was created between 1630 and 1680 and is presumed to have been used in religious practice until the 18th century.

The codex traveled an unlikely path to get to the United States. Two individuals were involved in bringing the codex into the country. Major Harry S. Bryan (1861–1942) is one of the individuals responsible for importing the codex into the United States. Bryan was a person with influence and ties to power. He was a major in the Ohio National Guard and was a veteran of the Spanish American War (*The Times Recorder* 1942). He was reported to be with U.S. Army Intelligence in Mexico City from 1910 until 1925. During this time, he met with Mexican President Victoriano Huerta. He was reported to have close ties to, and had received gifts from, Francisco "Pancho" Villa, a major figure in the Mexican Revolution. Furthermore, Bryan bragged in a letter about his ability to get what he wanted from Lindley Miller Garrison, the U.S. Secretary of War under President Wilson (*The Daily Times* 1914). The other person responsible for importing the codex into the United States is William Niven (1850–1937), who was a mineralogist by trade and an archaeologist by passion. Born in Scotland, he arrived in the United States in 1879 and briefly worked as a mineralogist for Thomas Edison. From 1890 through 1894, he worked in Mexico to locate minerals (Walsh 1992), after which he turned his focus to archaeology. During an expedition in 1897 (Wicks and Harrison 1999), supported by the American Museum of Natural History, he discovered prehistoric ruins, now called Omitlan, in the state of Guerrero (Wicks 2010). In 1910, he discovered an ancient burial ground at Placeres del Oro, identified as belonging to the Nahua people (Wicks and Harrison 1999). Last, in 1911, he discovered and documented ancient cities buried under volcanic ash on top of one another just north of Mexico City.

Niven was a founding member of the New York Mineralogical Club, an honorary life member of the American Museum of Natural History, a member of the Scientific Society Antonio Alzate in Mexico, and a fellow of the American Geographic Society of New York and the Royal Society of Arts in London. In 1929 he moved to Houston, Texas, where he donated a large number of Mexican artifacts to the new Houston Museum and Scientific Society and served on its board of trustees. In 1931, he moved to Austin. He died there on June 2, 1937 and was buried in Mount Calvary Cemetery (American Journal of Archaeology 1897).

It is documented that Major Bryan made a trip to Washington, DC in 1913 (*The New York Times* 1913) and that he made donations and loans of hundreds of historical and religious artifacts to the Smithsonian Institution's United States National Museum. Included in the report of these accessions is an entry, seen in figure 8, indicating that the items were loaned to the Smithsonian in 1913 under accession number 54644 including a "Pictographic record on cocoanut fiber, from Manzanillo, Mexico." The entry lists William Niven as the donor through Harry S. Bryan and specifies it as a loan. This entry directly refers to the Hidden Codex



150 REPORT OF NATIONAL MUSEUM, 1913.

NEILL, AARON S. (through Dr. H. Neill, Sibley, Iowa): Pitted stone from an Indian camp site in Minnesota (54582).

NEILSON, JOHN L., Surgeon, U. S. Navy, Washington, D. C.: A pandanus hat worn by the Moros of the plateau region of Mindanao, P. I. (55506).

NELSON, Dr. AVEN, University of Wyoming, Laramie, Wyo.: 4 living specimens of *Pediocactus simpsonii* from Wyoming (55537).

NELSON, CARL, Washington, D. C.: Moth from Washington (54396).

NEVADA, UNIVERSITY OF, Reno, Nev.: 67 plants from Nevada and California (54535); 7 specimens of *Trifolium* from California (55331). Exchange.

NEWCOMB, Mrs. SIMON, Washington, D. C.: The button of the Prussian decoration "Pour le Merite," which was conferred upon Prof. Simon Newcomb by the German Emperor in 1906, consisting of a black enamel shank and a small bow of black and silver ribbon

NEW YORK COMMERCIAL COMPANY, New York City: 22 samples of commercial grades of rubber (54794).

NICHOLS, FRED. C., Balboa, Canal Zone: Larva of a moth of the family Megalopygidae (54421).

NICHOLS, Mrs. J. R., Bedford, Va.: Beetle, *Lucanus elaphus*, from Bedford (55502).

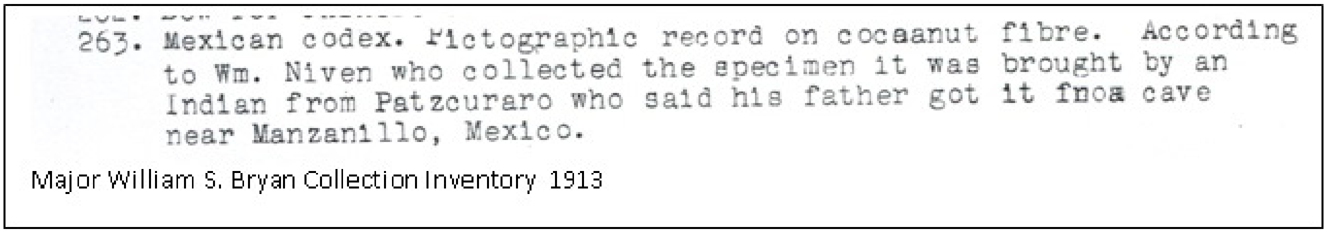
NICHOLS, JOHN T., American Museum of Natural History, New York City: 22 specimens of Cuban crustaceans (55208).

NICOL, Prof. WILLIAM, School of Mining, Kingston, Ontario: A piece of garnet rock (54685: exchange).

NIEUWLAND, Rev. J. A., Notre Dame, Ind.: 77 plants from Indiana (55241).

NIVEN, WILLIAM, Mexico, Mexico (through Harry S. Bryan): Pictographic record on cocoanut fiber, from Manzanillo, Mexico; and a painting of St. Augustine, on canvas, inlaid with pearl shells (54644: loan).

Fig. 8. Smithsonian inventory record of the Hidden Codex, 1913.


263. Mexican codex. Pictographic record on cocaanut fibre. According to Wm. Niven who collected the specimen it was brought by an Indian from Patzcuraro who said his father got it fnoa cave near Manzanillo, Mexico.

Major William S. Bryan Collection Inventory 1913

Fig. 9. Major Bryan inventory record.

as the "pictographic record" and proves that it was loaned to the National Museum in 1913. There is also a 1913 handwritten museum logbook that records the loaned collections from Major Harry S. Bryan. The logbook also specifies that the items were returned in 1936. The inventory record, seen in figure 9, was created by the Smithsonian, as part of the William S. Bryan Collection Inventory, when the collection was received in 1913. It describes the codex and its origins in detail (Smithsonian Institution 1913).

The original Major Harry S. Bryan inventory produced by the Smithsonian when many items were entered lists the following: "263. Mexican Codex. Pictographic record on cocoanut fibre. According to Wm. Niven who collected the specimen it was brought by an indian from Patzcuraro who said his father got it from cave near Manzanillo, Mexico" (Smithsonian Institution 1913).

4. PROVENANCE SUMMARY

The following is a summary of what is known of the provenance of the Hidden Codex.

- The artifact was voluntarily brought in and donated by indigenous Mesoamericans who had it in their possession. William Niven or Major Bryan had no reason to falsify the record to the Smithsonian. If they had purchased the item, it would likely have been recorded. Since the inventory specifies that it was "brought by an indian" and leaves out methods of payment and the like, it is impossible to speculate on alternate scenarios. It is known, however, that the indigenous people did consider these documents to be sacred and would not treat them carelessly since the inventory also specifies that the codex was handed down from father to son.
- The artifact was accepted by William Niven—a widely recognized archaeologist respected for preserving cultural heritage.
- Major Bryan and Niven worked together to deliver the codex to the Smithsonian Institution. It is not clear from currently available records why Major Bryan and Niven were associated. It is known that their association continued until 1921 (Walsh 1992).
- According to the inventory, long before it was brought in to the Smithsonian, the codex was moved across Mexico from its original location, to a cave near Manzanillo in the region of Western Mexico by the Mesoamerican people in an apparent effort to protect it from the Spanish. Also from the inventory, it was apparently retrieved from the Manzanillo cave and taken back across the country to Patzcuraro and passed from father to son until being presenting to Niven.
- The Hidden Codex was transported to Washington, DC. and loaned to the Smithsonian Institution.
- The codex remained with the Smithsonian until 1936, when it was sent with the loaned items from the Bryan collection to Major Bryan in Ohio. It is not known whether Major Bryan actually received the items or what may have transpired afterwards.

- In 1969, the codex was acquired by a private collector for a small sum from an art broker, which also included the Major Bryan Inventory listing the artifact. An LLC corporation was formed in 2012 that includes the original collector and other partners.

5. THE TONALAMATL: A DIVINATORY ALMANAC

The Hidden Codex is unique among Mixtec codices. All of the other eight known existing Mixtec codices portray information in two categories, either genealogical or historical. Genealogical codices describe marriages and alliances; historical codices are centered around conquest and property rights. Both types are sequential in nature.

As mentioned earlier, the Hidden Codex is a Mixtec pictorial record called a *Tonalamatl.* A Tonalamatl is described as a divinatory almanac, or a book of religious practices, and was used to orient certain discretionary events to the divine calendar and to predict the future. It was used in a fashion similar to today's horoscopes in making a personal astrological prediction.

The word *Tonalamatl* is an Aztec Nahuatl word meaning "Book of Days." *Tonal* refers to the order of things. In this case, it means the order of days. *Amatl* means "paper" or "paper book." The Tonalamatl is a working document organized in a cyclical order as opposed to the chronological sequential order seen in the other two types of codices. This document was used by a Mixtec priest in the field to perform such tasks as timing rituals, predicting the future, and determining if two people should be married based on their personal astrological aspects.

All of the Mixtec divinatory almanacs that portrayed religious information were systematically sought out, confiscated, and burned by the Spanish except for this one. There may be more yet-to-be-discovered examples; however, this is the only available one to date.

When the Spanish arrived in the Yucatan, they were welcomed and were shown the indigenous historical documents created by local artists and scribes. Friar Diego de Landa wrote in 1566, "We found a large number of books in these characters and, as they contained nothing in which were not to be seen as superstition and lies of the devil, we burned them all, which they regretted to an amazing degree, and which caused them much affliction" (Sharer 2006). These codices were sought out because they represented religious information.

6. THE SACRED COUNT OF DAYS MATH REVEALED

The layout of this document shows that it uses both the 365-day solar year and a 260-day ceremonial calendar based on calculations involving the synodic cycle of Venus. It has portions relating to the four seasons of the solar year and also portrays day sequences of 13 days called a *trecena*.

It is known that the significance of the number 13 is that it is the number of extra days added back into the calendar every 52 years during the New Fire Ceremony (Jeffries 2016). The New Fire Ceremony was an ancient and widespread ritual in Postclassical central Mexico. The Aztecs appropriated the New Fire Ritual and used it in their campaign of ideological control. This is one of the few rituals that can be documented both in the context of state and domestic religious practices (Elson and Smith 2001).

7. MATERIAL ANALYSIS

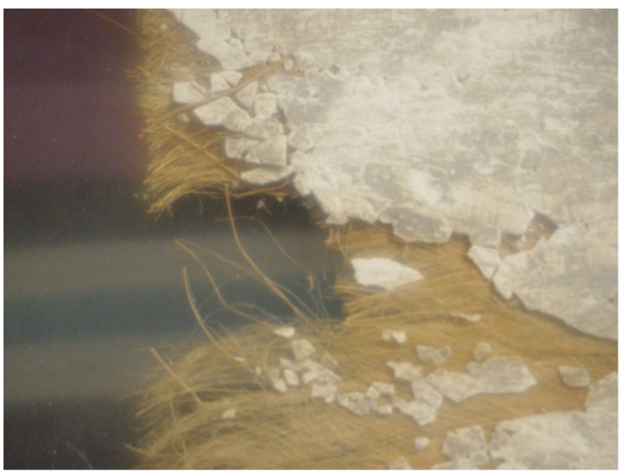
The following describes the results of analytical testing performed by Beta Analytics and McCrone Associates. Beta Analytics performed radiocarbon date testing in 2003 and McCrone performed pigment and background composition analysis in 2012. Samples were collected and sent to McCrone by the Intermuseum Conservation Association of Cleveland.

7.1 CARBON DATING

The plant fiber substrate in figure 10 was analyzed by Beta Analytic. The results indicate the age to be between 1630 and 1680 CE within a 95% probability (Beta Analytic 2003).

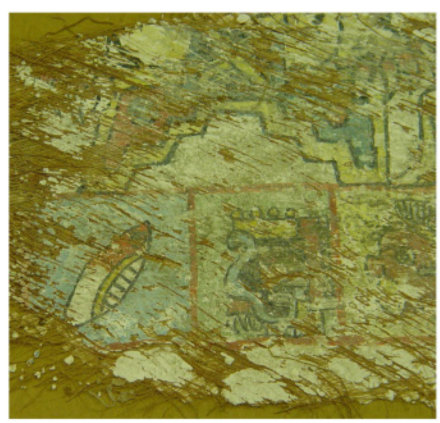
7.2 PIGMENT COMPOSITION

An ultraviolet study was conducted by Neil Steedy, as shown in figure 11. McCrone Associates conducted tests on nine samples, including the white ground layer, red, black, dark-blue, yellow, green, orange-brown, and light blue pigments, as well as the back-facing chalk surface. The tests performed by McCrone and Associates included energy-dispersive X-ray spectroscopy (EDX) to determine the composition of the pigment samples. EDX mass spectrograph test results by particle type can be seen in table 1.



Hidden Codex Fiber Substrate with carbon date sample extraction site

Hidden Codex Main Panel 2 detail



Hidden Codex Main Panel 1 detail

Fig. 10. Sample site for carbon date testing.

Fig. 11. Ultraviolet study image of codex surface.

Joseph G. Barabe, Director of Scientific Imaging at McCrone Associates, states the following: "These materials are unlike pigments used in conventional 18th century paintings. They may however, reflect traditional Central American materials" (McCrone 2006). Andrea Chevalier, Senior Paintings Conservator at Intermuseum Conservation Association, concludes, "From my examination of the codex, there were no obvious restorations or later applied materials which could have contaminated the surface. The analysis did not find any obviously modern materials" (Chevalier, 2006).

8. THE OPPOSITION CASE

The line drawing from the Codex Falsificado is a known forgery (Keller and Bruhns 2016) and is a poor facsimile of a codex because the day sign sequence of 13 is invalid since it does not total 13 in any configuration. Furthermore, the flint knife is misplaced, the significance of which cannot be overstated. The flint knife is a significant ritual marker used at the beginning and the end of the day-sign sequence, similar to Alpha and Omega in other cultures.

Because of their remote similarity regarding the basic festival deities, the Codex Falsificado and the Hidden Codex have likely been confused, causing some who may be familiar with the subject material to come to some hasty conclusions. In addition, the day signs and their order in the Codex Falsificado do not match those of the Hidden Codex.

Some experts have offered their opinion:

> "I do not believe it is an authentic codex painted by an indigenous artist trained in the native tradition ... Each day sign is enclosed in a red outline (which is usual) but in this document, the background of the

Table 1. Energy-Dispersive X-ray Mass Spectrograph Test Results by Particle Type

Element	Weight %	Atomic %
White from back surface		
C	15.07	23.88
O	50.03	59.49
Al	0.09	0.06
Si	0.26	0.17
Ca	34.55	61.40
Light Blue		
C	49.34	58.89
O	42.50	38.08
Na	0.017	0.011
Mg	0.10	0.06
Si	0.31	0.16
S	0.10	0.06
K	0.14	0.05
Ca	7.22	2.58
Fe	0.12	0.03
Orange-Brown		
C	27.89	42.86
O	42.21	48.69
Mg	0.12	0.09
S	2.49	1.44
Ca	11.77	5.42
Fe	0.33	0.11
Hg	15.19	1.40
Green		
C	22.09	31.24
O	55.88	59.32
Mg	0.12	0.08
Al	0.12	0.07
Si	0.27	0.16
Ca	21.53	9.13
Yellow		
C	9.97	22.13
O	21.34	35.56
S	1.57	1.31

(*Continues*)

Table 1. Energy-Dispersive X-ray Mass Spectrograph Test Results by Particle Type (*Continued*)

Element	Weight %	Atomic %
Ca	59.38	39.51
Fe	0.81	0.39
Cu	0.62	0.26
Hg	6.30	0.84
Black		
C	38.28	50.23
O	42.94	42.30
Al	0.17	0.10
Si	0.37	0.21
S	0.13	0.06
Ca	17.96	7.06
Fe	0.14	0.04
Red		
C	29.39	46.73
O	25.24	37.87
Al	1.33	1.18
Si	1.35	1.15
S	7.18	5.38
Ca	5.07	3.03
Fe	0.95	0.41
Hg	35.50	4.25
White ground		
C	10.54	18.69
O	42.14	56.09
Al	0.13	0.10
Si	0.42	0.32
Ca	46.41	24.66
Fe	0.37	0.14
Dark Blue		
C	4.57	11.56
O	14.52	27.61
Si	0.26	0.28
K	0.37	0.29
Ca	77.20	58.58
Fe	3.09	1.68

> cells are painted a different color. This use of different color backgrounds appears in no authentic codex" (Boone 2003).
>
> "In some cases the day signs are just made up. The day sign for rain for example is a combination of a rain god's mask and a butterfly. This is typical of an artist trying to "blur" his influences so that it wouldn't look like he was slavishly copying an original source ... I don't feel this is an original painting but rather an average attempt by a 19th-20th century artist to piece together something from several sources iconographically and make it look old" (Pohl 2003).

It has been written that ancient parchment without any writing or images was discovered in funerary caves in Mexico dating from the pre-conquest period. It has been theorized by experts (Pohl 2003) that these ancient blank sheets may have been used by later artists to apply a modern image in the 19th or 20th century. First, no such example of the blank paper has ever been recovered. It has only been mentioned that such items were found. Furthermore, there are no actual examples of ancient blank papers with modern images applied that have been introduced or studied. Second, the Hidden Codex is made of fig bark base substrate, seen in figure 10, not the parchment described in the cave find. Finally, McCrone conducted analytical tests on the pigments themselves and concluded that none of the pigments could be shown to have modern origins and the pigments and materials were consistent with the Central American traditional methods.

The codex analysis (Boone 2003) states that there were no authentic codices with cells of different-colored backgrounds. The Dresden codex, however, is well known and does include examples of cells with faint but distinguishable red and blue different-colored backgrounds, which is inconsistent with the previous statement.

9. CONCLUSIONS

The Hidden Codex has now been subjected to more physical tests, chemical tests, analytical tests, photomicrographs, radiography, and ultraviolet studies than any other codex in existence. The provenance has been recorded thanks to the documentation kept by the Smithsonian when it was loaned to the institution in 1913.

For all the reasons discussed, this artifact should be considered seriously in order to preserve possible irreplaceable cultural heritage.

http://www.hiddencodex.com

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AUTHOR BIOGRAPHY

KELLY H. GROSS is a five-year member of the American Institute for Conservation of Historic and Artistic Works and resides in Columbus, Ohio. He has served as the Midwestern Epigraphic Society Newsletter editor and is also responsible for several controversial articles and news photographs. Through his consulting work, Mr. Gross has been fortunate to engage with professionals in a variety of fields, including education, engineering, and business technology. Currently, Mr. Gross is in private practice and represents clients in health care, education, and information technology. Mr. Gross holds a bachelor's degree from the Ohio State University in Information Systems, and is a father and grandfather of 5. Address: 2626 Wildwood Rd. Columbus, OH 43231 Email: kellygross1@hotmail.com.

APPLICATION OF MULTISPECTRAL/MULTIBAND IMAGING IN THE PRACTICE OF TEXTILE CONSERVATION: DOCUMENTATION, INVESTIGATION, AND COMMUNICATION

KISOOK SUH

ABSTRACT—Among the many options in imaging techniques for examination of objects, multispectral/multiband imaging has not yet been fully explored for its use with textiles. Although multispectral/multiband imaging has limitations in providing conclusive information for material analysis, it provides valuable information about materials that cannot be captured with either visual examination or photography. This paper presents multispectral/multiband imaging as a stand-alone tool for examination and preliminary analysis of textiles. While this technique emphasizes the growing importance of image-based examination, image-based digital publication is suggested as a possible means for disseminating information and collective research.

APLICACIÓN DE IMAGEN MULTIESPECTRAL/MULTIBANDA EN LA PRÁCTICA DE CONSERVACIÓN DE TEXTILES: DOCUMENTACIÓN, INVESTIGACIÓN Y COMUNICACIÓN

RESUMEN—Entre las numerosas opciones de imagenología para el examen de objetos, las imágenes multiespectrales/multibanda no han sido exploradas en su totalidad en textiles. Pese a que esta técnica tiene sus limitaciones en proveer información conclusiva para el análisis de materiales, provee información de valor acerca de los materiales, que no puede ser captada en examen visual o fotografía. Este trabajo presenta imagen multiespectral/multibanda para el examen y análisis preliminar de textiles. Aunque esta técnica enfatiza la importancia del examen basado en imagen, la publicación de tales imágenes se sugiere como una manera posible de diseminar la información para promover investigación colectiva.

1. INTRODUCTION

Textile conservators have used various radiation sources, including x-ray and infrared, in the examination and documentation of textiles. UV radiation has also been used for examination but not commonly for photo documentation of textiles. Although the first publication on UV photography of textiles appeared in 1931 (Rorimer 1931), only recently has research on the subject been published (Borrego and Vega 2014).

The conservation field has commonly used the term "multispectral imaging" to describe the imaging technique that records reflectance and luminescence of objects under multiple radiation sources. Depending on the specific setup, bandwidths of radiation sources vary from a few nanometers to hundreds of nanometers. Imaging techniques that use calibrated narrower bandwidth radiation sources now tend to be called "multispectral imaging (MSI)" or "imaging spectroscopy" and those with uncalibrated wider bandwidth radiation sources, especially with use of modified digital cameras, are called "multiband imaging." However, the latter has also been called "multispectral imaging" as a part of the CHARISMA (Cultural Heritage Advanced Research Infrastructures: Synergy for a Multidisciplinary Approach to conservation and restoration) project (Dyer et al. 2013), to which this research is indebted. Therefore "multispectral/multiband imaging" is used to refer to the imaging technique in this paper.

Multispectral/multiband imaging with a digital camera provides a relatively simple and inexpensive method of acquiring reflectance and luminescence images of objects. Unlike other imaging techniques requiring specialized equipment, it uses a standard digital camera and imaging software programs, although spectral images can also be taken by separate equipment respectively and combined (Haldane et al. 2010). The technique can provide visual information in various colors and intensities. Quite different from reading quantified spectroscopic data, translating this noncalibrated visual information can be subject to many variables, including different conditions in capturing and processing images. In order to produce consistent visual information for precise documentation and further research by comparison, repeatability and standardization have been the keen interests of conservators and imaging specialists. The technique has often been paired with other analytical methods, most commonly high-performance liquid chromatography (HPLC). Other analytical techniques are also used to identify specific materials on textiles: fiber optic reflectance spectroscopy (FORS), and energy dispersive x-ray analysis with scanning electron microscopy (SEM-EDX) (Webb, Summerour, and Giaccai 2014; Dyer et al. 2018).

2. METHODOLOGY

The technical information involved in setting up the imaging station and capturing/processing images are from the AIC workshop (Chen and Kushel 2015), the AIC Guide (Warda et al. 2011) and the User Manual from the CHARISMA project (Dyer, Verri, and Cupitt 2013).

The multispectral/multiband imaging technique uses a modified standard digital camera and imaging software programs. A variety of spectral images are acquired by recording the reflectance and luminescence of a subject with combinations of radiation sources and lens filters.

A normal digital camera was modified by removing a filter that allows only visible light to pass. Due to the inherent sensitivity of a standard digital camera, it can cover from near ultraviolet (NUV or UVA, 320–400nm) to near infrared (NIR, 700–1000nm). For organic materials, only UVA is recommended because of possible damage caused by the strong energy in the UV range. The camera must be tethered to a computer with an imaging program.

In a space where light could be completely controlled, three different radiation sources were used: visible light from fluorescent lamps; infrared from tungsten lamps; and UVA from phosphor-coated, low-pressure mercury lamps with filtration. Although not adopted for this study, light-emitting diode (LED) lamps have greater potential for multispectral/multiband imaging because their radiation range can be modified by programming.

Four kinds of lens filters were used: visible band pass filter, UV/visible blocking filter, UV blocking filter, and UV band pass filter.

A set of color targets was necessary to produce consistent results in capturing and processing images: X-rite ColorChecker, Spectralon, and UV Innovations' Target-UV. In the CIE L*a*b* color space, each component has numerical color values: L* for the lightness; a* for the green-red; and b* for blue-yellow color components (Wikipedia 2018). L*a*b* value of these targets can be read through the image program Adobe Lightroom, chosen for this study as it is one of the few applications that provides a read-out of L* values. According to the L* value on the targets, exposure time was adjusted during capture. The targets were also necessary for processing the images after capture (fig. 1).

2.1 MULTISPECTRAL/MULTIBAND IMAGING

An imaging station was set up on an existing photo stand with necessary equipment and accessories in the Department of Textile Conservation at The Metropolitan Museum of Art (The Met) [1]. As standardization and

Fig. 1. A set of color targets. From left: X-rite ColorChecker, Spectralon, and Target-UV.

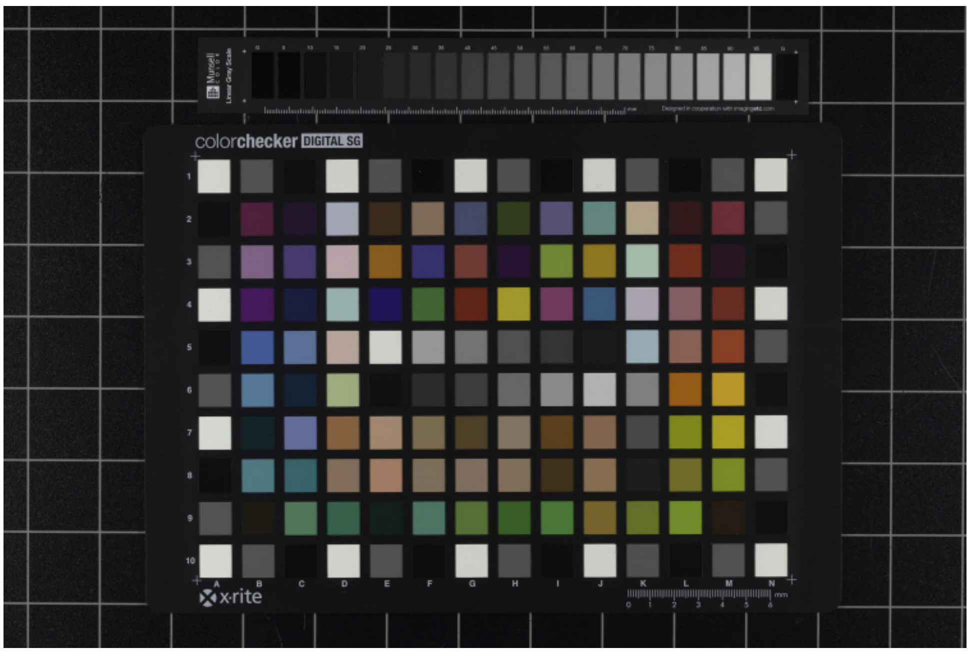

Fig. 2. X-rite ColorChecker Digital SG card and Munsell Linear Grayscale.

repeatability of imaging were critical in order to acquire consistent visual information, all steps involved in capturing and processing images followed a workflow developed by conservators and imaging specialists at The Met (Geffert et al. 2018). For scene referred capturing, the workflow uses targets to correct color and tone to achieve an image with repeatability regardless of the differences in camera, lens, and radiation sources used. All images were taken in RAW format for necessary further adjustments, including white balance and flat-field correction.

2.1.1 VIS: Visible Light Photography

In the Lightroom program, a color profile and tone curve were set validating the artwork reproduction standard by the International Organization for Standardization (ISO), ISO/TS 19264-1:2017, with the X-rite ColorChecker Digital SG Card and Munsell Linear Grayscale for visible light photography. The ISO specification applies to scanners and digital cameras used for digitization of cultural heritage material (ISO Online Browsing Platform). The profile and tone curve were subsequently applied to the images taken in the setup.

Visible light lamps were used with a visible band pass filter or IR and UV blocking filter. The L* value on the white step in the X-rite ColorChecker was used to determine exposure time (fig. 2).

2.1.2 UVL: UV-induced Luminescence Photography

Long-wave UV lamps were used with a UV blocking filter. The L* value on the correct white step in the Target-UV was used to determine exposure time. Depending on the intensity of luminescence, four options of scales are available in the Target-UV: low, medium, high, and ultra.

2.1.3 UVR: Reflected UV Photography

Long-wave UV lamps were used with a UV band pass filter. The L* value on the Spectralon was used to determine exposure time.

2.1.4 IRR: Reflected IR Digital Photography

Tungsten lamps were used with a UV/visible blocking filter as a visible/IR radiation source. The L* value on the black step in the X-rite ColorChecker was used to determine exposure time (fig. 3). This photography is taken only in the NIR range, different from the precedent "reflected infrared photography" or "infrared reflectography" taken in the 1,000 to 2,500nm range by electronic infrared imagers (Warda et al. 2011).

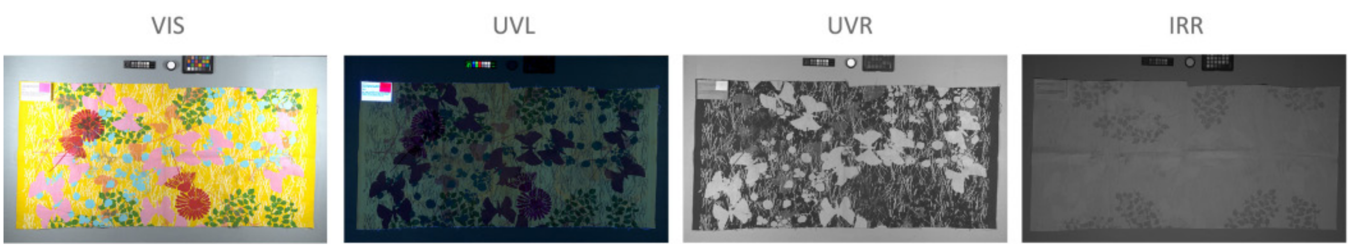

Fig. 3. VIS, UVL, UVR, and IRR of MMA 1985.198.157, textile fragment from Bauhaus Archive, 1920s to 1930s. Gift of Jack Lenor Larsen Inc., 1985.

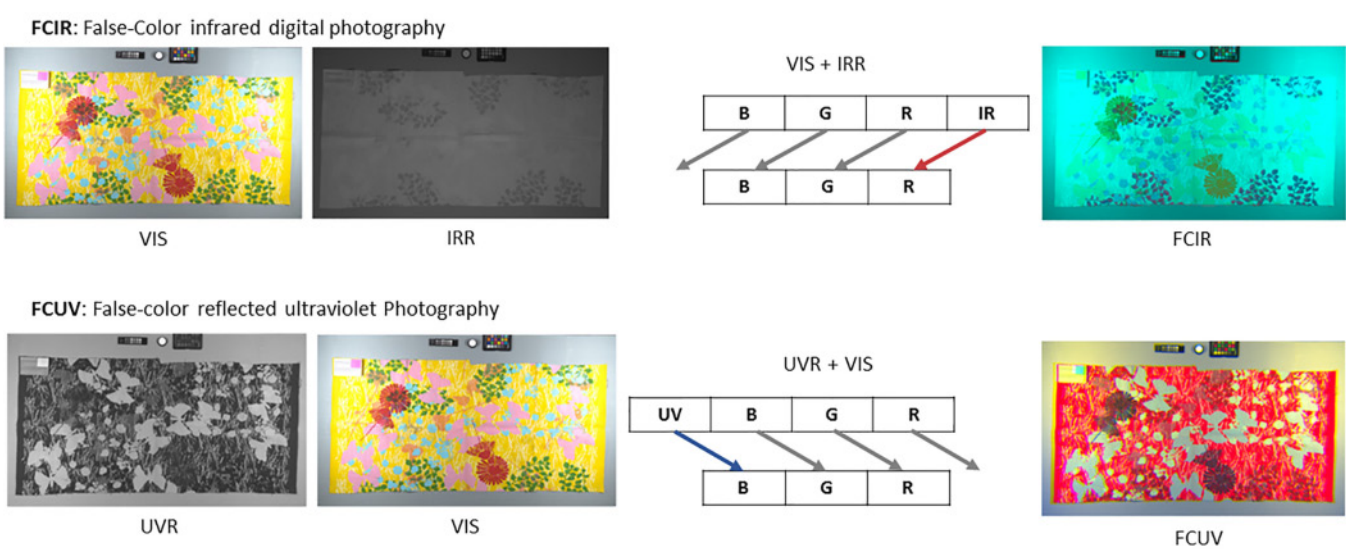

Fig. 4. Channel substitution procedure for FCIR and FCUV.

2.2 FALSE-COLOR IMAGING

The false-color imaging technique combines non-visible radiation images, UVR and IRR, with two visible light channels using a specific channel substitution procedure (fig. 4). This is an additional tool to characterize and differentiate materials similar in appearance when examined with VIS or UVL photography. False-color infrared digital photography (FCIR) and false-color UV photography (FCUV) use only three wavelength bands: RGB. They can be conveniently made by using the channel feature in the Adobe Photoshop program (Warda et al. 2011).

3. DISCUSSION

3.1 IMAGE-BASED EXAMINATION

With the universal use of digital technology, conservators have experienced a significant shift from object-based examination to image-based examination, with the now prevalent use of digital imaging techniques such as high-resolution images and photomicroscopy. Multispectral/multiband imaging provides an even wider scope of spatial data, or images, of materials and conditions of objects.

3.1.1 Differentiation and Characterization of Materials

IRR examination can easily detect and document the presence of underdrawings as well as metal threads. The x-ray image in figure 5 confirms the location of metal threads. IRR has been also used in enhancing obscured inscriptions and differentiating inks, dyes, and retouched areas (Warda et al. 2011).

UVL is powerful in detecting faded dyes and differentiating dyes by capturing unique luminescence of dyes after excitation under UV radiation. The original design of a textile fragment is much more legible in the UVL image in figure 6. The obscured design of figures on the proper left side of the fragment became clearer in the UVL image. Depending on the dyes, certain areas look darker by absorbing UV radiation and certain areas luminesce by emitting radiation after excitation. Because of their different reactions to UV radiation, the overall distribution of dyes and materials can be easily visualized with UVL. This visualized spatial distribution is useful in targeting areas for further analysis. Stains of organic substances, such as mildew and urine, showed noticeable luminescence by UVL. Areas contaminated with mildew luminesce in orange (fig. 7).

Fig. 5. VIS, IRR, and x-ray image of MMA 64.101.1271, cushion with Solomon and Sheba. Gift of Irwin Untemyer, 1964.

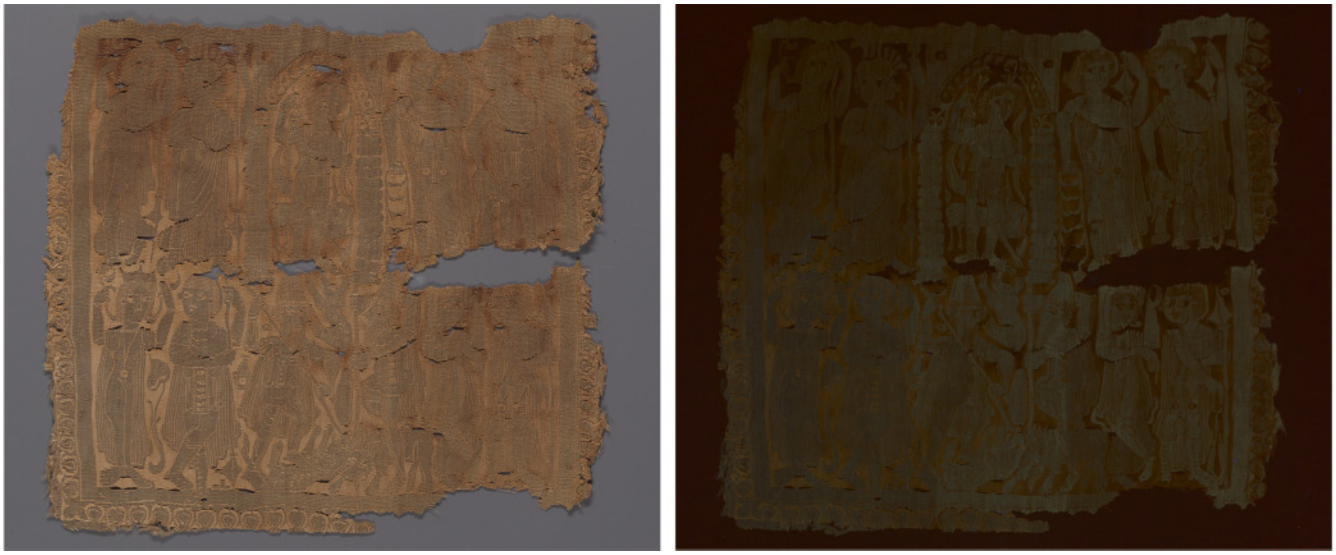

Fig. 6. VIS and UVL of MMA 2002.483.11, early Byzantine textile fragment, fourth to sixth century. Gift of Miriam N. Rosen, 2002.

Fig. 7. VIS and UVL of MMA 2015.796.28a, Indian textile fragment, 18th century. Bequest of Carolyn Kane, 2015.

UVR is effective in examination of surfaces. It enhances the visibility of many organic resins, gums, oils, varnishes, paint residues, and adhesives (Warda et al. 2011). The patches in figure 8 were removed from the back of a carpet by a colleague conservator, Julia Carlson, during conservation treatment in preparation for The Met's exhibition *Carpets for Kings: Six Masterpieces of Iranian Weaving* (March 3–August 27, 2018); adhesive residues on the patches were analyzed by Adriana Rizzo, research scientist at The Met. Natural rubber appeared dark while resin mixture appeared light in the UVR image because of the different reflectance of the materials.

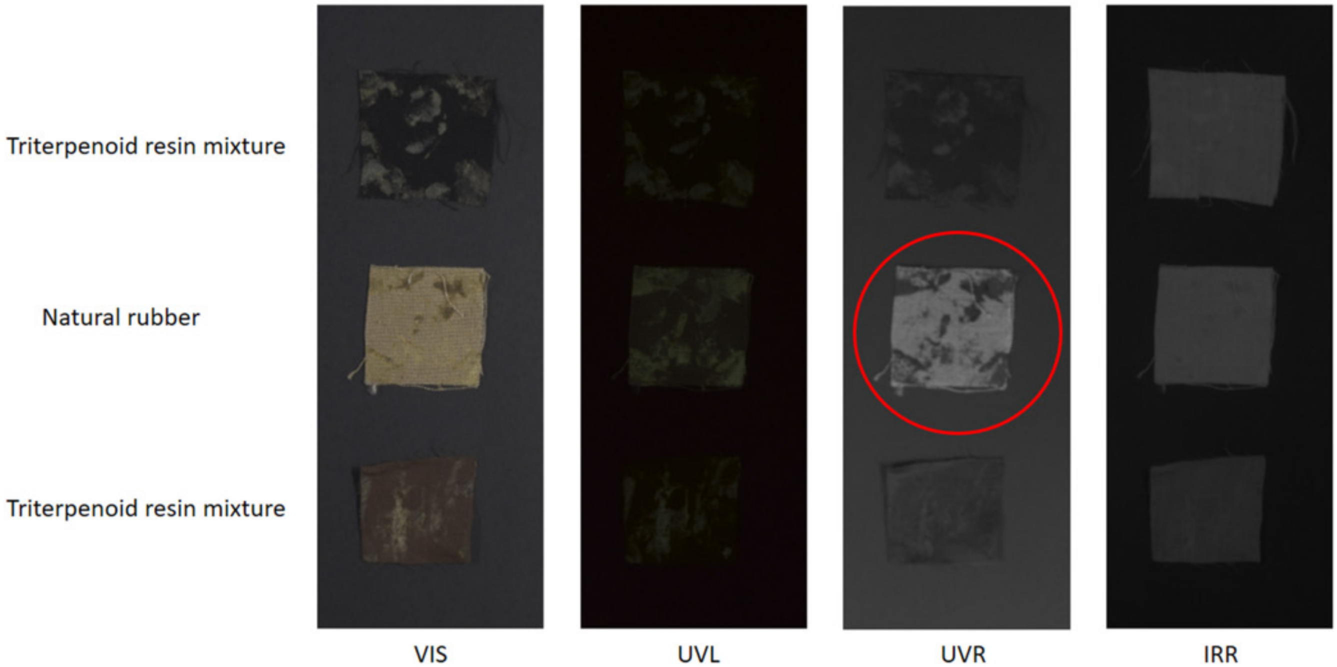

Fig. 8. Comparing spectral images of residue of resins on patches removed from a carpet.

3.1.2 Documenting Spatial Distribution

Multispectral/multiband imaging provides accurate spatial distribution of materials as well as their characterization. It has proven to be a great mapping tool for conservation documentation. Although digital mapping programs are evolving, this imaging technique offers a more efficient option without involving a laborious and time-consuming marking process by users (Suh 2014).

3.2 POTENTIAL FOR NONDESTRUCTIVE ANALYSIS OF DYES

Researchers have paid a great deal of attention to multispectral/multiband imaging hoping to find a nondestructive and affordable solution for material analysis, including dyes. It supplies noncalibrated spatial data, or images, that can provide qualitative information about the presence of certain materials but cannot deliver quantified data for material identification.

Sets of multispectral/multiband images, including false-color photographs, were taken with known dye samples [2] and textiles whose dyes had been analyzed and identified with quantified measures, including HPLC-PDA performed by Nobuko Shibayama, research scientist at The Met. The color and intensity in the multispectral/multiband images of dyes are subject to change by variables such as use of mordant, preparation method, and type of substrate, especially when the dye concentration is low (Derrick, Newman, and Wright 2017). Duckwall (2013) studied UVL to determine if it could distinguish red dyes of similar appearances. She concluded that it could not distinguish red dyes owing to the many variables affecting the result. The same investigation on red dyes with multispectral/multiband imaging was not successful either. However, with more layers of information from UVR and IRR, it showed some positive potential in characterizing other dyes.

Comparing sets of multispectral/multiband images revealed consistent and unique patterns in certain dyes, such as safflower red and indigo blue. These colorants showed consistent color patterns both on a number of textiles in The Met's collection and on the dyed yarn samples from the reference collection of the Department of Textile Conservation. Similar patterns were found among red dyes: madder, lac, brazilwood, cochineal, and kermes. Although in the FCUV image, cochineal red shows a subtle difference of lower saturation than other red dyes, more research is required to verify the pattern for identification (figs. 9, 10).

Dyed yarn samples of murex purple, Prussian blue, and archil red were chosen for comparison. The multispectral/multiband images of murex purple in figure 10 were compared with those of purple dyes often found on Coptic textiles in figure 9. The dyes of the latter were analyzed and determined to be a combination of madder and indigo. Similar-looking purples in the VIS images can be distinguished by the FCIR images, which clearly show the presence of indigo in red. The indigo dye's characteristic red in

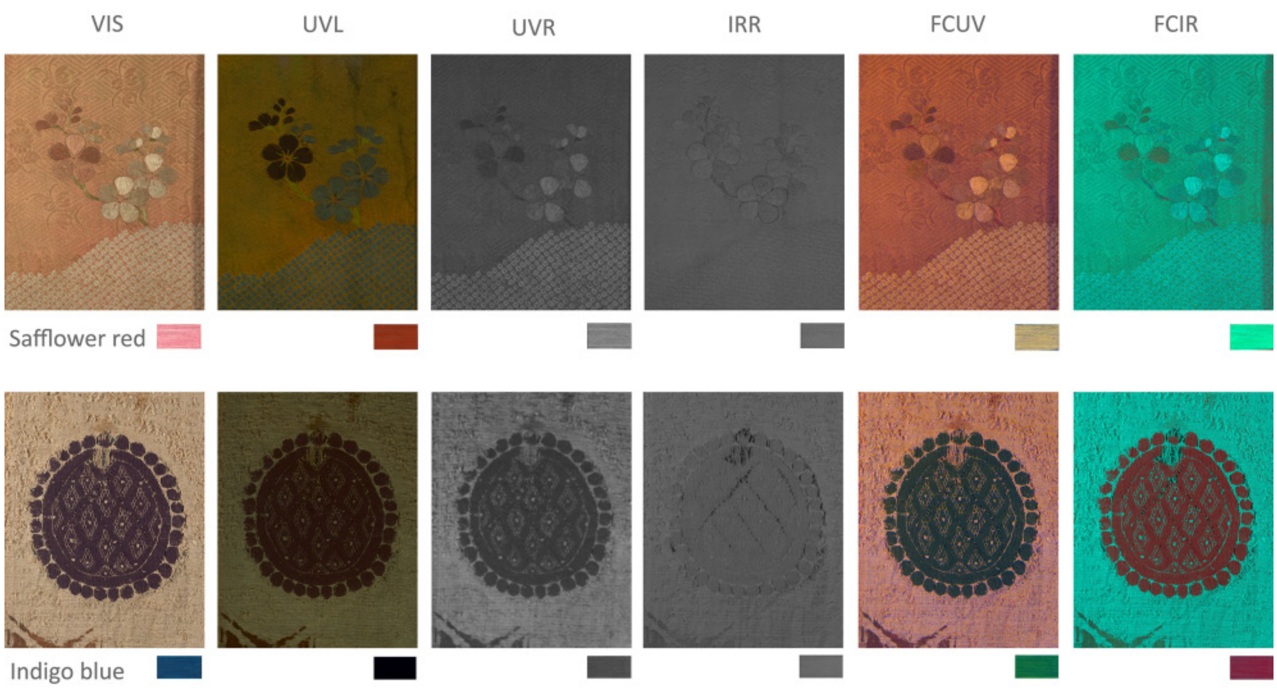

Fig. 9. Upper row: Spectral images of safflower red dyed on silk and MMA 2008.335.23, fragment from a Kosode with plum blossom and cloud, Edo period. Gift of Sue Cassidy Clark, in honor of Dr. Barbara Brennan Ford, 2008. Lower row: Spectral images of indigo blue dyed on wool and MMA 89.18.300, fragment made of wool and linen in Egypt, fourth century. Islamic Art Collection, 1889.

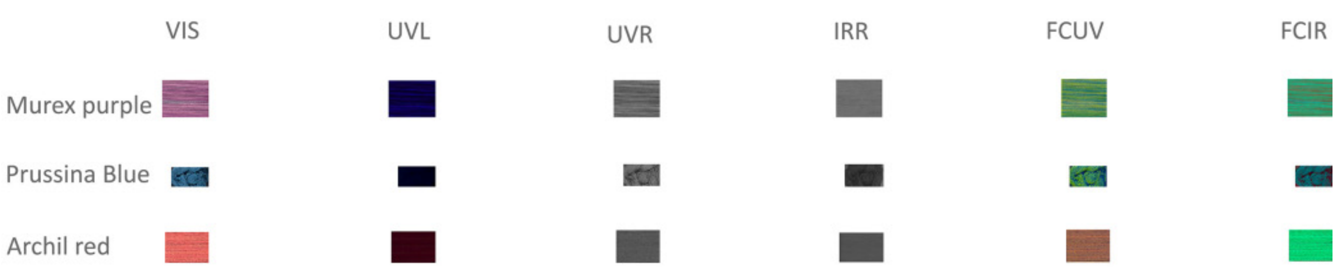

Fig. 10. Spectral images of murex purple dyed on cotton, Prussian blue dyed on wool, and archil red dyed on wool.

the FCIR image can also easily differentiate indigo blue from Prussian blue, which does not show red in the FCIR image in figure 10. In general, it is not easy to tell safflower red from archil red in the VIS images, but it is easier in the other spectral images. These two red dyes luminesce quite differently in the UVL images: safflower red in bright orange-pink in figure 9 and archil in dull red in figure 10. The chosen samples showed distinctive patterns in comparison with those of indigo blue and safflower red. However, the number of experimental examples were insufficient to confirm the patterns of the dyes in general.

3.3 COMMUNICATION

Qualitative analysis of multispectral/multiband images requires multiple examples of cases with variables that result in different material characteristics. The number of cases of historical dyes can be narrowed down by referring to historical recipes and considering material availability within the historical and cultural context of the textiles' origins. However, only collective effort from many researchers with varied resources will make it possible to collect comprehensive examples for qualitative analysis.

For this kind of collective research, it is crucial to provide an environment in which researchers can easily communicate with visual information. It is necessary to have a platform that can process and host considerable amounts of image data while being interactive with multiple users. As one possible platform, a board entitled *Multispectral/multiband Reference Images of Dyes* was created on the Department of Textile Conservation's existing Pinterest account: https://www.pinterest.com/textilesmet/ [3]. Captioned images were published, viewers could comment, and the contents could be easily revised. However, the interface was not as interactive for viewers as it was for publishers. A more desirable interface would work as an interactive image database that could grow organically with users' input.

3.4 STANDARDIZATION AND METADATA

It is necessary to share common standards in capturing and processing images in order to establish a shared language. As addressed earlier, conservators and imaging specialists are making significant efforts to establish standards for capturing and processing multispectral/multiband images, notably by the British Museum's Technical Imaging project within CHARISMA (British Museum 2013).

While following the same workflow, there are many case-specific details that are critical for the repeatability of images. These details can be recorded in metadata, a set of data fields. At the moment of capturing images, digital cameras automatically create exchangeable image file format (EXIF) metadata, including information of camera, lens, exposure, focal length, ISO, and so on. In addition, specific technical details in capturing and processing images are to be recorded: lens filters; radiation source; standard target details for exposure and white balance; channel substitution sequence of false-color techniques, and other aspects, depending on the setup.

Descriptive metadata is also necessary to make the image searchable with subject-related keywords: accession number, object name, project information, material identification, dye source, dye agent/mordant, finishing, additives, condition, etc. Any information related to material characteristics will help translate multispectral/multiband images. As the conservation field does not have a customized set of metadata fields, the International Press Telecommunications Council (IPTC) core/extension fields are commonly used.

4. FURTHER RESEARCH

4.1 IMPACT OF UV EXPOSURE

For textile conservators, one of the most important factors in deciding whether to adopt multispectral/multiband imaging techniques must be the amount of exposure to UV radiation during imaging. It is also important to be mindful that excessive exposure to UV radiation can be harmful to humans as well as objects. For safety, a few protective personal items are required: UV filtering safety glasses, long sleeves, and nitrile gloves (Measday, 2017).

UV exposure was not systematically recorded during this study. To investigate its impact, the intensity and duration of UV exposure during the entire imaging procedure should be measured in addition to the exposure time of capturing UVL and UVR.

4.2 VIL: VISIBLE-INDUCED IR LUMINESCENCE PHOTOGRAPHY

VIL was not included in this study, as the workflow for this technique was still in progress. VIL can be taken with visible light lamps and a UV/visible blocking lens filter. VIL will add another layer of information for characterizing materials. In a previous study of a textile sampler comparing VIS, UVL, and VIL, the luminescent elements in UVL and VIL did not necessarily coincide (Warda et al. 2011).

4.3 VALIDATING MULTISPECTRAL/MULTIBAND IMAGES WITH OTHER IMAGING TECHNIQUES

Although multispectral/multiband imaging can provide only qualitative analysis, the analytical results can be validated quantitatively by other imaging techniques, such as imaging spectroscopy. Webb, Summerour, and Giaccai (2014) used multispectral/multiband imaging in combination with hyperspectral imaging for identification and characterization of materials. Both false-color technique, used in this study, and the infrared subtraction technique with fiber optic reflectance spectroscopy, used in Webb's study, showed the same results in characterizing indigo and natural red dyes.

5. CONCLUSIONS

The major contribution of multispectral/multiband imaging would be to provide comprehensive information for image-based examination by illustrating information that cannot be detected in visible light. Along with object-based examination, it can assist conservators in achieving better understanding of an object's material and condition and in efficiently producing advanced documentation. Its use for material analysis is limited, but it offers great potential in differentiation and characterization of textile materials, particularly in known historical and cultural contexts.

All of this visual information can be easily communicated by transferring digital image files. It is important to share the same standards in capturing and processing images for repeatability and to prevent misinterpretation of others' visual information. Encoding metadata, so-called "data of data," is critical to translate the visual information correctly.

The advancements in imaging and communication technology present an exciting potential for collective research: access to advanced imaging technique is easier with increasing availability of inexpensive equipment and software; and the options for communication platforms on the web are only getting more numerous, especially for images. For such qualitative results that multispectral/multiband imaging provides, every case counts. Reviewing greater numbers of cases will enhance the refinement in translating information of multispectral/multiband images. It is particularly valuable to share the results that were already verified with other analytical tools. It will benefit conservators who have imaging tools but may not have access to those analytical tools. It is a feasible idea to build a collaborative image database alongside a virtual community of conservators and researchers.

ACKNOWLEDGMENTS

This project has been evolving for several years with the help of many colleagues at The Met: imaging specialists Scott Geffert and Chris Heins; and colleague conservators Ashira Loike, Maria Ruiz-Molina, and Anna Serotta. It all began in the summer of 2015 after attending the AIC workshop "Examination and Documentation with Ultraviolet Radiation." I was fortunate to have Dan Kushel and Jiun Jiun Chen as instructors. During the following year, I worked with a fellow, Chiara Romano, and her multispectral imaging project in collaboration with Joanne Dyer. This series of fortunate collaborations enabled me to set up a multispectral/multiband imaging station in the Department of Textile Conservation at The Met and carry on this research. I am also very thankful for my department colleagues and senior conservators' generous sharing of experience and knowledge. Special thanks to Florica Zaharia and Janina Poskrobko for their incredible support, allowing me to continue this project despite the many other demands and projects continually ongoing in the department.

NOTES

[1] The mobile photo stand set-up was designed by Emilia Cortes with BOSTONtec in 2007. It was fabricated specifically for flat textiles with an adjustable camera holder on a vertical stand in order to accommodate various sizes of textiles.

[2] Except for murex purple, all samples were dyed following the recipes from Dr. Schweppe's dye workshop, which was organized by the Smithsonian Museum Conservation Institute in 1980s (Schweppe 1986, 1987). The samples were dyed and compiled by Nobuko Kajitani, Elena Phipps and Kathrin Colburn. The sample for murex purple was taken from a skein of cotton yarn dyed with murex by an indigenous dyer on the Pacific coast in Mexico. It was purchased and donated to the reference collection of the Department of Textile Conservation by Maya Naunton in 2005.

[3] Publishing visual information related to conservation and research on Pinterest was initiated by Cristina Balloffet Carr in 2014. It was chosen as an alternative to conventional publication. It is easily accessible, interactive, and allows for immediate revision as research evolves.

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APPLICATION OF MULTISPECTRAL/MULTIBAND IMAGING IN THE PRACTICE OF TEXTILE CONSERVATION: DOCUMENTATION, INVESTIGATION, AND COMMUNICATION

AUTHOR BIOGRAPHY

KISOOK SUH is associate conservator in the Department of Textile Conservation at The Metropolitan Museum of Art. She is currently working on medieval tapestries from The Met's collections. She received her MA in museum studies from the Fashion Institute of Technology and was the recipient of an Andrew W. Mellon Conservation Fellowship. She was previously employed by the National Folk Museum of Korea. In addition to her continuing involvement with researching issues of early repairs on textiles, along with related practices of their restoration/reconstruction, her most recent interests are in digitization and advance imaging technique. Address: 1000 Fifth Avenue, New York, NY 10028. E-mail: Kisook.suh@metmuseum.org.

POINTING IN THE RIGHT DIRECTION: IDENTIFYING TECHNOLOGICAL FEATURES TO ORIENT NAVAJO TEXTILES

BETSY BURR, DR. NANCY ODEGAARD, BARBARA TELLER ORNELAS, ANN LANE HEDLUND, AND DELANA JOY FARLEY

ABSTRACT—Navajo textiles have been studied extensively by scholars and collectors. However, a review of the literature indicates there is little to no attention paid to determining their orientation. To address this gap, this technical survey includes a sample of frame loom Navajo textiles ranging from the mid-19th to late 21st centuries. Throughout this investigation, the research team found a number of technological features that can potentially provide clues to determine the top versus the bottom and the front versus the back of a textile as oriented during its manufacture. These features include design elements, changes in tension, and evidence of the work face of a textile and, when taken as a whole, can help determine the orientation of some textiles. While most Navajo textiles are woven to be used in any orientation, recording and understanding the manufacturing process can help train one's eye to look for technological features that could be misinterpreted as evidence of wear or other condition issues. This information can guide the proper placement of museum labels as well as appropriate positioning for documentation and exhibition, and can aid researchers and weavers studying collections.

EN LA DIRECCIÓN CORRECTA: IDENTIFICACIÓN DE CARACTERÍSTICAS TECNOLÓGICAS PARA ORIENTAR TEXTILES NAVAJO

RESUMEN—Los textiles Navajo han sido estudiados de manera extensa por académicos y coleccionistas. Sin embargo, una revisión de la literatura indica que determinar su orientación ha recibido mínima atención. Para atender esta falta de información, se realizó un estudio de textiles Navajo que incluyó ejemplos que incluyen ejemplos desde mediados del siglo XIX hasta finales del siglo XXI. A lo largo de esta investigación, el equipo de investigación halló varias características tecnológicas que pueden proveer información necesaria para diferenciar la parte superior de la inferior, y el verso del recto, y cómo el textil estuvo orientado durante su manufactura. Estas características pueden ayudar a determinar la dirección del factura del textil, e incluyen el diseño de elementos, cambios en la tensión, evidencia del trabajo en el frente del textil y en qué etapa el textil se desmontó del telar. Mientras la mayoría de los textiles Navajo están tejidos para usarse en cualquier orientación, registrar y comprender el proceso de manufactura puede ayudar a entrenar el examen adecuado que ayudará a diferenciar factura de daños por uso y otros aspectos de conservación. Esta información puede informar el lugar adecuado para poner etiquetas, la orientación adecuada para documentación y exhibición, y ayudar a investigadores y tejedores a estudiar colecciones.

1. INTRODUCTION

The Arizona State Museum (ASM) holds a world-renowned collection of roughly 650 hand-woven textiles from the American Southwest, ranging from the early 19th century to contemporary. Textiles in the Navajo collection have been frequently featured in publications and are of interest to researchers, tribal members, weavers, scholars, students, and the public. Colleagues and students associated with the conservation laboratory at ASM and the University of Arizona have conducted a variety of studies on traditional treatments and hanging methods as well as projects using XRF to assess the levels of toxic metal pesticide residues present in the collection (Dawley and Odegaard n.d.). The most recent work was presented at the 42nd AIC Annual Meeting and is available in the 2014 OSG Postprints (Anderson et al. 2014). Because of this work, high levels of toxicity are now known and have been verified on many textiles. As an outcome of this investigation, it is now an obligation and priority to label individual textiles with known levels of toxicity to inform anyone handling the collection. The goal in this current preliminary study is to illustrate the investigative process of determining label placement.

This labeling project is also an opportunity to evaluate and improve some of the current catalog labels in the Navajo textile collection. According to many labeling protocols for flat textiles, two labels are recommended to be stitched on the back, one on the lower right corner and one on the upper left corner. The goal would be to add the pesticide warning label next to the catalog number label. A review of the ASM collection revealed that application of the catalog number label at the time of accessioning was not based on a single criterion other than a general assumption of what might be the back or the bottom.

The top versus bottom and front versus back is often difficult to discern in Navajo textiles, which leads one to the question, is it possible to tell the front from the back and the top from the bottom? Based on a review of the literature and consulting with scholars, curators, and weavers, it appears that this question has not been adequately investigated. According to Dr. A. Hedlund, former Curator of Ethnology at the ASM and a noted scholar of Navajo textiles, idiosyncrasies in the design symmetry provide potential information on the top and bottom. In prior work, Dr. Hedlund looked for evidence of the top, where a weaver was either filling up extra space or running out of room in regard to the design symmetry relative the rest of the textile.

The first step in this study was to ascertain if determining orientation relative to the weaver's position while the textile was being woven was possible using technological features as clues. The answer to this question impacts not only labeling but also display, publication, storage, and documentation, such as imaging and conservation reports. It also has the potential to enrich our understanding of items in this important collection and the work that went into weaving them.

To best answer this question, a team of Navajo weavers and museum experts was assembled (fig. 1). Our team includes Barbara Teller Ornelas, a world-renowned master Navajo weaver from Two Grey Hills, New Mexico who lives in Tucson. Teller Ornelas's contribution was paramount to the success of this project, and

Fig. 1. (a) Delana Joy Farley, (b) Betsy Burr, Dr. Nancy Odegaard, and Barbara Ornelas, and (c) Dr. Ann Lane Hedlund.

the ease and confidence with which she can identify the orientation of Navajo textiles is nothing short of impressive. For the museum members in the museum profession, this solidified the importance of the project and its findings. If a master weaver can discern the orientation of textiles, then the museum owes it to its constituency to be getting it right as well. Our team also included Dr. Ann Hedlund; Delana Joy Farley, a Navajo weaver and curator at the Southern Ute Museum in Colorado; Betsy Burra, postgraduate Conservation Kress Fellow at ASM; and Dr. Nancy Odegaarda, conservator with over 30 years of experience working with the ASM collection and leading conservation studies.

For this preliminary investigation, the team looked at 13 museum textiles from the ASM collection ranging from the mid-19th to late 20th century, including a two-panel dress (known as a bil), large serapes, blankets, and small to mid-sized rugs. Observed technological features were documented through annotation of images of both faces of the textile and by filling out a form created for this purpose. The location of the current catalog label on each textile was demarcated as “Face A and End A” in the documentation. This provided a nomenclature for referring to the textiles while they were being studied.

2. NAVAJO WEAVING TECHNOLOGY

It is first necessary to have a basic overview of Navajo weaving techniques and technology to facilitate reading technological features. Though complex and variable, there are basic commonalities within this weaving tradition. Most types of Navajo textiles are woven on an upright frame loom with a heddle bar using a comb to pack the weft. The weaver works from the bottom to the top to create a four-selvedge textile with a weft-faced plain weave structure, and tapestry joins to create designs. The warp is a continuous thread, which is attached to the loom bars using twined warp selvedge cords. These remain a part of the textile when it is removed from the loom. Most Navajo textiles have additional side cords at the weft selvedges, which are twined at intervals while weaving. These cords help to maintain a straight and even selvedge while weaving.

Traditionally, a weaver begins weaving while seated on the floor. As the weft elements are built up, she has a few options for reaching the unwoven section of the warp. She can either sit progressively higher or can turn the warp upside down on the loom so that the unwoven section is now within reach. This is done by detaching the loom bars from the frame, turning them upside down, and reattaching them to the loom frame. She again weaves from bottom to top, finishing her weaving mid-textile rather than at a selvedge.

As a third option, she can lower the warp on the loom. There are different ways to do this depending on the type of frame loom available. During the 20th century, it became more common for weavers to advance their projects by turning the warp around the lower beam of the loom. Prior to the 20th century, it was common to physically stitch the woven section of the warp to the lower bar of the loom. This method creates a permanent scar on the textile known as stitch down lines, which are visible often at regular intervals over the length of the textile, as seen in figure 2 (Wheat 2003).

Weavers often add the weft in sections rather than full loom widths. This increases efficiency when creating a large textile in which the side selvedges are out of reach from one seated position. Doing so creates what is referred to as “weaver’s lines” or “lazy lines” in areas of solid color, which are common features of large Navajo textiles from the 19th century. Regardless of method, as weaving progresses, the workspace becomes increasingly shallower and tighter (fig. 3), making it difficult to insert the final rows of the weft. Once complete, the textile is untied from the loom. The ends of the selvedge cords form tassels in the corners of the finished textile.

Fig. 2. Stitch down line present on a 19th century bil, ASM 2011-665-43.

Fig. 3. Remaining visible warp present at the top of a textile still attached to the loom.

3. RESULTS

The results of our preliminary study are a series of clues that, taken as a whole, can help differentiate the orientation of the textile from the weaver's perspective during its manufacture. In most instances, no single feature is sufficient to base a determination on it. These technological features are presented here in three categories: design, distinction of the top from the bottom, and distinction of the front from the back.

3.1 CLUES IN DESIGN

The most obvious clues are design elements that have a directional aspect. These include text, numbers, representational images, or, for example, the presence of colors assigned by Navajo to each cardinal direction. These may provide information on top versus bottom, front versus back, or both. When imagery is woven perpendicular to the warp, design clues are more difficult to interpret.

A weaver's pathway is a line of weft thread that interrupts an outer border and terminates at the selvedge (fig. 4). It is often placed in the upper right-hand corner when viewed from the weaver's perspective (Bennet 1974). However, not all textiles with borders have this feature, and individual weavers vary their placement of a weaver's pathway. While this clue is a common feature used to determine orientation, it must be read along with other information owing to its lack of reliability.

Fig. 4. A weaver's line is a continuation of yarn that intercepts an outer border, terminating at the selvedge of ASM 2014-169-3, woven by Ruth Wilson Hubbard. This feature is commonly used to orient Navajo textiles; however, the placement can vary depending on the choice of the weaver.

Design may inadvertently provide information on which end is top or bottom when there are inconsistencies in a symmetrical pattern. Examples include when a pattern is either stretched out or cramped tightly at one end compared to the rest of the design layout. In the wedge weave blanket shown in figure 5, the zig-zag pattern is uniform at one end and irregular at the other. It drifts in size and terminates abruptly rather than at the peak in the pattern. It is more likely that the weaver began with a uniform pattern and ended abruptly as she was reaching the end of the warp. Again, this clue is good evidence to combine with technological features present in the textile to determine its orientation.

3.2 CLUES TO DETERMINE TOP VERSUS BOTTOM

To distinguish the top from the bottom, differences in tension and density from one end to another can help make a determination. One example of this is a change in the width of the textile, as the top end is often narrower than the bottom, referred to as "draw-in." This is caused by tension placed on outer warps as the weft is wrapped over the selvedge, effectively pulling the outer warp inward. This change in width from one end to another can be extreme or subtle, and in master pieces it can be absent. Weavers also devise methods for countering draw-in. This includes stretching the width of the textile and fixing it down with stitch down lines during the weaving process. This can create a flare along the weft selvedge without an increase in warps (fig. 6). If a sudden increase in width is present, it is likely a form of compensation, and the widening points toward the finish at the top of the textile. Distortions from display or use could mimic this clue and vice versa. Being aware of the feature can help distinguish weaving technology from a condition issue. This feature was found on multiple 19th century textiles included in this study. In other examined textiles, it appears that

Fig. 5. Textile ASM E-2722 is irregular in the spacing and layout of its design at the top compared to the rest of the design.

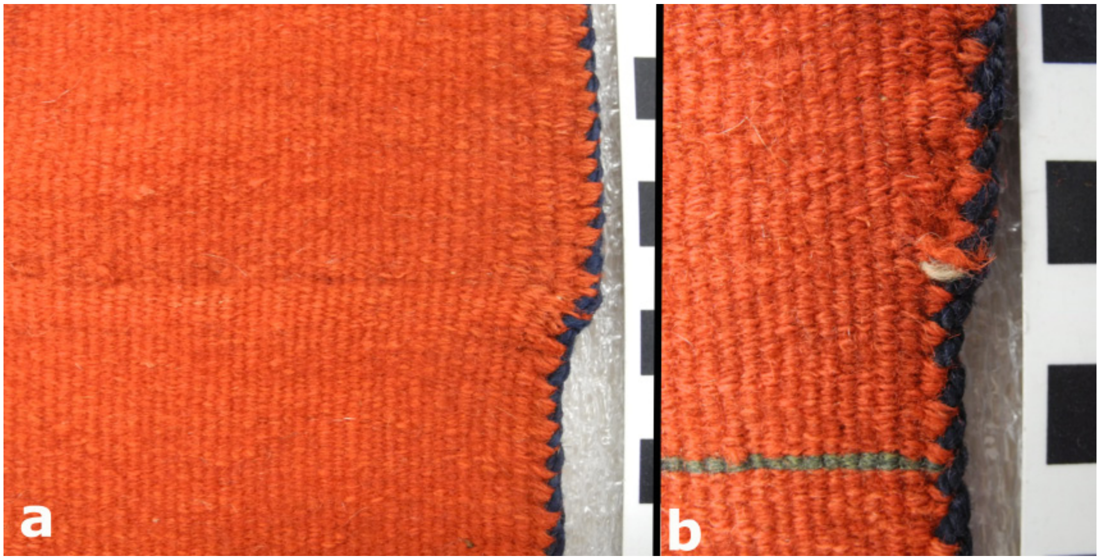

Fig. 6. (a) Textile ASM 22078 widens significantly at the point of a stitch down line, suggesting that it was stretched and fixed down to gain width during weaving. (b) The same textile also has multiple locations where a change is width is associated with a change in the number of warps present. This example appears to be an increase of warps.

warps were added to compensate for narrowing (see fig. 6). This evidence requires further investigation, however, as there are other factors that would cause a weaver to add or subtract warps while weaving. In other instances, warps were both added and subtracted on the same textile, the purpose of which is unclear.

Another common distinction between the top and bottom is the density of the weft pack at each end. The top tends to have fewer wefts per centimeter compared to the bottom (fig. 7). During the weaving process, as wefts are continuously added and beaten down, the wefts below the shed become more compacted. Without the additional weight and packing from wefts above, the wefts at the top of the textile tend to be much less compact. This can be identified by comparing the thickness and stiffness of the textile at both ends and by counting the wefts per centimeter. However, clearly there are also weavers who are able to minimize the

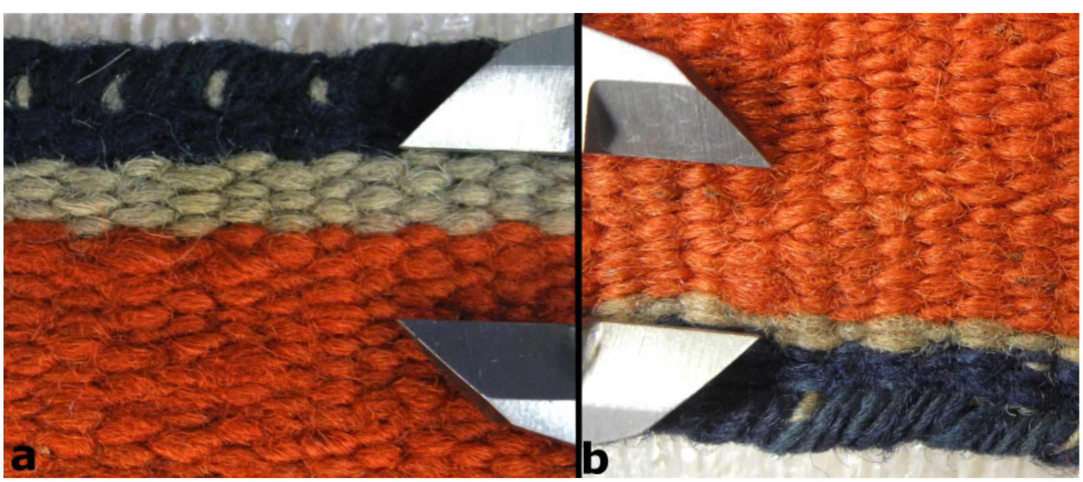

Fig. 7. (a) This end of textile ASM E-3272 has approximately 13 wefts per centimeter compared with the opposite end seen on the right. (b) The opposite end of same textile with approximately 19 wefts per centimeter. Based on the density of the weft packing, it appears that (a) is the top of the textile and (b) is the bottom.

difference between the two ends. This clue may also be difficult to read when a textile is heavily worn or damaged from hanging.

Other clues may be found when looking for signs of difficulty with tension, which are more common at the top of a Navajo textile than the bottom. The warp threads have an even tension when weaving begins, but as weaving progresses, the tension increases or may become varied. Signs of difficulty include a wavering selvedge or design stripes and an increase in broken and mended warp threads. However, it should be noted that these features may mimic wear or restoration and must be carefully read and combined with other information when determining orientation.

Additional clues may be found in the curved shapes present in the weaver's lines. When a section is woven, it typically has straight diagonal sides, which sometimes curve inward at the top, forming a concave mound. As other sections are filled in next to and on top of areas already woven, they conform to the shape of areas already woven. Figure 8 is an example of area of weaver's lines where the curvature provides an indicator of the order in which the sections were likely woven and, by extension, indicates the top and bottom of the textile.

When reading orientation of 19th century textiles, it is necessary to look for signs of a finish that occurs in the middle rather than the top of the textile. These occur when textiles are turned upside down on the loom. The telltale sign of a finish at the midpoint is the presence of side cords that terminate in the middle. These may be woven in with the weft, bound to the selvedge, or left loose as tassels (fig. 9). There may also be a change in side-cord twining direction, which meets at the finish (fig. 9c). In these instances, features associated with top finish may be found in the middle. For turned textiles, it can be challenging to determine which end was the first start and which end was woven after turning, though applying these other clues helps in distinguishing this aspect. Often, the wider warp selvedge is where the weaver began.

Figure 10 is an example of combining multiple clues in a single textile. First, End A is wider than End B by 30cm, suggesting that End B is the top. Next, there are two areas closer to End B where the textile was stretched wider, seemingly while working toward End A, indicating that End A is the top. These features point in opposite directions; however, at the center of the textile, there are side-cord tassels that indicate that both

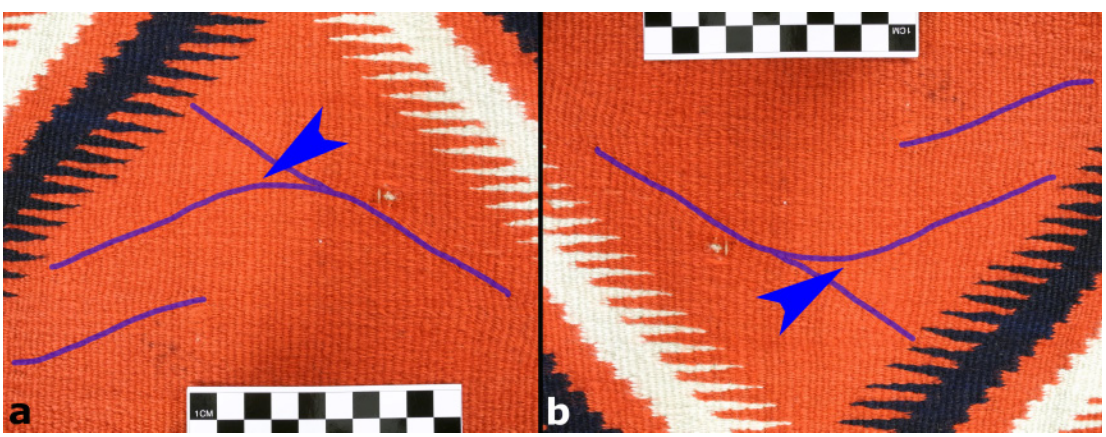

Fig. 8. Sometimes curved shapes in weaver's lines can help determine orientation, as seen here in textile ASM 8418. (a) The highlighted weaver's lines are depicted here with what is likely the top correctly oriented. There is a mound form in the center, with the section on top conforming to its shape (*arrowhead*). (b) If the opposite end was the top, then a shallow concave shape would have been woven first (*arrowhead*), and a section with a rounded base filled in on top of it. This is an unnatural shape, suggesting that we're viewing the textile upside down in the image on the right.

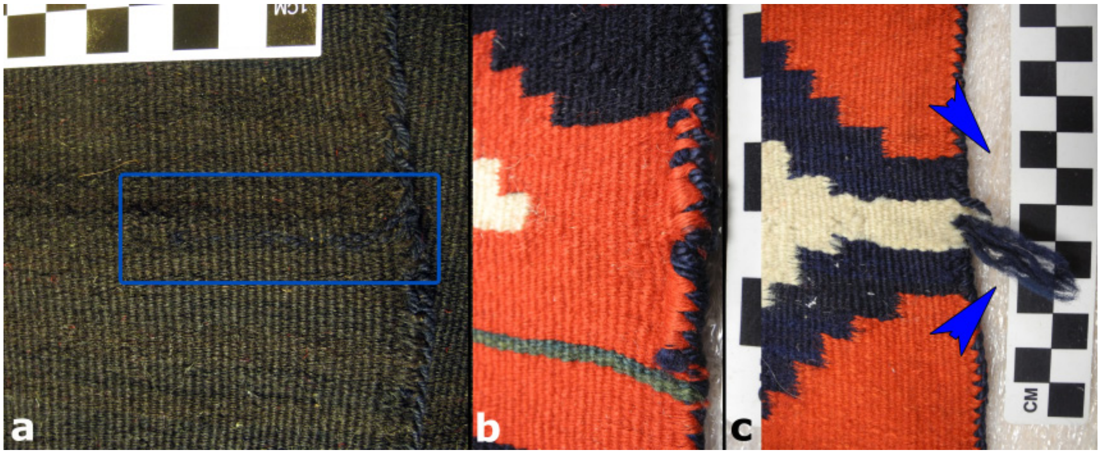

Fig. 9. When Navajo textiles are turned on the loom and finished in the middle rather than the warp selvedge, two sets of side cords are used on each weft selvedge. The ends of these side cords are visible in the location where weaving finished. These side cords may (a) be woven into the textile, (b) bound to the selvedge, or (c) left loose as tassels. Sometimes the direction that the side cords are worked may be different between the two sets of side cords (c).

ends were woven toward the center. There are two points at which additional warps were added to both side selvedges near End A, seemingly to gain width. These warp threads remain a part of the weave structure through to the selvedge at End B. This indicates that the warps were present before End B was woven. Because End A is the widest portion of the textile and the added warps were in place before End B was woven, End A

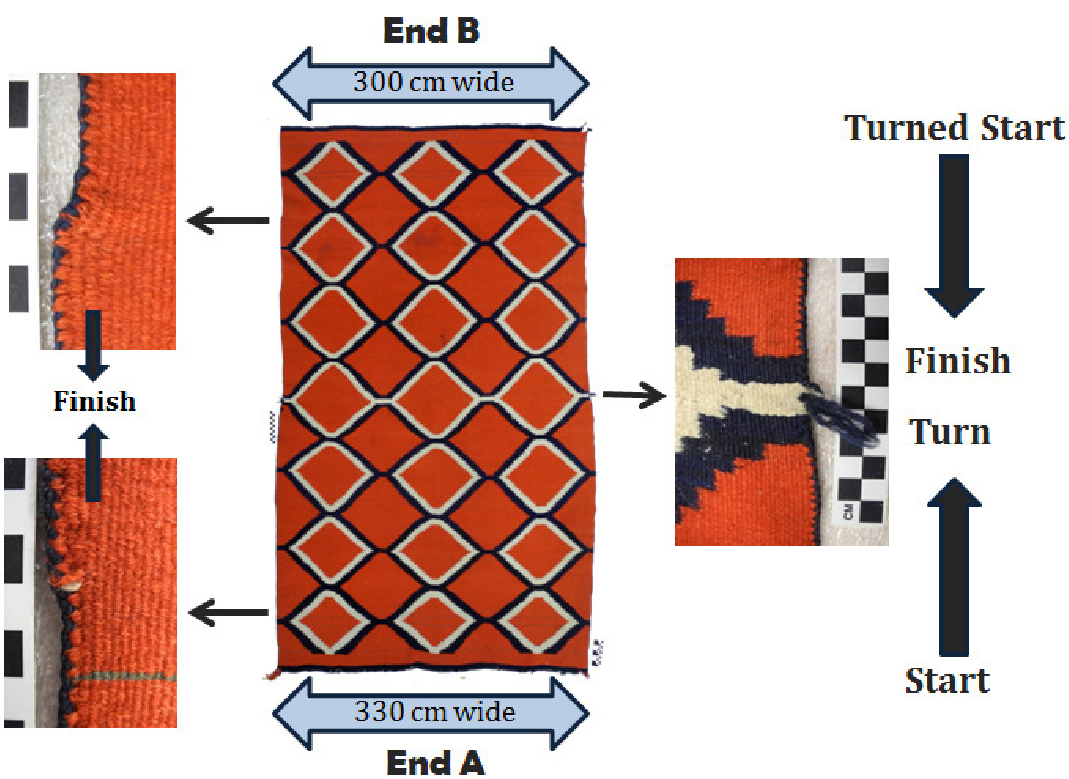

Fig. 10. An overview of multiple clues combined in one textile

is likely where the weaver began weaving and is therefore the bottom of the textile. The top half was woven after turning the textile upside down on the loom; this half is significantly more narrow than the bottom half.

3.3 CLUES TO DETERMINE FRONT VERSUS BACK

The determination of the front versus the back of a textile relies on evidence that distinguishes the work face during manufacture. According to Teller Ornelas, while working the weft in the shed and packing it with the comb, fibers in the weft thread are pulled from the back to the front, toward the weaver. As a result, the back has a slightly crisper appearance than the front. This effect is seen in the loose fibers present in the spin of the weft and in the interlocking tapestry joins of design work (fig. 11). Because of its clarity, panels of a bil dress are often stitched together with the back side facing outward. This effect may be partially obscured by wear in older textiles and can be minimized by expert weavers.

Also pointed out by Teller Ornelas, the work face can be identified in the warp repairs executed during the weaving process, which are more often visible on the front face than the back (fig. 12). When a warp thread breaks, there are a variety of ways to repair it, including tying a knot to join the broken warp to a new replacement thread, which is done from the work face. Because of this, the knot is pulled outward from the front face, causing it to pull inward on the back face, which impacts its visibility. It should be noted that warp repairs may be restorations that are not original to the construction of the textile. A change in material type, the presence of the other repairs, and potential disruption to the weft would all be signs that a knot in the warp was not executed by the weaver. Additionally, the way in which a knot lays or behaves within the textile could potentially be affected by the way it is handled, stored, displayed, or used. Further research may help to clarify the interpretation of this feature.

The front and back sides may also be determined by the direction in which the side cords are twisted. According to Teller Ornelas, the side cords are worked from the front face toward the back on both sides while weaving. This creates an S-traveling direction on the weaver's left-hand side (fig. 13), and Z-traveling on the right-hand side as the weaver turns the cords outward over the selvedge and into the weft on the back face. This has the effect of cords turning outward toward the top on the front face and inward on the back. This is true when viewed with the known top already oriented or when viewed upside down from the back side. Because of this, the top and bottom must already be established if side cords are to be used as an indicator for the front and back faces. Although side cords twined from front to back is the norm, individual weavers may

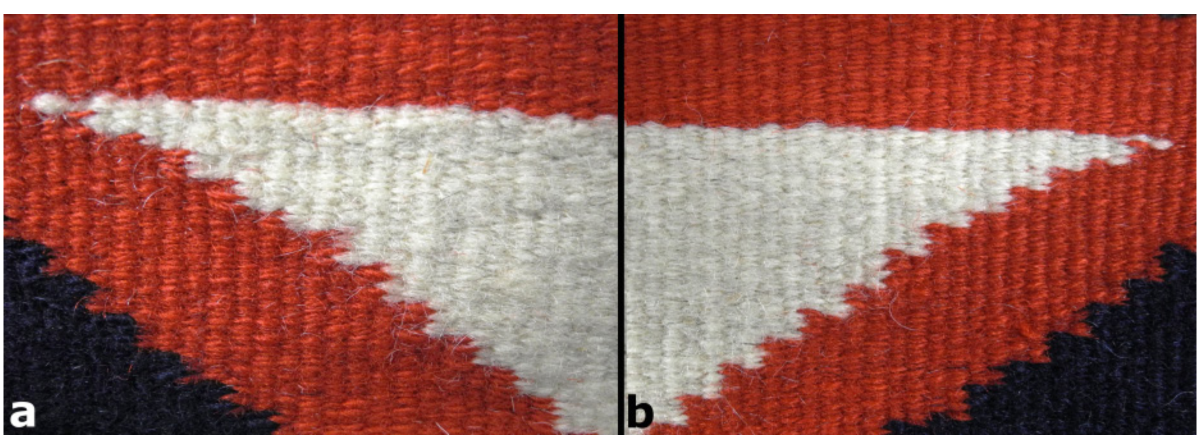

Fig. 11 (a) The front side of textile ASM E-2724 has more irregular interlocking joins and color transitions and a fuzzier overall appearance compared with the back side (b).

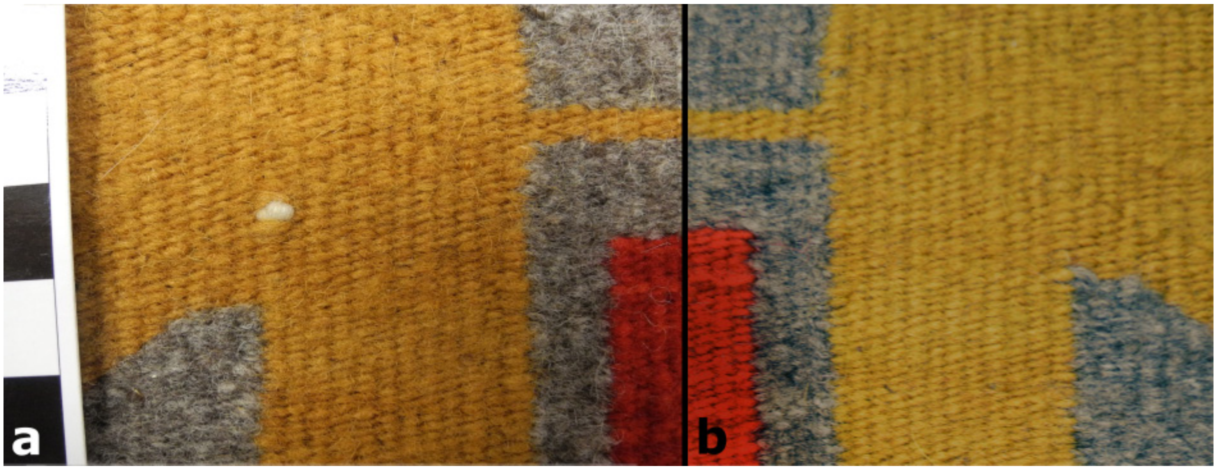

Fig. 12. Knotted warp repairs made by the weaver during manufacture are often more visible from the front than the back because they are formed on the front face rather than from the back. The front of textile ASM 2012-2-4, woven by Ason Chitty Begay, has visible knots in the warp as seen here from the front (a), while the knots are obscured by the weft on the back side (b).

Fig. 13. Side cords are often turned outward on both sides from the front face and back into the weft on the back side. This creates an S-traveling direction of the left-hand side both from the front (a) and the back (b), when viewed with the top correctly oriented. As shown here, the side cords travel outward on the front side and inward on back. In this particular example, textile ASM 2011-665-23, the side cords were twined parallel to each other without a Z-traveling direction on the right-hand side. In this instance, this clue cannot be used to determine the front from the back.

use a different technique. This clue is not inherent to the weaving technology but rather is based on a technical decision that the weaver made, making it less reliable. Some textiles in this study had side cords twined parallel to one another where this feature could not be used to orient, which includes on the textile shown in figure 13. Also, side cords are frequently replaced during restoration and repair and may not be twined in the direction of the original cords. In one textile, the twining direction worked in opposition to the other clues; however, the cords did not appear to be original.

4. CONCLUSIONS

Based on the outcome of this study, it is possible in some cases to identify the likely orientation of a Navajo textile while it was woven. Textiles woven by a master offer fewer clues of orientation; textiles with significant wear and damages are more difficult and ambiguous to read. However, many textiles demonstrate evidence inherent to the weaving technology that suggests the likely perspective of the weaver during manufacture. In most cases, textiles are woven to be used in any orientation, suggesting that there is no true top or bottom or front or back. However, the ability to differentiate how a textile was woven provides a deeper understanding of the textiles that we work with and provides a framework to distinguish technological features from condition issues arising from use and wear.

The next steps of the project are to continue collaborative technical examinations and dialogues between weavers and museum professionals and to include additional textiles beyond this initial survey. A more systematic and comprehensive study will undoubtedly help clarify the current understanding of these technological features and potentially help identify additional features used to orient. A number of features investigated were promising, though inconclusive, and call for further research. The results of this investigation will be applied to the orientation of textiles in future photos and written documentation. Finally, museum staff will apply labels that provide orientation information to textiles in the wider study, along with warning labels for those with known pesticide residues on the textile's back face proper left-hand corner.

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AUTHOR BIOGRAPHIES

BETSY BURR is an objects conservator at the Western Archeological and Conservation Center (WACC), National Park Service, in Tucson, Arizona and holds an MA from the University of California, Los Angeles (UCLA) in Conservation of Archaeological and Ethnographic Materials. Prior to her position at the WACC, Betsy was the Samuel H. Kress post-graduate Conservation Fellow and a graduate student intern in the Preservation Division at the Arizona State Museum, University of Arizona. Betsy is from Minneapolis, Minnesota and is also a weaver. Address: Western Archeological and Conservation Center, 255 N. Commerce Park Loop, Tucson, AZ, 85745 E-mail: betsy_burr@nps.gov.

NANCY ODEGAARD is a conservator and head of the Preservation Division at the Arizona State Museum, and a professor in Materials Science & Engineering, Anthropology, and American Indian Studies at the University of Arizona. She holds a PhD in Resource, Environment, & Heritage Science from the University of Canberra, an MA in Museum Studies and Anthropology from George Washington University, and an advanced certificate in Ethnographic and Archaeological Conservation from the Smithsonian Institution. She holds an honorary doctorate from the University of Gothenberg and is an advisory board member for the Iraqi Institute for the Conservation of Antiquities and Heritage. Address: 1013 E. University Blvd., Tucson, AZ 85721. E-mail: Odegaard@email.arizona.edu.

BARBARA TELLER ORNELAS is a fifth-generation Master Navajo weaver who specializes in Two Grey Hills style. Her father, Sam Teller, worked at the Two Grey Hills Trading Post in New Mexico, where she was raised with her two sisters and two brothers. Teller Ornelas learned to weave from her mother when she was 8 years old. Teller Ornelas feels a "responsibility of carrying on our family's tradition by teaching my family and mentoring others to help preserve this cultural legacy." Teller Ornelas teaches Navajo weaving workshops with her sister, Lynda Teller Pete, at Idyllwild Arts Academy's Native American Arts Program. Address: 4802 E. Copper St., Tucson, AZ 85712. E-mail: navajo_weaver_diva@yahoo.com.

DR. ANN LANE HEDLUND served from 1997 to 2013 as museum curator at the Arizona State Museum and anthropology professor at the University of Arizona, and directed the Gloria F. Ross Center for Tapestry Studies until her 2013 retirement. Dr. Hedlund is a cultural anthropologist who collaborates with Native

American weavers and other artists. Among her publications are *Gloria F. Ross and Modern Tapestry* (Yale, 2010), *Navajo Weaving in the Late Twentieth Century* (University of Arizona Press, 2004), and editor/compiler of *Blanket Weaving in the Southwest* (University of Arizona Press, 2003). She received her PhD from the University of Colorado at Boulder. Address: PO Box 1906, Silver City, NM 88062-1906
E-mail: ahedlund@email.arizona.edu.

DELANA JOY FARLEY is from Little Water, New Mexico in the Navajo Nation. She is a third-generation weaver and also a museum professional. She graduated with a BA from the Institute of American Indian Arts in 2006 and also with an MA from New York University in Museum Studies in 2008. She has interned at The Metropolitan Museum of Art, and El Museum del Barrio. Joy is currently the museum curator at the Southern Ute Museum and weaves in her spare time. Address: PO Box 1966, Shiprock, NM 87420. E-mail: delana.joy@gmail.com.

LET THERE BE LIGHT? AN INVESTIGATION INTO LIGHT-INDUCED CHANGES OF THE EARLY SYNTHETIC ANILINE DYE MAGENTA UNDER INDOOR LIGHTING CONDITIONS

MICHELLE HUNTER AND ANITA QUYE

ABSTRACT—A major development of the 19th century was the discovery of synthetic textile dyes. Magenta, also called fuchsine, was on the market in 1859 and gained major commercial success despite its known high sensitivity to daylight. Magenta proved to be a fashionable and useful color until the end of the 19th century and is therefore present on many museum textiles from this period. Since light is essential for viewing, color preservation of magenta-dyed textiles is a challenge when the definition "highly sensitive to light" is unclear. Additionally, accounts of magenta fading are historical and describe exposure to sunlight, not modern controlled collection lighting. This paper shares the results of an investigation into the light-induced changes of magenta-dyed textiles exposed to indoor lighting environments. Silk and wool fabrics dyed with commercial magenta (basic form) were exposed in real time to different lighting scenarios for six weeks. Changes were measured using a spectrophotometer and ultra high performance liquid chromatography coupled with photodiode array detection (UHPLC-PDA). Results indicated that lighting, even in "safe" workrooms and controlled displays, can induce changes in magenta. This is the first known reported evidence of real-time magenta color change under indoor lighting conditions.

¿A ENCENDER LA LUZ? UNA INVESTIGACIÓN DE LOS CAMBIOS INDUCIDOS POR LA EXPOSICIÓN A LA LUZ DEL TINTE DE ANILINA MAGENTA EN CONDICIONES DE ILUMINACIÓN INTERIOR

RESUMEN—Uno de los desarrollos más destacados del siglo diecinueve fue el descubrimiento de los tintes sintéticos para textiles. Magenta, también llamada fucsina, salió exitosamente al mercado en 1859, pese a su gran sensibilidad a la luz. El magenta resultó un color de moda y que siguió en uso hasta finales del siglo diecinueve, y por tanto está presente en varias colecciones textiles de este periodo. Dado que la luz es esencial para apreciar los bienes, la preservación de lo textiles teñidos con magenta resulta un reto cuando la definición "sumamente sensible a la luz" no es clara. Adicionalmente, los reportes de decoloración del magenta son históricos y describen exposición a la luz solar, no condiciones de iluminación moderna y controlada. Este trabajo comparte los resultados de la investigación relacionada con los cambios de textiles teñidos con magenta, expuestos a iluminación en interiores. Textiles de seda y lana teñidos con magenta comercial (forma básica) se expusieron en tiempo real a diferentes escenarios de iluminación por seis semanas. Los cambios se monitorearon por cromatografía de líquidos de ultra presión acoplada a un arreglo de fotodiodos (UHPLC-PDA por sus siglas en inglés). Los resultados indican que esta iluminación, aunque "segura" para varios artefactos, puede producir cambios en el magenta. Es la primera evidencia reportada de cambios del magenta en tiempo real.

LET THERE BE LIGHT? AN INVESTIGATION INTO LIGHT-INDUCED CHANGES OF THE EARLY SYNTHETIC ANILINE DYE MAGENTA UNDER INDOOR LIGHTING CONDITIONS

1. INTRODUCTION

Providing adequate lighting is an integral part of museum display, but many dyes used to color textiles are vulnerable to detrimental changes from light exposure. Since this type of damage is cumulative and irreversible, conservators aim to minimize the damage by controlling the dosage of visible light and eliminating the UV component (British Standard Institute 2012; Timár-Balázsy and Eastop 1998). Striking a balance between preserving and providing access is a difficult task for conservators, especially when a textile contains colorants known to be light-sensitive.

Among the most light-sensitive historical dyes are the early synthetic aniline dyes, including magenta, introduced in the mid-19th century (Scharff 1999; Barnett 2007). Increasing interest in the study and display of textiles from this historic period brings an expectation of color loss. However, the perceptions of magenta sensitivity are based on more anecdotal observations of color differences in exhibited objects and historical accounts than on laboratory-based studies. This signals a need to understand better the effects of actual indoor lighting environments on this important historical dye, especially when light sources can influence its perceived color (Bolin and Ballard. 2017).

This paper reports findings from a master's dissertation project at the University of Glasgow Centre for Textile Conservation and Technical Art History (CTCTAH) to investigate the real-time effect of indoor collection lighting on the color of magenta-dyed silk and wool test fabrics (Hunter 2016). The aims of the project were to determine the following:

1. Whether magenta is as light sensitive as reported under indoor collection lighting conditions;
2. What light-induced changes mean for magenta-dyed textile surface color and chemical composition; and
3. Which lighting environments have the most potential to cause the most change.

Color differences of the magenta-dyed test fabrics before and after a six-week exposure period were measured using a spectrophotometer, while chemical changes were investigated using ultra-high performance liquid chromatography coupled with photodiode array detection (UHPLC-PDA).

2. SYNTHETIC TEXTILE DYES

A major development of the mid-19th century was the discovery of synthetic textile dyes. The invention and use of gas lighting in the early 19th century produced copious amounts of coal tar, a sticky black waste product (Haber 1958). Chemical studies of coal tar revealed many benzene-based chemicals for manufacturing aniline and other useful organic compounds (Reimann 1868).

Chemical modification of aniline led to the discovery of colored compounds suitable for dyeing textile fibers, aptly named aniline or coal tar colors (Travis 1993). These artificial colorants gained popularity with industrial dyers and textile manufacturers because their composition and supply were more consistent and efficient than natural dyes as well as some creating bright and striking colors on cloth (Knecht, Rawson, and Loewenthal 1893).

3. MAGENTA

Magenta was discovered in 1858, patented in 1859 under its original name of Fuchsine, and in commercial production that same year. This vivid red dye established itself globally as a major commercial success—more so than the first aniline dye, Perkins Mauveine, which was discovered in 1856, available in 1857, and eventually mass produced in 1859 (Travis 1993; Cooksey and Dronsfield 2009).

3.1 USE OF MAGENTA

Magenta is classified as a basic or triphenylmethane dye (Society of Dyers and Colourists, 1971), and exists as a water-soluble salt, manufactured historically in chloride and acetate forms. It is a dark-green crystalline material and when added to water creates a brilliant red-blue color with a strong affinity for the protein fibers wool and silk (Trotman 1970). Magenta can also be used to color cellulosic material after pretreatment with a mordant (Knecht, Rawson, and Lowenthal 1893).

Magenta proved popular for many decades for coloring yarns and cloth used in high-fashion costume, embroidery threads, trimmings, and undergarments (van Brommel and Wallert 2007; Scholler 2014; Nicklas 2017). It was also highly useful to industrial dyers for shading, as described in published books and personal notebooks of the time (Smith 1880; Hummel 1888; Knecht, Rawson, and Loewenthal 1893).

From 1877, acid magenta became available for combined dyeing with acid dyes, but the popularity of the more strongly colored basic form continued until the end of the 19th century when new ranges of synthetic colorants became available (Rawson, Gardner, and Laycock 1918; Knecht, Rawson, and Loewenthal 1893). Magenta can still be obtained for use as a textile dye and in medical applications as a biological stain even though it is extremely toxic (Cooksey and Dronsfield 2009; International Agency for Research on Cancer 2010). Throughout this paper, the magenta referred to is basic magenta.

3.2 LIGHT FASTNESS OF MAGENTA

Since their creation, early aniline dyes were synonymous with fugitiveness (Slater 1870). In 1870, Slater, who was experienced in the dye industry, stated that magenta was not a fast color and "often spoiled if exposed to really bright sunshine" (Slater 1870, 112). Despite magenta being especially sensitive to daylight (Dufton 1891), it remained popular with dyers and consumers.

The German chemist, Kallab, conducted one of the first investigations into lightfastness of dyes, exposing 55 colorants, including magenta and other synthetics, to sunlight from July to September 1872. His observations, translated into English and published in 1874 by Crookes, described magenta as "duller and paler" after three to eight days and "bluish, much bleached" after three months (Crookes 1874, 660). In 1875, the dye chemist Napier commented in his *Manual of Dyeing* that magenta "becomes very light" when exposed to the sun, often in a few hours (Napier 1875, 11).

In 1888, the dyer and academic John J. Hummel studied the lightfastness of 100 different dyes on wool, including magenta, after one-, two-, four-, eight-, and twelve- month periods of light exposure. He assigned each dye a value of fast, medium or fugitive after observation, and placed magenta in the fugitive category (Hummel 1888, 487).

These first-hand observations of magenta and its daylight-fastness plus early anecdotal experiences were much referred to in the 19th century dyers' literature and in later publications, perhaps explaining why magenta is perceived to be very sensitive to all light. Today, when conservators and curators consider the display of a mid- to late-19th century red-blue textile, expectations are that the dye is magenta and that its color will fade quickly when exposed to indoor lighting.

While the historical commentary on the highly fugitive nature of magenta to outdoor sunlight is important, it is the limited and unreferenced accounts of magenta color change found peppered throughout conservation, museum, and dress and textile history literature that raise concerns for collections. The literature suggests that magenta is problematic within a collection lighting environment (Ginsburg 1984; Thomson 1986; Mills and White 2011). However, it is unclear how quickly these changes occur under controlled indoor lighting conditions, especially during shorter exposure times when a textile undergoes conservation, study, or short-term display.

4. MODEL TEST SAMPLES

Model test samples were created using plain-woven silk and wool fabric substrates dyed with modern basic magenta (Cl. 42510, Kremer pigmente). Dyeing was conducted using the appropriate health and safety procedures [1]. The model test samples were placed into an acid-free cardholder that masked a section from exposure.

5. LIGHTING SCENARIOS

Five real-life lighting scenarios were chosen for textiles examined, treated, and stored in the CTCTAH and displayed at a local museum. The sixth scenario was a windowsill and included as an extreme environment. Light sources were UV-filtered and unfiltered artificial lighting, UV-filtered and unfiltered natural light, and combinations of the two.

The test samples were exposed to each lighting scenario between June and August 2016 for a total of six weeks. Monitoring of light exposure levels, the presence of UV, and the spectral makeup of the light was undertaken (table 1). As the investigations were conducted in real working environments, they were subject to fluctuations in the amount and duration of exposure to light. For these reasons, it was not possible to calculate the exact exposure for these dynamically-lit environments, apart from the exhibition space which received approximately 30,000 lux hours during exposure.

6. COLOR CHANGE

Color changes were measured using a handheld Konica Minolta 2600d spectrophotometer, with setting parameters of an 8 mm aperture, 10° viewing angle (CIE 1964), 100% UV, D65/SCI illumination, and L*a*b* CIE00 color space. Changes in the L*, a*, and b* values and the overall color differences (ΔE_{00}) were observed through weekly measurements. The spectrophotometric results for changes between the initial and final week are presented in table 2. Figure 1 shows the test samples after six weeks of exposure alongside the unexposed controls.

6.1 CHANGES IN L*

L* represents the numerical lightness of a color, where 0 = black and 100 = white (Timár-Balázsy and Eastop 1998). There were changes in all L* values for samples exposed to light. The silk samples lightened slightly. The majority of the wool samples had a slight darkening, except for the windowsill sample, which initially darkened, but began to lighten after week four of the study.

6.2 CHANGES IN a*

a* is the balance between green and red. If the numerical shift between two values is negative, this indicates a shift toward green, while a positive value indicates a shift toward red (Timár-Balázsy and Eastop 1998). Both the silk and wool samples had a negative value change, which indicates a shift toward green. A shift in

Table 1. Specifics of the Lighting Scenarios During the Case Study

Scenario	Light Source	Lux (min/max)	UV (min/max)	Spectral Data (Ocean Optics USB 2000 Fiber Optic Spectrometer)	Notes
No. 1 Conservation Workroom 1	UV-filtered fluorescent and UV-filtered diffused natural light through glass (west facing)	0-1324	0 detected by Hanwell LuxBug	Intense peaks at • 550 nm • 620 nm	Artificial exposure 8 hours/Monday–Friday, natural light during daylight hours
No. 2 Conservation Workroom 2	UV-filtered fluorescent light	0–580	0 detected by Hanwell LuxBug	Intense peaks at • 550 nm • 620 nm	Artificial exposure 8 hours/Monday–Friday
No. 3 Windowsill	Unfiltered diffused natural light through glass (north facing)	0–6295	0–430 μW/L	Broad peak 350 nm–750 nm. Maximum peak height 500 nm–600 nm.	Light exposure during daylight hours
No. 4 Office	Unfiltered fluorescent and diffused unfiltered natural light (south facing)	0–739	0 detected by Hanwell LuxBug	Broad peak with only small intensity of light	Light exposure during daylight hours
No. 5 Dark storage	UV-filtered fluorescent when light on (only when in use)	0–580	0 detected when lights off/on with Elsec	Not measured	Light exposure as needed
No. 6 Exhibition space	HalogenTrack lighting: Havells Sylvania Torus 100FX fitted with Sylvania 12 V 100 W GY6.35 UV Stop capsule axial filament lamp	90 lux	0 UV detected with Elsec	Not measured	8 hours/7 days (30,240 lux hours total)

green would cause a loss in the overall red tone, which could cause the samples to appear duller. This was observed visually, particularly for the windowsill samples (see fig. 1).

6.3 CHANGES IN b*

b* is the balance between yellow and blue. If the numerical shift between two values is negative, this indicates a shift toward blue; a positive difference indicates a shift toward yellow (Timár-Balázsy and Eastop 1998). The silk samples had a positive shift, becoming more yellow, likely due to the degradation of the silk substrate.

Table 2. Differences in L*, a*, b*, and ΔE_{00} Between Initial and Final Weeks of Light Exposure

Lighting Scenario	L* ($L^*_{wk1}–L^*_{wk6}$)	a* ($a^*_{wk1}–a^*_{wk6}$)	b* ($b^*_{wk1}–b^*_{wk6}$)	ΔE*	L* ($L^*_{wk1}–L^*_{wk6}$)	a* ($a^*_{wk1}–a^*_{wk6}$)	b* ($b^*_{wk1}–b^*_{wk6}$)	ΔE*
	Silk				Wool			
No. 1 Workroom 1	0.23	–11.01	0.46	**2.67**	–1.80	–2.65	–5.02	**2.98**
No. 2 Workroom 2	0.24	–4.29	0.32	**1.01**	–0.73	–0.94	–2.54	**1.21**
No. 3 Windowsill	12.36	–51.81	13.86	**21.44**	1.47	–20.04	–7.85	**7.53**
No. 4 Office	0.05	–5.11	0.92	**1.15**	–0.64	–0.72	–2.91	**1.30**
No. 5 Dark storage	0.03	–0.01	0.27	**0.03**	–0.03	0.20	–0.51	**0.04**
No. 6 Exhibition	0.82	–4.83	0.28	**1.53**	–0.07	–0.22	–3.50	**1.79**

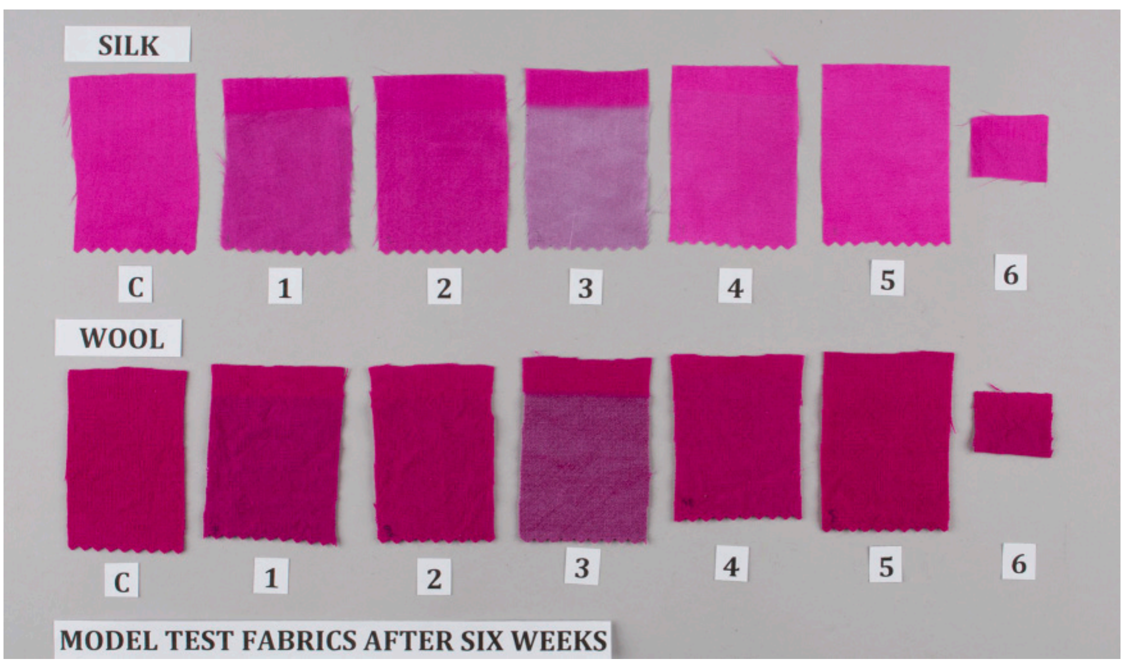

Fig. 1. Magenta-dyed silk and wool model test samples after exposure (scenarios 1–6) for six weeks, shown with the unexposed controls (C). The area masked during exposure for each sample is illustrated at the top of the two samples comprising no. 3.

6.4 OVERALL COLOR DIFFERENCE

Overall color difference values have been used to monitor color change in a range of historical materials, including textiles. A ΔE_{00} of 1.5 has been used as the threshold for perceptible change, when difference in color becomes discernible (Ashley-Smith, Derbyshire, and Pretzel 2002; Pretzel 2008).

The overall color differences of the magenta-dyed test samples were calculated. Changes in the samples exposed to light were found to be between E_{00} 1.01 and ΔE_{00} 21.44 (table 2). Areas considered safe working and display spaces had overall changes between ΔE_{00} 1.01 and ΔE_{00} 2.98.

There were differences in the L* and b* value shifts for the exposed silk and wool model test samples. These differences between the substrates were likely due to the different chemical properties of the silk and wool; however, further investigation was beyond the scope of this study.

7. UHPLC-PDA ANALYSIS

Exposure to light can cause the photochemical degradation of dyes, resulting in color loss and change from the breakdown of the chromophoric (colored) system of the dye molecules (Tímár-Balázsy and D. Eastop 1998). This results in the formulation of new colored and noncolored products (Brill 1980), which can be determined by chemical analysis (Quye, Wouters and Boon 1996; Ferreira et al. 1999; Han 2016; Hulme et al. 2017).

Dyes and their degradation products are a unique combination of chemical components; UHPLC allows for these components to be separated and possibly identified (Stuart 2007). Changes within the magenta-dyed test samples after light exposure were investigated using UHPLC coupled with photodiode array detection (PDA) at the CTCTAH (Waters ACQUITY UPLC H-class system). Dyes were first extracted from the fiber using a two-step process with DMSO and oxalic acid. They were then analyzed with a 40-minute gradient elution program of methanol and water (Han 2016, 116–119) [2].

The PDA detector enabled the ultraviolet and visible spectra (UV-Vis) of separated chemical components to be measured between 190 nm and 800 nm with a resolution of 1.2 nm (Han 2016, 101–119). Using Empower software, results from the PDA were plotted as spectra and chromatograms were generated for each sample where the x axis shows the retention time in minutes for each separated component in the sample and the y axis shows the absorbance intensity at specified wavelengths. For this study, the selected wavelengths were 254 nm and 560 nm: 254 nm to detect generic aromatic structures present in both colored and colorless compounds (including those from fiber degradation); and 560 nm because it is the maximum wavelength absorption of pararosaniline, rosaniline, and two rosaniline methyl isomers—the four major components of historical and modern basic magenta (International Agency for Research on Cancer 2010; Han 2016; Quye, Wertz, and Degano 2017) (fig. 2).

7.1 UHPLC-PDA RESULTS

The UHPLC-PDA results for the model test samples before and after light exposure were compared to identify chromatogram differences in the peak areas and heights of the four main compounds of magenta, pararosaniline, rosaniline, and two rosaniline methyl isomers (fig. 3). Smaller peaks for these compounds in after-exposure chromatograms would indicate lower amounts caused by molecular breakdown and changes, presumably related to photodegradation (light damage), while additional new peaks would indicate the formation of photodegradation products.

For the scope of this project, it was sufficient to note the gain or loss of chemical components with the aim of observing obvious trends and correlation with the spectrophotometer color measurements. This was done by overlaying chromatograms for each test fabric from before and after exposure to each lighting scenario.

Comparative assessment of the unexposed and exposed samples revealed smaller and fewer peaks for the four main components of magenta (fig. 4). This showed that the perceptible color changes measured by the

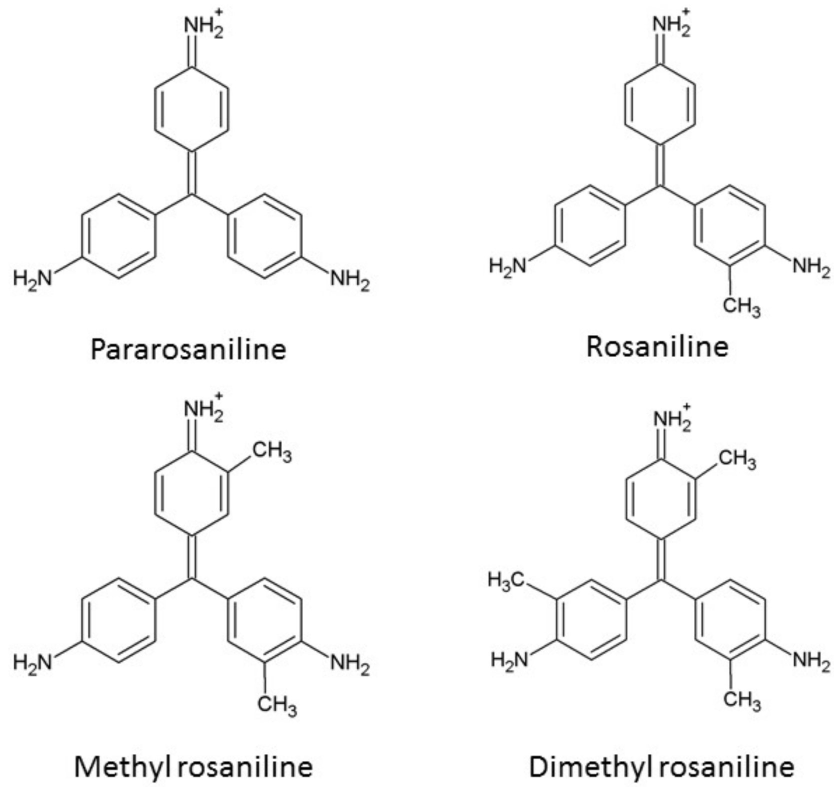

Fig. 2. Chemical structures of the four main compounds of basic magenta as their soluble salts.

spectrophotometer ($\Delta E_{00} > 1.5$) corresponded to chemical changes in the dye. The greatest reduction in the dye components' peak sizes, and hence degradation, was for the wool sample exposed on the windowsill (no. 3), which also showed the greatest ΔE_{00} change and most noticeable color difference.

New compounds were detected in the exposed samples, notably a component at 15.14 minutes with maximum absorption between 555 nm and 565 nm, indicating that it was colored (table 3 and fig. 5). A spectral shift from 560 nm to 565 nm would lead to observable blue color absorption, which may explain the blue color shift (negative b* values) measured by the spectrophotometer for the wool windowsill sample.

This study gave no clear correlation between chemical changes and perceptible color differences detected by spectrophotometry, possibly because loss of original colored components was balanced by formation of new ones. Answers will be found from other research projects, including a more controlled and extensive investigation at the CTCTAH in collaboration with Edinburgh Napier University into the effect of visible light on light-sensitive dyes (Quye, Han, and Innes 2016).

8. DISCUSSION

Color changes to silk and wool dyed with modern basic magenta were detected by spectrophotometry and UHPLC-PDA analysis after exposure of the fabrics to six weeks of real-time conservation and museum indoor lighting environments. At the chemical level, changes to the magenta dye resulted in new, missing, and

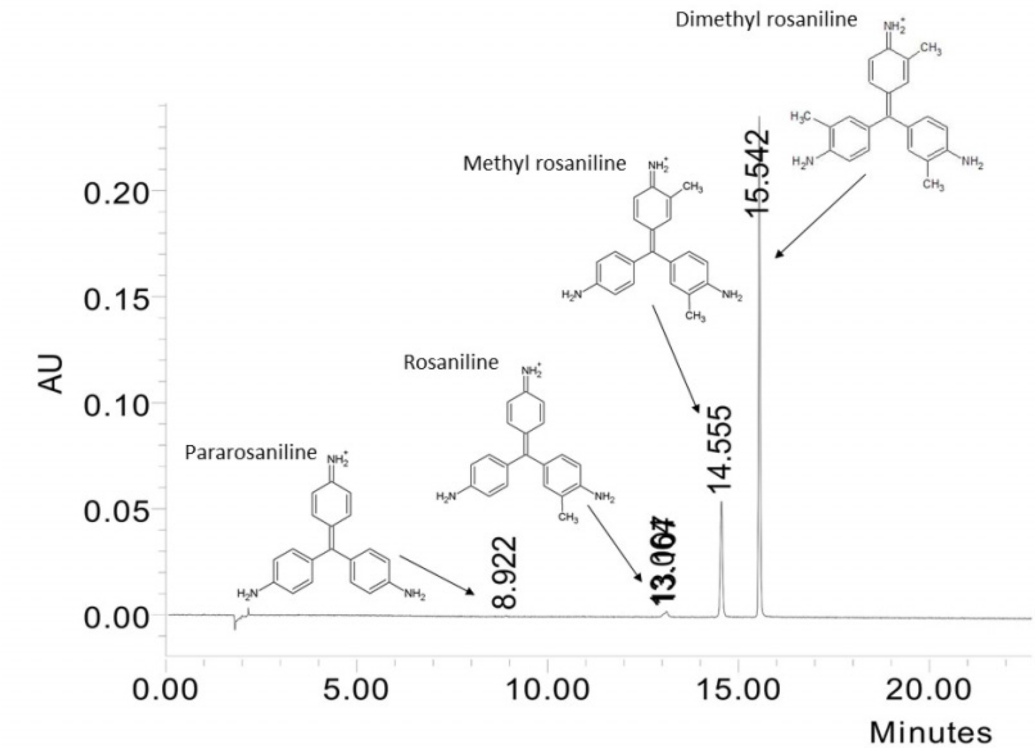

Fig. 3. Chromatogram at 560 nm of modern basic magenta extracted from dyed silk before exposure to light, showing pararosaniline at 8.92 minutes, rosaniline at 13.10 minutes, and two methylrosaniline isomers at 14.55 minutes and 15.54 minutes.

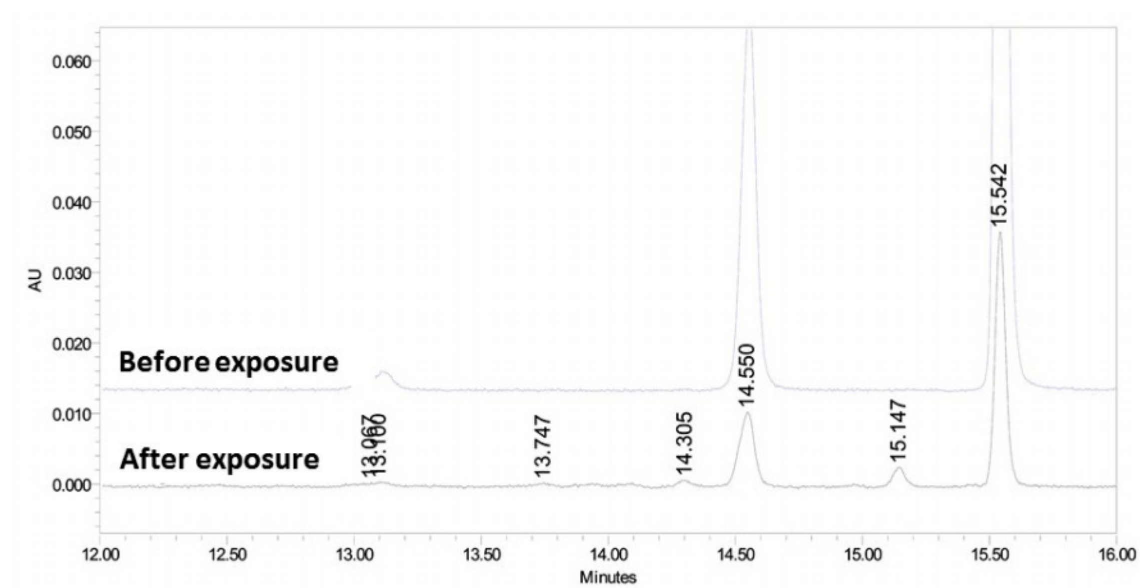

Fig. 4. Chromatographic overlay at 560 nm of basic magenta extracted from silk before and after exposure to light, showing reduced magenta components peak heights (13.10, 14.50, and 15.54 minutes) and new components (13.74, 14.30, and 15.14 minutes).

Table 3. Absorption Spectra of Peak at 15.14 minutes

Lighting Scenario	Silk (nm)	Wool (nm)
No. 1 Workroom 1	560	559
No. 2 Workroom 2	565	559
No. 3 Windowsill	562	565
No. 4 Office	559	555
No. 6 Exhibition	560	559

decreasing components detectable at 254 nm and 560 nm. This means that the loss of original colored components and the formation of new components are concurrent; therefore, photodegradation-related changes to magenta may not be immediately obvious because the resulting product is still colored.

It was surprising to observe measurable color change in conservation workrooms, generally considered to be safe environments for textiles, even though they usually have higher amounts of light (UV-filtered) than display areas, as light is required to perform examinations and delicate treatments. Magenta changes within these environments are concerning, as sometimes textiles require intense interventive treatments or other preparations that require weeks of work, which often includes brighter additional task lighting. Between the two conservation workrooms, workroom no. 1 had the most change. The spectral makeup of the artificial light source may have been a factor, as there were several intense peaks, particularly at 550 nm, which is around the maximum absorption of magenta. Additionally, the test samples were continuously exposed and not protected with a covering to limit light exposure, as objects in conservation workrooms usually are. This study therefore emphasizes the importance of covering textiles with protective inert materials when not worked on.

Samples exposed on the windowsill represented non-ideal conditions, such as a breech in UV light-reducing filters on window glass or an uncontrolled environment. These samples turned lighter, paler, and slightly

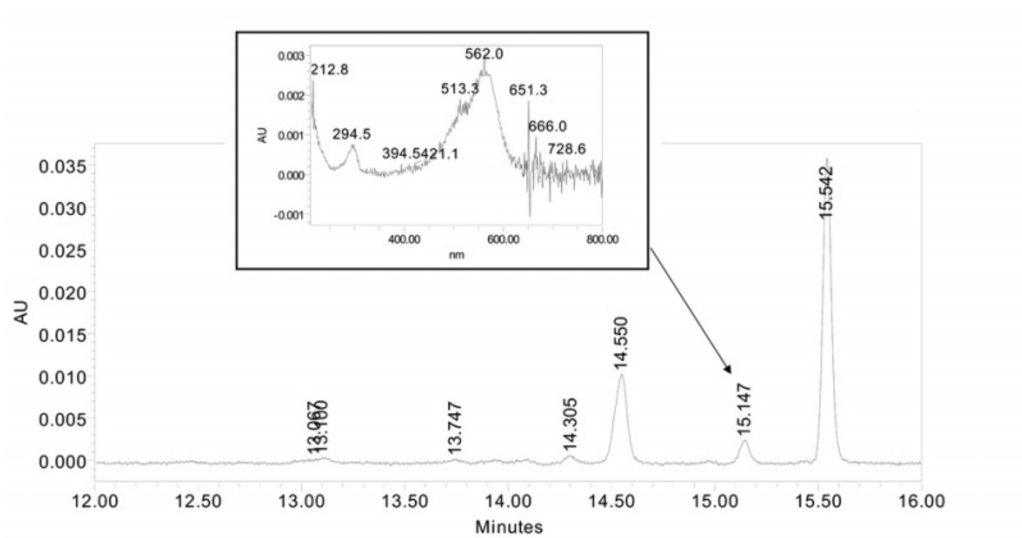

Fig. 5. UV-Vis spectrum and chromatographic peak exemplifying the new chromophoric compound detected in magenta-dyed fabrics after six weeks of light exposure (sample No. 3, silk).

bluer after six weeks of exposure. This corresponded to chemical loss of magenta's main colored components and the formation of a new compound absorbing at a longer wavelength, as detected by UHPLC-PDA analysis. These results, along with negative b* values from the spectrophotometric color measurement for the wool samples, revealed measurable changes corresponding to a visually discernible blue tone in the exposed samples of this study and to historical observations from 19th century lightfast studies of magenta in direct sunlight. It is therefore possible for indoor lighting conditions to have a damaging impact on magenta.

It should also be noted that this study used newly dyed magenta, which can be expected to be in the initiation reaction phase of greatest chemical change (Cox Crews 1987).

Historical magenta-dyed textiles exposed to light through past usage or exhibition may have already undergone a color shift and may be relatively more stable, having gone beyond this induction period. However, this study highlights a risk for historical dyed textiles with limited light exposure, such as fabrics inside pattern books, because there was minimal color and chemical changes to the magenta-dyed test samples placed in a dark storage area with intermittent artificial lighting. Thus, it can be hypothesized that historical magenta textiles protected from light exposure have potential to be most susceptible to color change when eventually exposed to light for extended periods because the induction phase has not been reached. This phenomenon has been observed in other studies of real-time museum lighting (Ford and Smith 2017). Further research is necessary to test this theory.

9. CONCLUSIONS

Magenta can undergo color and chemical changes in "safe" collection lighting environments, confirming perceptions that magenta is vulnerable to change under controlled indoor lighting conditions typical for museum textiles. The next step is to decide how much color and chemical change is acceptable when providing access through study, conservation, or display. This level of acceptable change many differ depending on the significance of the object in question.

In cases in which a textile suspected of being dyed with a fugitive colorant is going to be exposed to light, decision-making tools such as micro-fade testing and monitoring color change with a spectrophotometer can be useful in drawing up lighting and care guidelines for a specific object. However, access to this type of equipment may be costly and out of reach for some. For now, continuing with established lighting protocols such as UV-filtered light sources and minimizing light exposure, as well as following simple lab procedures such as ensuring that objects are always covered when not needed, are the best options for preservation of these colorants until more information is known or new technologies are developed.

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NOTES

[1] Dyeing model test samples with basic magenta

- Silk (5 g) and wool (20 g) substrates were scoured to remove all surfaces in a solution of sodium bicarbonate (pH 9, Acros Organics 99.7 ACS regent) and ultra-pure water, and boiled for 15 minutes.
- Silk and wool were dyed in different baths. The recipe for mid-shade magenta from David Smith's 1880s *Practical Dyers Guide* was followed (Smith 1880, 125). Basic magenta (Fuschin; CI. 42150) obtained from Kremer Pigmente GmbH &CO KG (0.0125 g for silk bath and 0.05 g for wool bath) was added to 800 mL of ultra-pure water and heated to 50°C/122°F. Once mixed, it was filtered through cotton lawn fabric.
- Fabric samples were placed in their respective baths around 50°C/122°F. No additives were used.
- Dye baths were slowly heated to 60°–70°C/144°–159°F for 40 minutes to ensure that both baths were fully exhausted. Dyes took up quickly.
- Samples were rinsed four times using ultra-pure water.
- Dye bath and rinses were disposed of in non-chlorinated waste.

[2] Dye extraction method

Dye extractions at the CTCTAH were conducted using a two-step process (Han 2016).

- Step 1: A 2 mm × 2 mm sample was removed from the model test fabric and transferred to a 1 mL flat bottom glass vial; 50 μl of dimethyl sulfoxide (DMSO) was added to the vial and heated to 80°C/176°F for 10 minutes in a Talboy block heater. The DMSO extract was then transferred using a micropipette with a disposable tip into a vial insert, which was kept aside.
- Step 2: Then, 75 μl of oxalic acid solution composed of a mixture of 0.5 M oxalic acid/acetone/water/methanol (1:30:40:30 (v/v/v/v)) was added to the fiber sample remaining in the vial. The sample was heated for 15 minutes at 80°/176°F. The extract was then completely evaporated using a BUCHI R-125 Rotavapor at 15–18mbar.
- Step 3: The dried extract was reconstituted using the first DMSO fraction, thereby combining the extracts from the two steps. The extract was then filtered through a 0.2 μm Premium Syringe Filter into a glass vial, which fit into the UHPLC auto sampler.

The extraction was carried out under the supervision of Dr. Jing Han.

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SOURCES OF MATERIALS

Medium Weight Silk Habotai and Volatie Fine Wool
Whaleys (Bradford) Ltd
Bradford
West Yorkshire
BD7 4EQ
England, UK
Tel: +44 0 1274 576718
Fax: +44 0 1274 521309
https://www.whaleys-bradford.ltd.uk/

Basic Magenta Dye (Fuschin CI. 42150)
Kremer Pimente GmbH & CO KG
Hauptstr. 41-47
DE 88317 Aichstetten
Germany
Tel: +49 7565 91448 0
Fax: +49 7565 1606
https://www.kremer-pigmente.com/en/dyes-und-vegetable-color-paints/synthetic-dyes-watersoluble/4078/fuchsin

AUTHOR BIOGRAPHIES

MICHELLE HUNTER is a 2016 graduate of the MPhil textile conservation program at the University of Glasgow Centre for Textile Conservation and Technical Art History. Since completing her studies, she has worked in private conservation in the United States and was most recently the 2017 to 2018 paid postgraduate intern in textiles at the Canadian Conservation Institute. E-mail: michellehunter.tc@gmail.com

DR. ANITA QUYE is the senior lecturer in Conservation Science at the University of Glasgow, teaching mostly in the postgraduate programs of the Centre for Textile Conservation and Technical Art History, and is also the head of History of Art. Before joining the university in 2010, she was the organic analytical research scientist for National Museums Scotland. Address: History of Art, 8 University Gardens, Glasgow, UK G12 8QH. E-mail: anita.quye@glasgow.ac.uk

AMBIENT MASS SPECTROMETRY ANALYSIS OF ALIZARIN-DYED TEXTILE AND DYE TRANSFER TO PAPER

REGINA A. BAGLIA, G. ASHER NEWSOME, AND MARY W. BALLARD

ABSTRACT—Nondestructive and minimally destructive analytical chemistry techniques are valuable tools to the conservation field. Direct analysis in real time (DART) is an ambient ionization method that uses a heated helium post-plasma gas stream to desorb and ionize molecules from a sample surface that then enter a high-resolution mass spectrometer (MS). DART-MS has been used for many different applications, but recent literature in the field of conservation has focused on new methods for the dye analysis of historic textiles. In the current work, we present our DART-MS analysis of historic textiles related to madder dyeing on cotton, including samples removed from accessioned textiles and from intact samples mounted in swatch books. Our data demonstrates that DART-MS can detect compounds associated with textile processing in addition to the dye chromophore. These additional compounds may provide insight into the complexity associated with historic textile production, use, and degradation.

ANÁLISIS POR ESPECTROSCOPÍA AMBIENTAL DE MASAS DE TEXTIL TEÑIDO CON ALIZARINA Y TRANSFERENCIA DE TINTE AL PAPEL

RESUMEN—Las técnicas anaíticas no destructivas o mínimamente destructivas son valiosas en el campo de la conservación. El método de análisis directo en tiempo real (DART, por sus siglas en inglés) es un método de ionización ambiental que utiliza una corriente de helio caliente en forma de plasma para desorber y ionizar moléculas de la superficie de una muestra, que luego entran en un espectrómetro de masas de alta resolución (MS, por sus siglas en inglés). DART-MS ha sido utilizado para varias aplicaciones, pero una revisión de la literatura reciente en el campo de la conservación se ha enfocado a métodos nuevos para el análisis de textiles históricos. En este trabajo, presentamos nuestro análisis por DART-MS de textiles históricos, relacionados con el teñido de algodón con rubia (madder), incluyendo la remoción de muestras de textiles en nuestro catálogo y de muestras tomadas de muestrarios textiles. Nuestros datos demuestran que DART-MS puede detectar compuestos asociados con el procesamiento de textiles, además del cromóforo. Estos compuestos adicionales pueden proveer datos relacionados con la complejidad asociada a la producción textilera, uso, y degradación.

1. INTRODUCTION

During the late 18th century and 19th century, spurred on by continuing developments in dye chemistry, monochromatic and polychromatic printed cottons with detailed imagery were wildly popular in Western Europe and the United States, available in a variety of styles and colors. With active innovative manufacturing and competition among printers, dye manufacturers, and distributors of this new industry, textbooks and chemical clarifications did not always stay current or have all the necessary procedures enumerated precisely. Consequently, a perusal of 19th and early 20th century dye swatch books can often reveal that the cotton swatch, now pasted into the textbook, has produced over time an image transfer or partial offset on the adjacent page. At the National Air and Space Museum (NASM), a set of bed hangings were found to be transferring an actual *colored* ghost image, a shadowy dyed print or offset, directly onto adjacent tissue or mat board

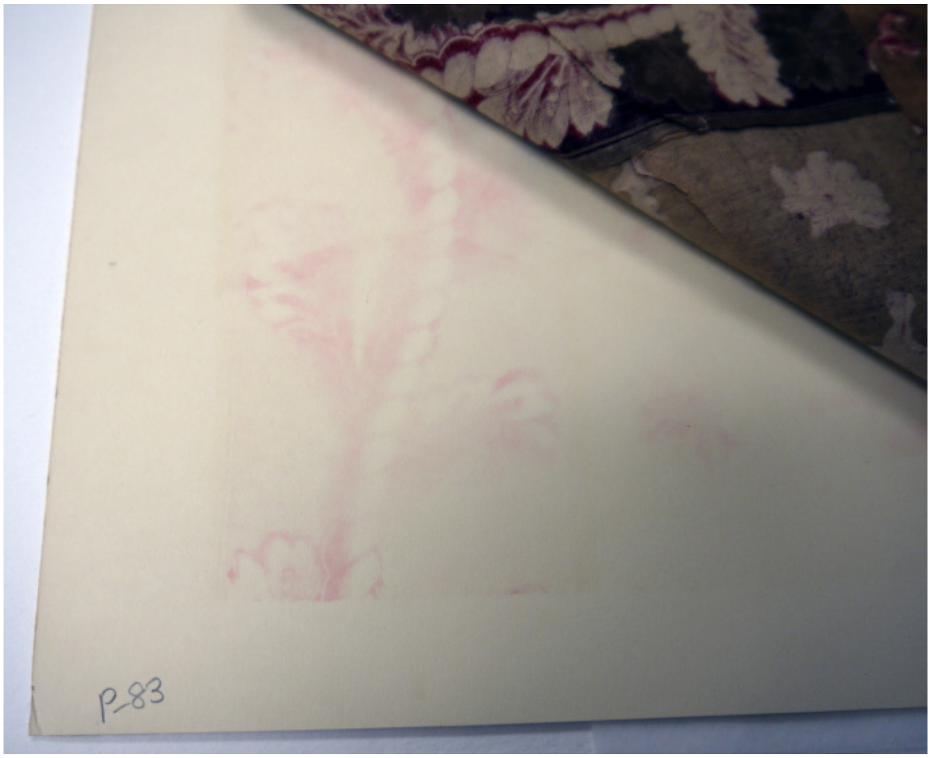

Fig. 1. Detail of ghost image revealed behind fragment of printed cotton toile (Courtesy of the National Air and Space Museum, photograph by Greta Hansen).

(fig. 1). In some instances, these images may well be leaching or off-gassing of volatile materials, unfixed auxiliaries, or dyes. However, without chemical analysis, there can be no definitive identification. Even uncolored ghost images are known to be difficult and time-consuming to replicate and identify (Heald et al. 1994; Padfield and Erhardt 1987).

In the field of conservation and preservation, in which analytes or samples are often too rare or too precious to be physically sectioned from intact objects, nondestructive and minimally destructive analysis methods are especially important. For example, x-ray fluorescence spectroscopy (XRF) can identify inorganic elements associated with mineral dyes or mordants. Until recently, the most comparable analytical method for organic compounds has been Fourier transform infrared spectroscopy (FTIR), which identifies species by the spectral pattern of covalent bonds. Identification by FTIR is complicated by the simultaneous detection of all materials present in a single spectrum. In order to determine the color component, a mere 0.2% to 3.0% by weight of the fabric itself, the dye must first be separated from the fiber. The most accurate and precise organic dye analysis for dyed and printed fabric requires the removal and processing of a small dyed sample by high performance liquid chromatography (HPLC) coupled to ultraviolet-visible (UV-Vis) spectroscopy, a diode array detector (DAD), or mass spectrometry (MS). Unlike FTIR, HPLC separates the chemical components for individual detection, and known chromophores are characterized by absorbance, chromatographic retention time, and/or molecular mass. The finding is confirmed by its congruency to a library of references containing known dye standards, each previously characterized.

Ambient mass spectrometry describes a set of techniques performed at atmospheric pressure with little or no sample preparation or sectioning. Chromatography is not employed, and high mass resolution distinguishes compounds that are not separated in time (Gross 2011). DART ionization is one such technique.

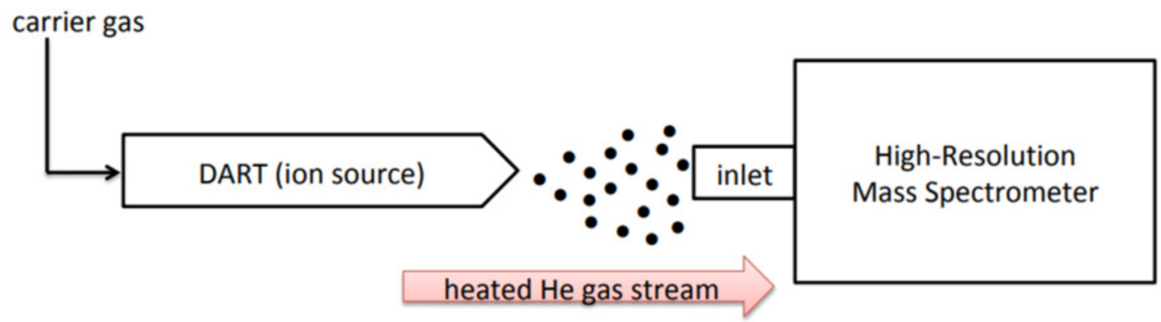

Fig. 2. Schematic of direct analysis in real time (DART) ion source positioning relative to the mass spectrometer inlet.

Helium flows through a heated cell where an electrical discharge creates metastable ions (fig. 2), which exit through a port in a ceramic cap in a plume of gas and interact with both the sample and water in the ambient atmosphere (Cody, Laramée, Durst 2005). Analyte molecules are thermally desorbed off a sample surface, ionized, and pulled through a transfer tube into the mass spectrometer vacuum for analysis. The DART experiment can be performed in transmission mode, in which the DART probe is directed straight at the transfer tube with samples held in between (fig. 3a) (Cody, Laramée, Durst 2005), or in reflection mode, in which the DART probe is directed at an angle to a horizontal sample surface positioned in front of the mass spectrometer (fig. 3b) (Gross 2014; Habe and Morlock 2015; Newsome, Kayama, and Brogdon-Grantham 2018). DART ionization has been used for a variety of small-molecule applications, including dye analysis (Armitage Jakes, and Day 2015; Armitage, Day, and Jakes 2015; DeRoo and Armitage 2011).

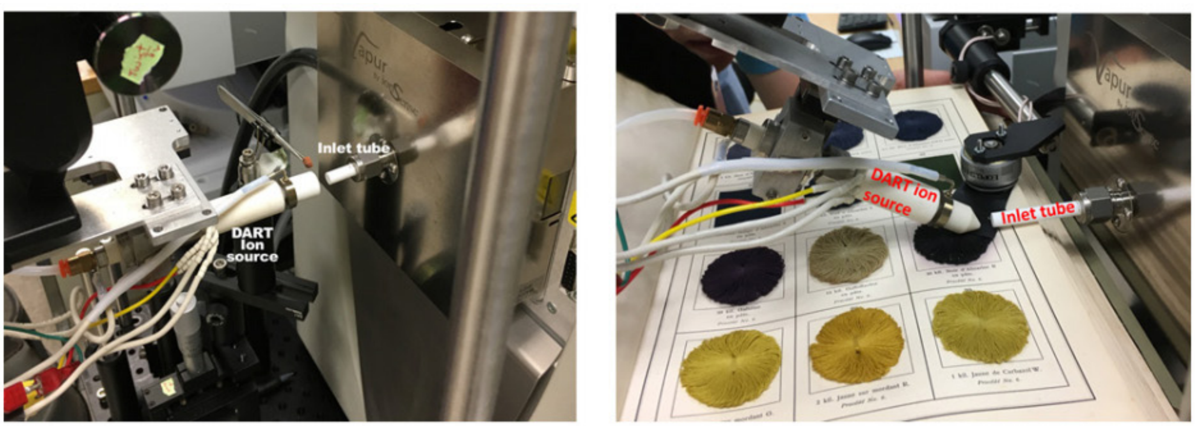

Fig. 3. (a) Sample positioned directly between the ion source and inlet in transmission mode. (b) Ion source positioned in reflection mode at an angle to the object surface in front of the inlet.

Three examples of DART-MS analysis are described in this paper. First, a comparison with the HPLC-DAD/MS results was made using a part of the same sample removed from a set of bed hangings and related printed textiles (figs. 1, 4a). Second, the identification of the colored ghost image on paper associated with these hangings (figs. 1, 4b) was confirmed, including cases in which the colorant ghost itself had dissipated throughout the paper to imperceptivity. Last, an offset stain associated with a dyed swatch sample in a dye manufacturer's swatch book of sample dyes was analyzed. The offset images were found on the cover and facing papers across from the dye when the book was opened (figs. 5a left, 5b left).

Fig. 4. (a) Fragment of bichromatic printed cotton toile and (b) offset image of the red component of the same printed cotton toile found on mat board beneath the printed toile (Courtesy of Greta Glaser, photograph by National Air and Space Museum).

2. EXPERIMENTAL

2.1 SAMPLES

HPLC-DAD/MS results had previously established the chromophores on a printed toile as chemical components of alizarin dye: alizarin, purpurin, and three other anthraquinones, analogs of purpurin—anthrapurpurin, flavopurpurin, and an unknown—along with ellagic acid, present in tannic acidbased dyes (Mori 2017) [1]. In preparation for comparable analysis using DART-MS, several sources of alizarin were used as standards: (1) muslin cloth dyed with madder that had been post-treated with $SnCl_2$; (2) powdered alizarin (Aldrich, 97%) dried onto Whatman paper; (3) madder root (Kremer pigments); and (4) fibers from wool yarn dyed with madder and post-treated with $SnCl_2$.

No sample preparation was performed for the extant samples of the toile textile. A fragment of tissue paper containing a colored ghost image had been set aside, folded into a small, compacted sample, and wrapped tightly in aluminum foil. As of October 2017, the offset had faded, dispersed throughout the paper within the confines of the aluminum foil. Although contained, they were now rendered almost imperceptible. For more distinctive, conventional offsets, the dye swatch book *Les Couleurs d'Alizarine* was selected and its Swatch No. 36 "Noir d'Alizarine R, en pate" (fig. 5a right) and its offsets (figs. 5a left, 5b left) were tested (BASF n.d.)[2]. Because of the size of this object, reflection mode was used for DART-MS analysis.

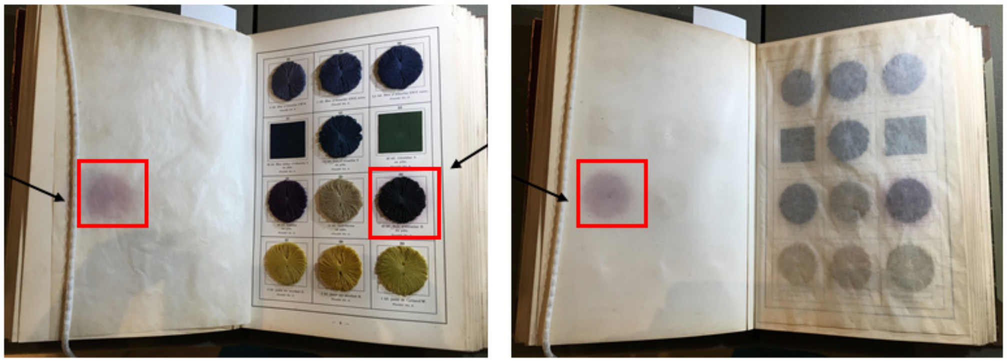

Fig. 5. The dye swatches were placed only on the right side of the open swatch book pages. Each swatch page was faced with a thin glassine like tissue. This tissue was covered then by the back of the previous page of swatch samples, known as the board paper. (a) On the left image, arrows point to the actual swatch Noir d'alizarine R, on pâte #36 and its tissue offset to the left and (b) On the right image, the tissue now covers the swatches and an arrow points to the offset of #36 that has migrated through the tissue and into the board paper.

2.2 INSTRUMENTATION

A DART 100 probe operated by an SVP controller (IonSense) was custom mounted in front of an LTQ Orbitrap Velos mass spectrometer (Thermo Fisher Scientific) fitted with a differentially pumped Vapur interface. Mass spectra data were acquired at 30,000 resolving power with a maximum ion trap fill time of 100ms. In transmission mode, a flat ceramic insulator cap was offset from the ceramic transfer tube by 7 mm (fig. 3a). There can be a limit to the size of the sample, but this configuration provides the greatest ion sensitivity. In reflection mode, an electronically controlled shutter was mounted beneath the insulator cap and transfer tube and above sample surfaces (Newsome Kayama, and Brogdon-Grantham 2018). A tapered ceramic insulator cap with a 0.5 mm orifice was positioned approximately 5 mm in front of the transfer tube and 45° to and 0.5 mm above the sample surface. Samples were exposed to the DART gas plume for three seconds using the shutter (fig. 3b). This configuration provides a greater protection from temperature for the object. Several helium gas temperatures were tested to determine optimum signal intensity. Optimum signal was observed with a helium gas temperature of 400°C.

As madder standards for DART, muslin cloth dyed with madder and post-treated with $SnCl_2$ along with the other references were examined by DART-MS in transmission mode at various temperature settings for the presence of alizarin and derivatives. Signal abundance from alizarin increased with DART helium temperature setting up to 400°C. No alizarin was detected at 100°C. To prevent thermal damage to samples at 400°C, most samples were run with a helium temperature setting of 300°C. The discrete samples, like the madder materials, also were run in the transmission mode.

3. RESULTS AND DISCUSSION

Formulas of alizarin derivatives and their respective exact mass values are shown in table 1. Table 2 lists the samples tested in this study. In the madder root sample, signal from alizarin derivatives dominated the mass spectrum, shown in figure 6. For all other samples (including the alizarin reference and madder-dyed samples), alizarin and/or its structural isomers were a trace signal in the spectrum at

Table 1. Most Common Red Colorant Compounds in Madder Dyed Materials (Schweppe 1989)

Compound	**Neutral Formula (M)**	**Exact Mass of Protonated Molecule ($[M+H]^+$)**
Alizarin	$C_{14}H_8O_4$	241.0501
Purpurin	$C_{14}H_8O_5$	257.0450
Pseudopurpurin	$C_{15}H_8O_7$	301.0348
Xanthopurpurin	$C_{14}H_8O_4$	241.0501
Lucidin	$C_{15}H_{10}O_5$	271.0606
Rubiadin	$C_{15}H_{10}O_4$	255.0657

m/z 241.0504 (fig. 7). Balloon-printed fabric samples remaining from dye analysis with HPLC-DAD/MS were then analyzed (figs. 8, 9). With permission for destructive analysis of the tissue paper wrapping, the balloon offset was examined at 400°C. The mass spectrum is given in figure 10, with the inset showing the alizarin peak. In figure 11, the selected ion signals for several alizarin derivatives are plotted over collection time. The mass-resolved analyte signal was observed when the sample was placed between the DART source and the inlet tube with zero background signal otherwise. The results are generally consistent with the HPLC data; DART-MS was able to detect alizarin and its derivatives, including on the invisible offset on acid-free tissue.

Dye swatch books containing "alizarin" swatches were also occasionally found to contain offset stains on paper directly in contact with the swatches. In the book *Les Couleurs d'Alizarine*, Volume II, one particular offset stain from swatch no. 36 (dye: Noir d'Alizarine R) was present on both the glassine tissue paper in direct contact with the swatch and on paperboard that covered the tissue (figs. 5a, 5b). Because of the large size and dark discoloration of the offset, it was chosen for analysis by DART-MS. Analysis in reflection mode was collected on the swatch, tissue offset, and paperboard offset. As a control, data was also taken in unaffected areas of the tissue and paperboard where no discoloration was observed. A summary of the mass spectral data for these five sample sets is presented in table 3. The results indicate the presence in

Table 2. Summary of Alizarin Derivatives Detected in Samples, a Comparison of the Results from the Known Samples to the Unknown Samples in the NASM Toile and Its Paper Offset

Sample Source	**Alizarin Detected at *m/z* 241.0504**	**Purpurin Detected at *m/z* 257.0453**	**Other Derivatives Detected**
Madder on cotton muslin (after-treated with $SnCl_2$)	✓	✓	Rubiadin
Alizarin powder	✓	✓	-
Madder root	✓	✓	Rubiadin, lucidin
Madder on wool yarn (after-treated with $SnCl_2$)	✓	✓	Rubiadin, lucidin
Printed toile (red)	✓	✓	Rubiadin, lucidin
Printed toile (brown)	✓	✓	Rubiadin
Tissue paper offset	✓	✓	Rubiadin, lucidin

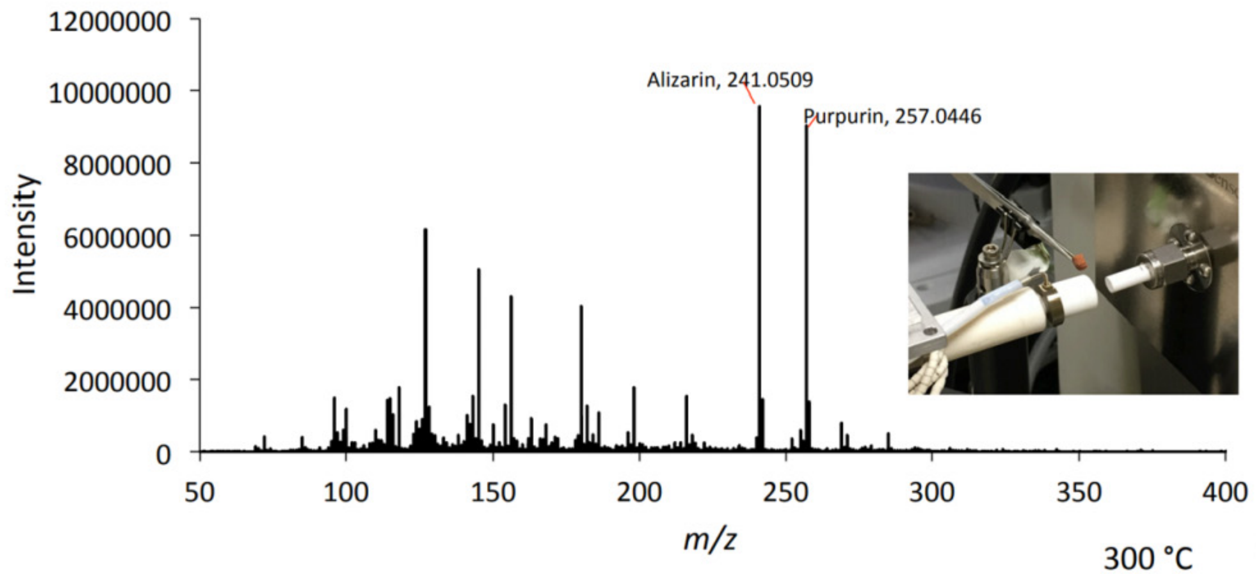

Fig. 6. Spectrum and detail of madder root control sample moving toward the DART helium flow. Note the intensity of the alizarin and purpurin peaks.

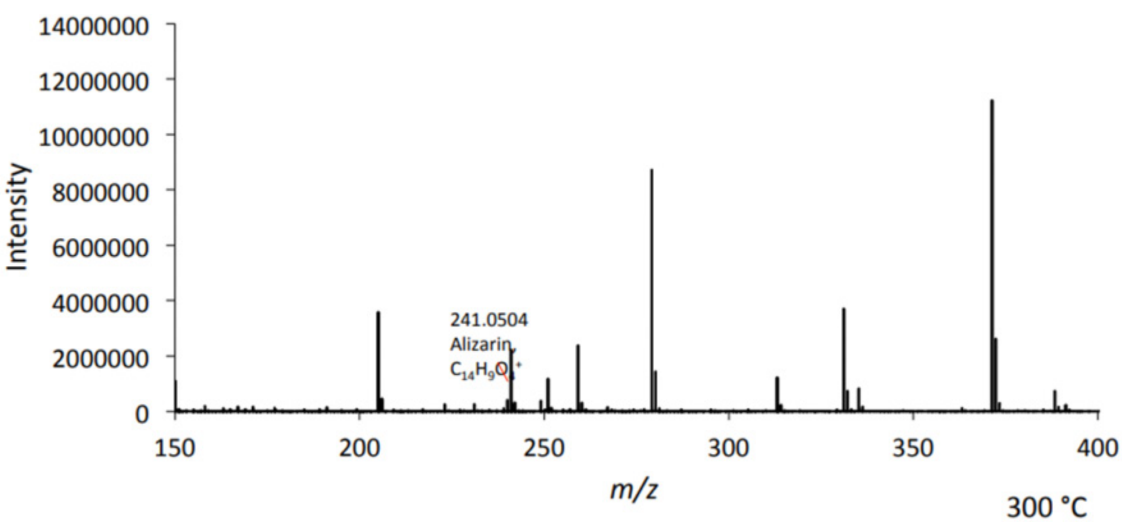

Fig. 7. Spectrum of alizarin powder reference. Note the lower intensity of the alizarin peak, compared with that in figure 6.

the textile of ricinoleic acid and linoleic acids—components of castor oil soap, recommended as an auxiliary or assist in the dyeing of Alizarines, synthetic anthraquinones (BASF n.d.; Hummel 1906; Knecht, Rawson, and Loewenthal 1910; Pellew 1918). In addition, resin acids (rosin) were detected on both the swatch and the papers containing the offset, which may be associated with the paper processing (Adams 2011). The presence of rosin suggests that the offsets or discolorations may travel from the paper to the textile and not just from the textile to paper.

Fig. 8. The red colorant from the balloon-printed toile ready for direct transmission mode.

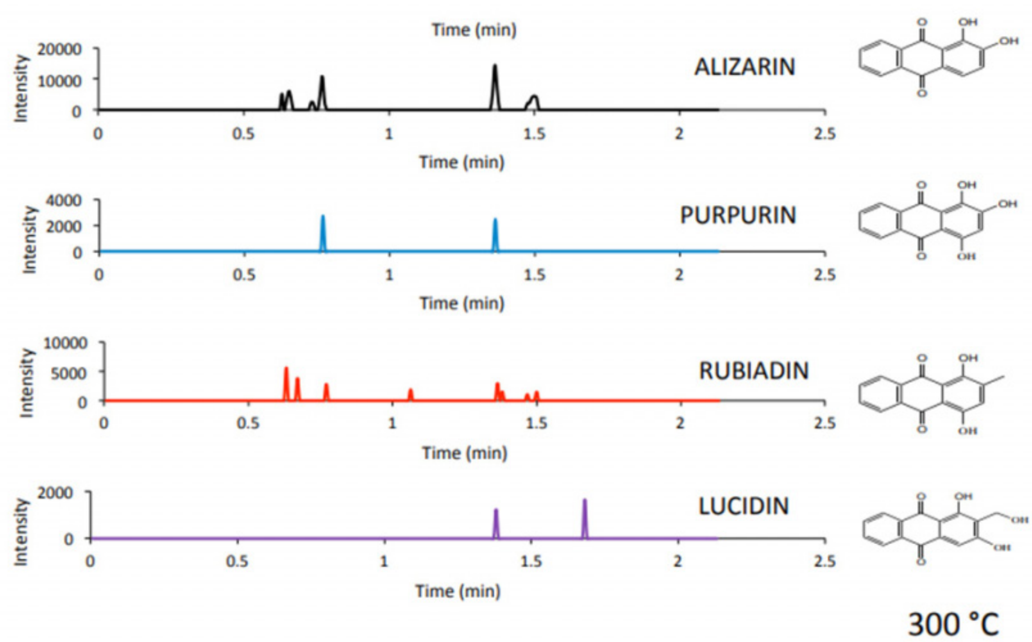

Fig. 9. The detailed spectra results obtained from figure 8.

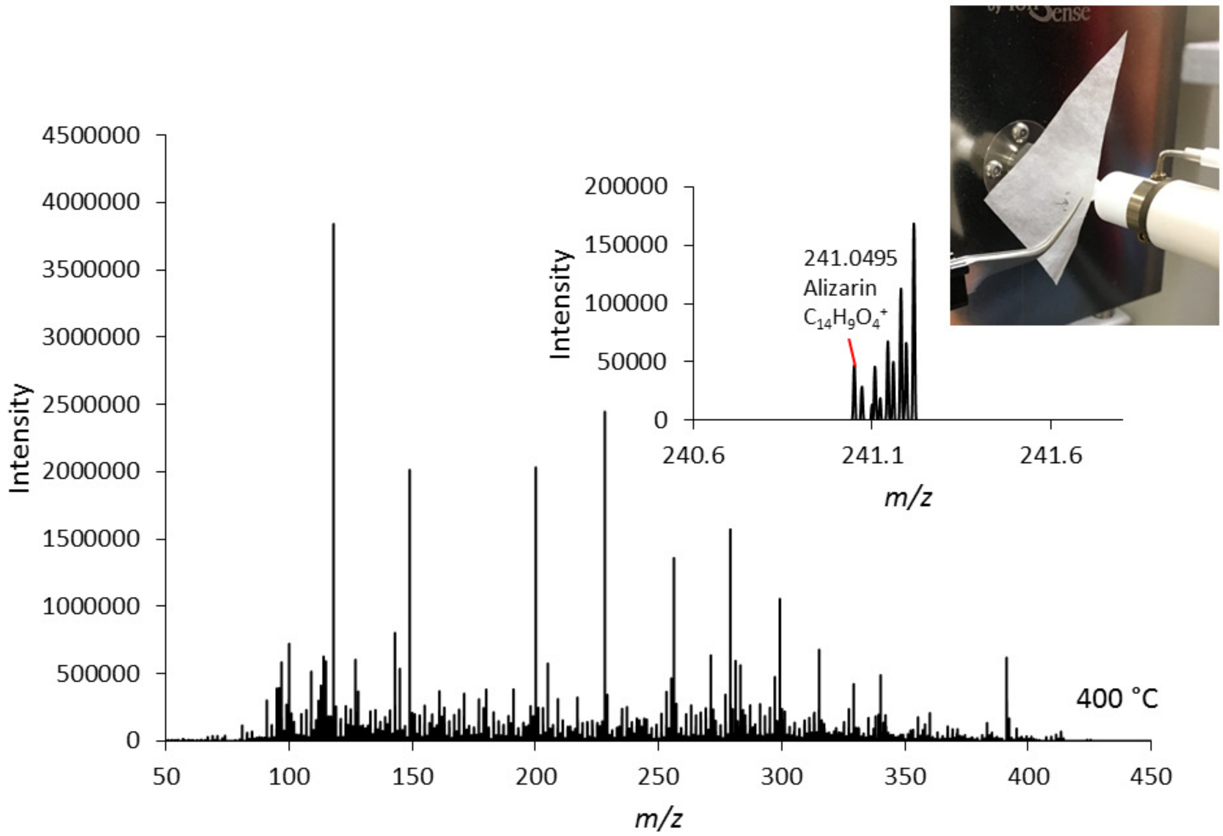

Fig. 10. Spectrum of the offset image from of the red colorant from the balloon-printed toile with an inset detail of the alizarin-related spectra at *m/z* 241.0504 and a photo of the sample in place.

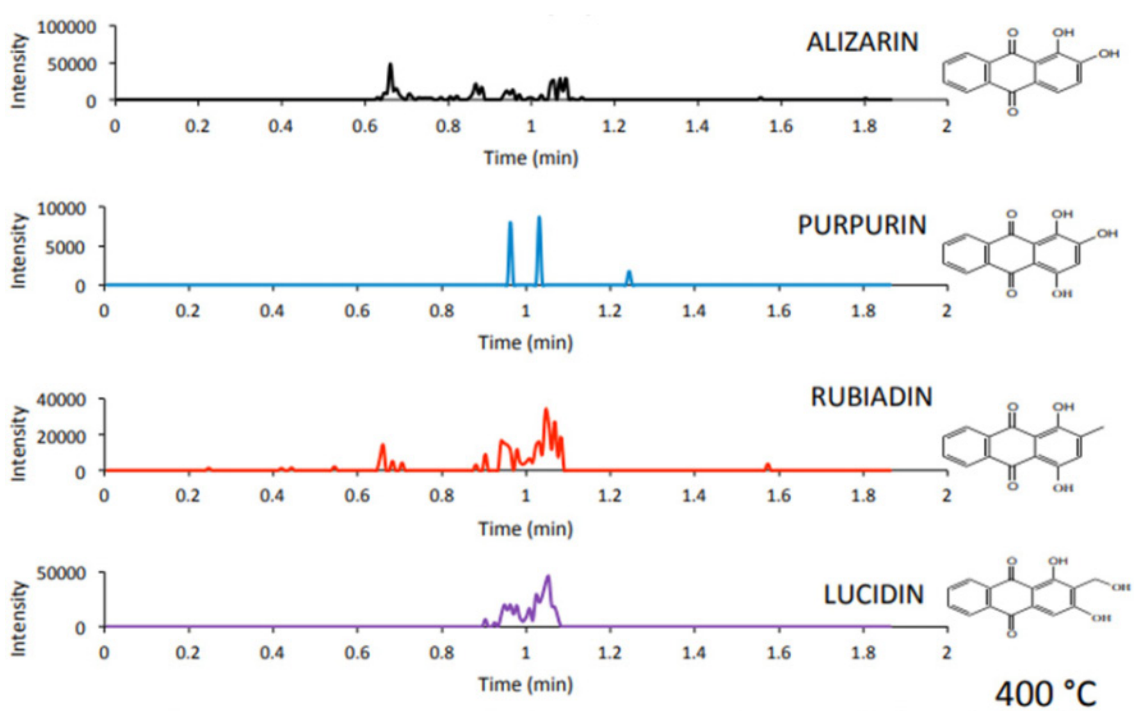

Fig. 11. The detailed spectra from figure 10 elucidated from the spectral detail in figure 10.

Table 3. Summary and Comparison of Compounds Detected in Textile, Its Off-sets, and Paper Controls

Observed *m/z*	Compound Class	Neutral Formula and Compound	Textile	Tissue Offset	Tissue Control	Board Offset	Board Control
263.2364	Fatty aldehyde	$C_{18}H_{30}O$ Linolyl aldehyde	✓	✓			
281.2485	Fatty acid	$C_{18}H_{32}O_2$ Linoleic acid	✓	✓			
289.2534	Resin acid	$C_{20}H_{32}O$ Abietol	✓			✓	✓
299.2578	Fatty acid	$C_{18}H_{34}O_3$ Ricinoleic acid (castor oil)	✓	✓			
299.2014	Resin acid	$C_{20}H_{26}O_2$	✓	✓	✓	✓	✓
301.2161	Resin acid	$C_{20}H_{28}O_2$ Dehydroabietic acid	✓	✓	✓	✓	✓
303.2312	Resin acid	$C_{20}H_{30}O_2$ Abietic acid	✓	✓	✓	✓	✓
315.1945	Resin acid	$C_{20}H_{26}O_3$ 7-oxodehydro abietic acid		✓		✓	✓

4. CONCLUSIONS

Our data demonstrate the utility of DART-MS for routine analysis of dyed fiber samples. We observed compounds associated with textile processing, which can provide insight into the complexity associated with historic textile production, the quality of the manufacturing, or the postproduction use and misuse as well as fabric degradation. DART-MS can also detect when the leachings have gone from the paper into the textile swatch, as seen in table 3.

The DART-MS instrumentation can also provide varying levels of sensitivity depending on the configuration and the setting temperature of the helium stream. With direct transmission, alizarin and its various analogs can be distinguished at temperatures between 300 and 400°C. With reflection mode, the actual chromophore remains obscured at lower temperatures, but the out-gassings or leachings are clearly represented. Reflection mode may provide book conservators, bibliophiles, and antiquarians as well as textile conservators and scientists with insights into the gradual changes that can occur within a closed volume.

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NOTES

[1] The NASM permitted sampling from the interior of a valence (T20140072370) from a set of bed hangings and associated fabric fragments (Ballard 2017).

[2] The Smithsonian Dibner Library of the History of Science and Technology holds two copies of the BASF swatch volumes, with sets published in Ludwigshafen s/Rhin and Neuville sur Soane. The swatch #36 studied in this paper is from the version published in Neuville sur Soane. The other version has soap offsets, another type of ghost image.

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SOURCES OF MATERIALS

DART 100 Probe Operated by an SVP Controller
IonSense
999 Broadway, 4th Floor
Saugus, MA 01906
Tel. 781-484-1043

LTQ Orbitrap Velos Mass Spectrometer
Thermo Fisher Scientific
168 Third Ave.
Waltham, MA 02451
Tel. 800-556-2323

AUTHOR BIOGRAPHIES

REGINA A. BAGLIA received her PhD in chemistry at The Johns Hopkins University in 2016, where she worked with Prof. David P. Goldberg. Her research was focused on bioinspired synthetic inorganic chemistry. In 2017, she took up a postdoctoral internship at the Museum Conservation Institute working on light-emitting

diode lighting issues for the "Ruby Slippers" exhibition. She is currently an adjunct professor in chemistry at Southern Methodist University. Address: Southern Methodist University, Department of Chemistry, 3215 Daniel Avenue, Dallas, TX 75275 E-mail: regina.baglia@gmail.com.

G. ASHER NEWSOME received his PhD in analytical chemistry at the University of North Carolina–Chapel Hill. He has studied a wide variety of analytes using novel mass spectrometry methodologies. Since joining the Smithsonian in 2017, he has been developing ambient techniques for cultural heritage and conservation science. Address: Museum Conservation Institute, Smithsonian Institution. 4210 Silver Hill Road, Suitland, MD 20746-2863. E-mail: newsome@si.edu.

MARY W. BALLARD, senior textiles conservator at the Smithsonian's Museum Conservation Institute, helped organize multiple sessions with the late Dr. Helmut Schweppe on dyeing and dye analysis of natural and early synthetic dyes. She is a fellow member of the American Institute of Conservation. Address: Museum Conservation Institute, Smithsonian Institution. 4210 Silver Hill Road, Suitland, MD 20746-2863. E-mail: ballardm@si.edu.

AN ENLIGHTENED PERSPECTIVE: BALANCING ARTIST INTENT WITH CONSERVATION CONCERNS

SARAH SCATURRO AND CHRISTOPHER MAZZA

ABSTRACT—Rei Kawakubo, avant-garde fashion designer and founder of the fashion label Comme des Garçons, is known for her ability to push boundaries. Thus, unsurprisingly, the monographic exhibition organized by The Metropolitan Museum of Art's Costume Institute was in many ways the antithesis of a typical museum exhibition. Standard exhibition practices, such as displaying objects on platforms and maintaining safe touch distances, were abandoned in allegiance to Kawakubo's creative vision. The most challenging aspect was the lighting design: a diagonal grid of over three hundred 72"-long T12 fluorescent lamps that illuminated objects to a projected 123 footcandles. As with all exhibitions involving living artists, Costume Institute conservators engaged in constructive dialogue in order to reach a solution that balanced Kawakubo's wishes with conservation concerns. Paramount to the conservators' approach was using conservation ethics as the guiding framework structuring decision-making and compromise efforts. In recognition that the ultimate lighting design still fell short of conservation standards, the Costume Institute conservation team seized the opportunity to collect data that could inform future exhibitions, taking a wide-ranging approach that included microfading testing, tracking lamp lumen depreciation, and placing Blue Wool Standard cards throughout the exhibition as a means to evaluate cumulative light exposure.

UNA PERSPECTIVA ILUMINADA: EL BALANCE ENTRE LA INTENCIÓN DEL ARTISTA Y LA CONSERVACIÓN

RESUMEN—Rei Kawakubo, diseñadora de moda avant-garde y fundadora de la marca Comme des Garçons, es reconocida por su habilidad para expandir fronteras. No es de sorprender, entonces, que la exposición monográfica de la diseñadora en el Instituto del Vestido del Museo Metropolitano de Arte (Costume Institute, Met) haya resultado la antítesis de una exhibición museística. Prácticas estándar, como el montaje de objetos en plataformas para mantener la distancia entre el visitante y el objeto fueron abandonadas para ser fieles a la visión creativa de Kawakubo. El reto más grande fue el diseño de luz: una retícula diagonal de más de 300 lámparas fluorescentes de 72 pulgadas de longitud, que iluminaron objetos con 1323.96 luxes de magnitud. Al igual que todas las exhibiciones que involucran artistas vivos, los conservadores del Instituto del Vestido mantuvieron un diálogo constructivo para llegar a una solución intermedia entre los deseos de la diseñadora y las necesidades de conservación. Lo más importante para los conservadores fue usar la ética de la conservación para guiar las decisiones y los sacrificios que cada parte haría. Reconociendo que el diseño de luz no fue el ideal desde el punto de vista de la conservación, el equipo de conservación del Instituto tomó esta oportunidad para colectar datos para informar futuras exhibiciones, tomando en cuenta: microexámenes de decoloración (micro-fate testing), monitoreo de los cambios de los focos (lamp lumen depreciation), y el uso de las tarjetas de lana azul (Blue Wool Standard), tanto durante la exhibición, como el acumulativo.

AN ENLIGHTENED PERSPECTIVE: BALANCING ARTIST INTENT WITH CONSERVATION CONCERNS

1. INTRODUCTION

With its unorthodox use of over three hundred 72”-long fluorescent light bulbs, the Spring 2017 Costume Institute (CI) exhibition *Rei Kawakubo/Comme des Garçons: Art of the In-between* was a literal bright spot in The Metropolitan Museum of Art’s yearly exhibition program. A groundbreaking look at one of the most innovative fashion designers practicing today, Rei Kawakubo (b. 1942), the exhibition included a lighting program that pushed normal museum conventions with an average illuminance nearly 16 times standard conservation recommendations for fashion objects. The program was created at the request of Kawakubo, who was granted an unprecedented level of control over the exhibition’s design. In seeking a balance between artistic intent and concerns over damage to both Kawakubo’s archives and a select number of other museum objects, the conservators developed a multifaceted approach that recognized and honored the artist’s wishes, sought adequate protection where possible, and collected data that could inform subsequent costume displays at The Met. The results of this ad hoc research project demonstrated both quantitatively and qualitatively that photochemical damage occurred to the artworks on display.

2. A COLLABORATIVE PROCESS: COMME DES GARÇONS AND THE COSTUME INSTITUTE

Considered one of the most important, yet reclusive, designers practicing today, Rei Kawakubo’s public involvement in The Met’s exhibition was a coup. Securing her participation was the result of over 13 years of effort by the Costume Institute’s curator-in-charge, Andrew Bolton (Friedman 2017). In an interview in the exhibition’s catalog, she described why she decided to finally move forward with the exhibition: “Recently I came to the conclusion that I wanted to collaborate with a museum on the essential Comme des Garçons exhibition...so that when people do shows after I’m gone they can refer to it as a model” (Bolton 2017). Thus, her goal in creating the quintessential artist-approved message meant that the CI’s exhibition was as much an artistic gesture as it was a curatorial exercise. She chose The Met since it promised her significant control over the content and design and, ultimately, because she trusted the curatorial vision of Bolton. The exhibition was The Met’s first monographic look at a living fashion designer since a controversial 1983 exhibition on Yves Saint Laurent.

2.1 REI KAWAKUBO AND COMME DES GARÇONS

As an artist, Rei Kawakubo is known for being fiercely private while paradoxically influential in fashion design over the past 40 years through her imaginative designs. In 1973, she started her Tokyo-based label Comme des Garçons (“like some boys”), which quickly became known for its avant-garde styles. Kawakubo is adamant about retaining complete control over her creative output, and she views her clothes as only one aspect of a larger holistic vision that encompasses architecture, media, and design.

2.2 THE COSTUME INSTITUTE’S CONSERVATION DEPARTMENT

The Costume Institute’s conservation department is structured uniquely within The Met. First, unlike other conservation laboratories that work with many curatorial departments throughout The Met, the CI’s conservation lab is associated with a single curatorial department. CI’s conservators report to the department’s curator-in-charge, Andrew Bolton, primarily handling objects held within the department’s collection. This structure is an asset in that it encourages strong collaboration, allowing the conservators to be a key voice in curatorial functions such as acquisitions, loans, and exhibition planning. Additionally, the CI is well funded and has excellent press exposure—benefits that also positively affect the conservation lab. However, there are challenges related to the department's schedule, which is more akin to fashion's fast cycle than a typical museum timeline. The department's conservators are heavily pressed upon to maintain as much flexibility as possible, especially when working with fashion designers. A significant difference between the CI and other departments is its requirement to raise its own operating budget, instituted in 1946 when the Museum of Costume Art merged with The Metropolitan Museum. This is accomplished through a renowned annual fundraiser marking the opening of the CI's spring exhibition, called the "Met Gala/Ball," organized by Vogue editor Anna Wintour. This self-funding requirement means that a collaborative and productive relationship with the fashion industry is paramount and is a key factor for the continued success of the department's exhibitions. It is with this collaborative spirit that the conservators approached the conservation program for *Rei Kawakubo/ Comme des Garçons: Art of the In-between.*

2.3 THE EXHIBITION DESIGN PROCESS

Kawakubo specifically chose to set the exhibition within the Cantor Gallery at The Met's main building because she "wanted to work with the Museum to create an installation that people would find both astonishing and challenging … and ... felt that the neutrality of the galleries at The Met Fifth Avenue better lent them to creating something extraordinary" (Bolton 2017). The design was planned by Kawakubo, with input from Bolton. It was intended to be a holistic, immersive experience by forgoing intended pathways and wall didactics, instead allowing visitors to choose their own path through a forest of towering white geometric structures filled with Kawakubo's strange creations (fig. 1).

Fig. 1. Installation of the exhibition (Courtesy of The Metropolitan Museum of Art).

AN ENLIGHTENED PERSPECTIVE: BALANCING ARTIST INTENT WITH CONSERVATION CONCERNS

Bolton interviewed Kawakubo during the early design development phase using questions provided in part by conservation staff. The interview clarified to the conservators that Kawakubo considered the exhibition design to be as much an exhibition object as her garments. She told Bolton that, "I would find it impossible to see my clothes in a space designed by someone else. My clothes and the spaces they inhabit are inseparable—they are one and the same. They convey the same vision, the same message, and the same sense of values" (Bolton 2017). Knowledge of Kawakubo's perspective enabled the conservators to approach the design development with a spirit of compromise.

2.3.1 Exhibition Architecture

Kawakubo desired the objects to be displayed within a warren of massive, white, geometric architectural shapes, with the objects placed inside, underneath, or on top of each structure (fig. 2). While digital renderings and scaled maquettes were helpful in visualizing proportion and object placement, it was only through the creation of a life-sized model of the exhibition's architecture in a warehouse in Tokyo that it quickly became apparent that the shapes caused touch distance issues, and limited the count of objects that could be included. Kawakubo intended objects to be placed directly on the floor, allowing visitors to wander between them. She considered this a democratic gesture that further enhanced the immersion in the world she was creating and diminished the physical distance between the viewer and object. Through careful compromise with her, The Met was able to move some objects to platforms and place hurdle-like barriers designed by Kawakubo in front of objects placed on the floor within the silo-like shapes. However, about a third of the objects were ultimately placed on the floor between the built structures, with only guards, alarms, and floor tape as protection. In addition to overhead alarms, conservation worked closely with The Met's security team to embed the mannequins and garments with shock and tilt sensors to further monitor object handling.

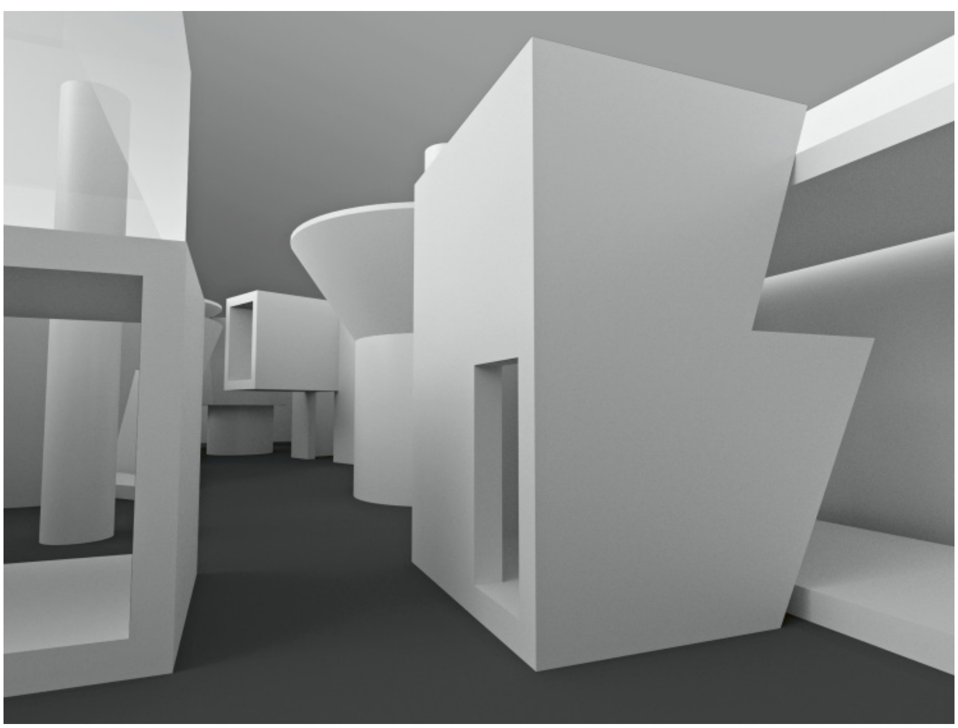

Fig. 2. Computer rendering of exhibition design (Courtesy of The Metropolitan Museum of Art).

2.3.2 Lighting Schematic

By far, the most problematic design aspect from a conservation perspective was the lighting program designed by Thierry Dreyfus, a longtime collaborator of Kawakubo's. The intended effect of the lighting design was to immediately shock the visitor into another realm, signaling that this was no ordinary fashion exhibition. Rather than create drama with shadows and spotlights, the goal was a clinical appearance of shadowless cold light. Dreyfus is fiercely loyal to Kawakubo and her vision; therefore, he was firmly unreceptive to requests to diminish lighting to acceptably safe levels.

After initial discussions and testing with all stakeholders made little progress toward achieving conservation-appropriate light levels, the CI's conservators paused for reflection. While the desired lighting design program ran counter to acceptable conservation norms, this exhibition was intended by the artist herself to serve as the first and only artist-approved display of her work. Moreover, almost all objects were to come from Kawakubo's archive, and she was willing to sign a legal waiver that protected The Met from any damage owing to the placement of objects on the floor or from excess light. Guided by the department's collaborative aims and conservation ethics that privilege honoring artist intent, the conservation team members refined their goal to support Kawakubo's efforts completely, making conservation gestures only when possible without compromising artistic intent. The team also recognized that it had the unique opportunity to collect real-time data on the effects of the exhibition's lighting scheme on object degradation, with the hope that it could be used to influence future curatorial and artistic decision-making.

3. RESPONDING TO THE LIGHTING DESIGN

The Daylight White T12 fluorescent is an unusual choice for lighting artwork. It has an extremely high color temperature (6500 Kelvin), which can alter the way that colors are perceived: whites appear blue, blues are intensified, and reds appear dull or even brownish. The color rendering index (CRI) for the Daylight White is 76, which essentially means that colors viewed under this light source, compared to colors viewed under a source such as daylight, are only three-quarters accurate (Feller 1985). As a reference, The Met's own lighting specialists look for a CRI of 90 or above, with most lights selected to have a CRI of 98.

Based on the sheer quantity of T12 fluorescents included in the lighting schematic, it was evident early in the exhibition planning process that light levels would be an obstacle to safely displaying objects. Generally, because of the time constraints and the use of outside lighting vendors, the conservation team is faced with negotiating light levels after object installation. For this exhibition, however, the CI worked with design firm SBLD Studio to project gallery light levels before the lighting grid was installed since it was understood that the lighting program was exceptional with regard to conservation standards. Using the building information modeling software Autodesk Revit, SBLD Studio factored together the lighting designer's schematic with the overall exhibition design (fig. 3). As anticipated, the software projected light levels far above safe levels for displaying costume with estimated light levels in excess of 100 footcandles and an average illuminance of 79 footcandles. Having access to this information early in exhibition planning allowed the conservation team to proactively respond before object installation.

In response to these projections, the conservation team set the following three objectives:

- First, to strive to create museum-appropriate conditions for the museum objects appearing in the exhibition; this objective was imperative given that objects from at least one other museum lender would be on display.

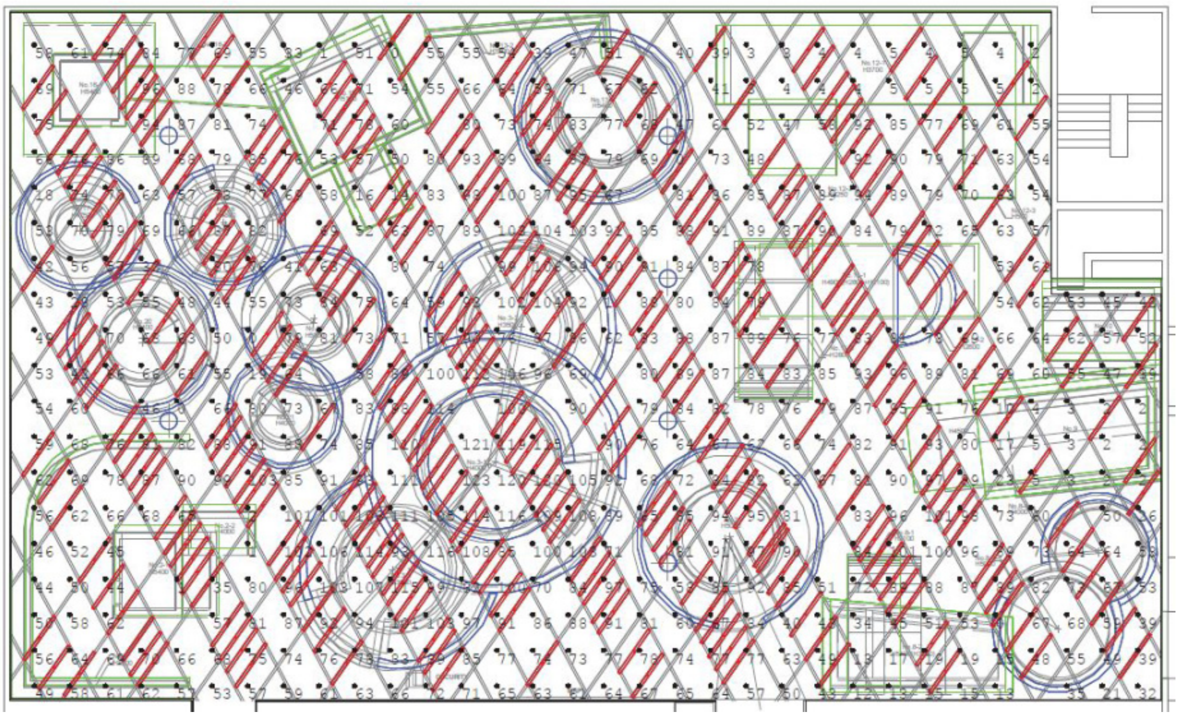

Fig. 3. Simplified exhibition floor plan overlaid with Autodesk Revit projected light levels (Courtesy of The Metropolitan Museum of Art). Red lines indicate placement of light bulbs.

- Second, to track light exposure for all exhibited objects over the four-month exhibition. Additionally, because it is common practice for the Costume Institute to acquire a selection of loans that appear in the exhibitions, the conservators were interested in tracking light exposure for potential acquisitions.
- Third, to identify the key takeaways that will help inform future exhibitions. The conservation team's experience recognizes that every exhibition presents its own unique set of challenges and, therefore, also presents learning opportunities.

3.1 CREATING MUSEUM-APPROPRIATE CONDITIONS WITHIN THE LARGER EXHIBITION SPACE

One aspect of the T12 fluorescent that runs counter to safe object lighting is its UV output. It is widely understood that UV radiation accelerates the fading of textiles and contributes to the photochemical degradation of textile fibers (Tucker, Kerr, and Hersh 1985). Compared to an incandescent lamp, in which UV light comprises less than 1% of its total output, the UV light output of a fluorescent lamp comprises anywhere from 3% to 7% (Macleod 1975). While filtering out the UV light was met with resistance by the lighting designer, the conservation team made the successful case to all other stakeholders that the light being targeted was outside the visible spectrum and its elimination was imperative to meet the most basic of museum lender requirements.

To filter out UV light, conservators worked collaboratively with The Met's lighting specialists to select the 226 Lee UV filter: a dye-coated polyester film that could be applied to each lamp as a sleeve. With the filter in place, the transmittance of UV light below the 380nm range was reduced to approximately 4% of the lamp's output at this range (LEE Filters 2015). The unintended consequence was the slight reduction in the lamp's overall visible output: approximately 9% overall with a greater loss at the 400 to 420nm range: violets and purples (LEE Filters 2015). While these were positives from a conservation perspective, the lighting designer noted the slight reduction and—as a compromise—added additional lamps to the lighting grid to achieve his desired prefiltered illuminance levels.

Microfading testing was performed on the CI objects selected to appear in the exhibition. The goal of testing was to better understand the susceptibility of each object to light-induced fading and take a seemingly theoretical concept—an object's photosensitivity—and create quantitative data that could be presented to the curator. If the objects proved light sensitive, then it would confirm the necessity of creating a space within the exhibition with appropriate light levels.

The photosensitivity of six CI objects was tested using the Newport Oriel Fading Test System. Using a xenon arc lamp, the system delivers a concentrated point of light (~0.4mm in diameter and filtered to remove UV and infrared radiation) directly to the surface of the test object to induce fading (Whitmore, Bailie, and Connors 2001). An integrated spectrophotometer measures the reflectance of this illuminated point, calculating color difference by using one of the CIE L*a*b* color models. By comparing the change (the Delta E [ΔE_{00}]) to known benchmarks such as Blue Wool Standards [1], it is possible to make qualitative and quantitative conclusions about the photosensitivity of the tested object (del Hoyo-Melendez and Mecklenburg 2011).

The conservators worked in collaboration with The Met's Photograph Conservation Department for the testing, using the procedure that they developed for testing photographs. Object test sites were selected based on the areas that were likely to receive the highest light exposure; for costume displayed beneath overhead lighting, this typically occurs at the shoulders (Museum and Galleries Commission 1998). For objects composed of multiple fabrics, each fabric type was tested. The general protocol followed when testing each object or object location was to terminate the test at a ΔE of approximately 0.5 (a barely perceptible color change is ΔE_{00}1–2). This conservative approach reduced the prospect of visibly damaging the object.

As evaluated using Delta E 2000, the four objects demonstrated a high sensitivity to light, performing between a Blue Wool Standard 2 and 3 (but generally testing closer to a Blue Wool Standard 3; fig. 4). In accordance with ICOM's guidelines for displaying historic costumes, the objective is to display CI objects at a maximum light level of 5 footcandles (ICOM 1983). However, based on the results of this test and the limitations of the exhibition space, the conservators made the recommendation that the objects be displayed at a maximum level of 5 to 10 footcandles.

With an average projected illuminance of 79 footcandles, there was nowhere in the exhibition with the appropriate light levels to display the tested objects. Two silo-like structures were identified where the lighting grid could be adapted to achieve lower light levels (fig. 5). A number of approaches to reducing light levels were discussed, including adding a roof or scrim to each structure. However, Kawakubo saw these changes as compromising the integrity of her exhibition design. Thus, ultimately, it came down to removing overhead lamps, one by one. When an acceptable light level could be reached in only a single structure, the curatorial decision was made to cut all but one of the CI objects slated to appear in the exhibition. For the CI object that remained, as well as six loans from the Kyoto Costume Institute (KCI), the curator positioned them along the inside wall of the structure to shield them from raking light coming in through the structure's door. Through this combination of approaches, it was possible to achieve a light level of 3 to 7 footcandles.

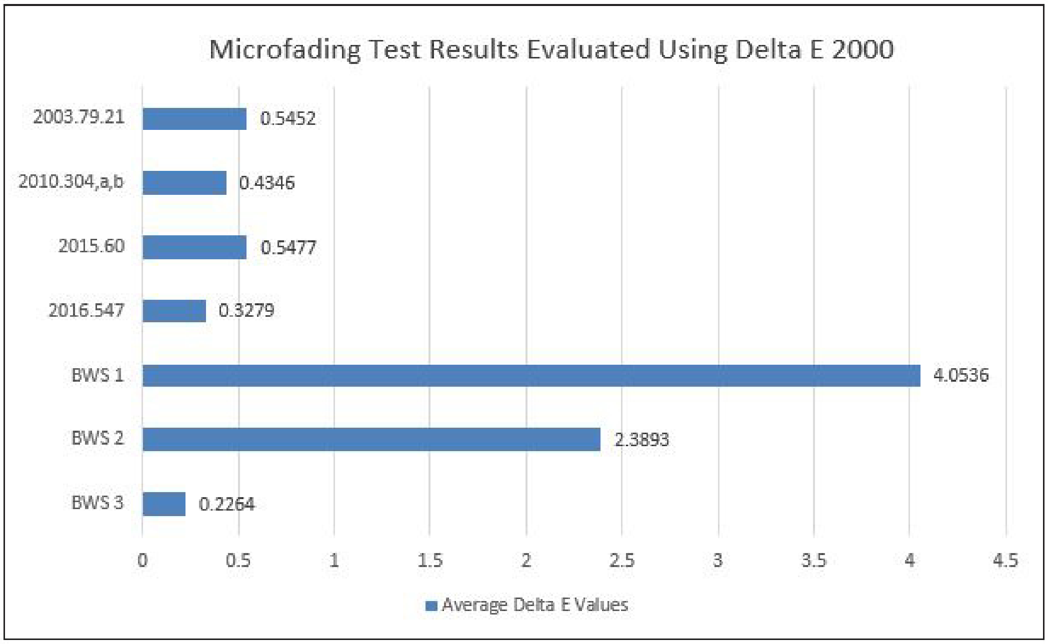

Fig. 4. Delta E [ΔE_{00}] results of microfading tests. The four objects are listed by accession number. Test results for Blue Wool Standards 1 to 3 are provided as a reference.

Fig. 5. Silo-like structures selected for display of photosensitive objects (Courtesy of The Metropolitan Museum of Art).

3.2 TRACKING LIGHT EXPOSURE OVER THE COURSE OF THE EXHIBITION

To track cumulative light exposure over the course of the exhibition, the conservation team used a combination of light data loggers (the U12-012 manufactured by ONSET Computer Corporation), Blue Wool Standard cards, and an ELSEC light meter. While these are all tools for monitoring light, the objective was to use each of these tools for the unique insights that they could provide.

The ELSEC light meter was extremely useful in taking targeted light measurements. This was essential in confirming the accuracy of the light levels projected by the Autodesk Revit software and taking periodic readings at the locations where the Blue Wool Standard cards were placed.

The HOBO light loggers, which were intended to track total hours of cumulative light exposure, also proved useful in tracking lamp lumen depreciation. Lamp lumen depreciation is the gradual reduction in a lamp's output over time; for fluorescent lamps it occurs for a variety of reasons, including the photochemical degradation of the phosphor coating (DiLouie 1994). Thus, the reduction in light output occurred at a uniform rate throughout the four-month exhibition; for example, over the first month of the exhibition, the HOBO light loggers recorded a reduction in light output of one footcandle per week. Because of this known depreciation, fluorescents are often rated for both their initial output and their mean output.

A total of seven Blue Wool Standard cards were placed throughout the exhibition. In a gallery setting, Blue Wool Standard cards have the potential to provide more information than other types of sensors because they can account for the other environmental factors that influence fading, such as temperature, humidity, and even environmental pollutants (Bacci et al. 2004). While the fading that occurs to a Blue Wool Standard may not represent a direct equivalent to the object with which it is placed, it can provide a characterization of what is occurring at a given location.

Prior to the placement of the Blue Wool Standard cards, the conservation team worked collaboratively with The Met's Department of Textile Conservation, using a Konica Minolta portable spectrophotometer to take colorimeter readings of the seven cards, focusing measurements where the greatest change would occur: Blue Wool Standards 1 to 3. These readings served as the baseline from which the post-exhibition measurements were evaluated. The Blue Wool Standard cards were placed alongside the one CI object as well as the Comme des Garçons objects that the curator was interested in acquiring. The collected data would become part of the object's record once the object was acquired, and the data would inform the way that the objects were lent or displayed in the future.

At the end of the exhibition, with the exception of the Blue Wool Standard card placed alongside the CI and KCI objects previously discussed, all Blue Wool Standards 1 to 3 underwent a significant amount of light-induced fading (fig. 6). Reviewing the results using CIE Standard Illuminant D65 [2] for Location 1, a location with projected light levels of 53 footcandles and an estimated cumulative light exposure of approximately 60,160 footcandle hours over the course of the exhibition, significant color change was observed for Blue Wool Standards 1 and 2 with a just perceptible visual change (ΔE^*ab 1.59) for Blue Wool Standard 3. The $L^*a^*b^*$ values provided by the spectrophotometer show that Blue Wool Standards 1 to 3 became lighter along the L^* value and greener along the a^* value, with the most significant change occurring along the b^* value (the blue shifting toward yellow). These results were consistent for all monitored locations with the exception of Location 2. The Blue Wool Standard at Location 2 (the structure where light levels were reduced to safeguard museum objects) showed significantly less light-induced fading. What came as a surprise, though, was that at a light level of 3.8 footcandles, there was still a noticeable change (ΔE^*ab 3) for Blue Wool Standard 1 and a just perceptible change (ΔE^*ab 1) for Blue

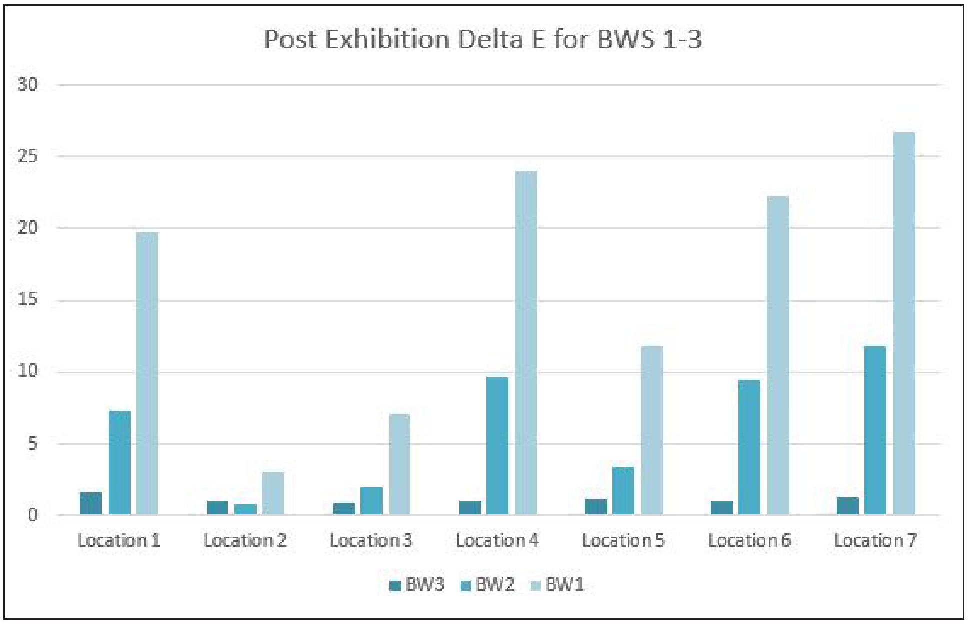

Fig. 6. Post exhibition Delta E (ΔE*ab) for Blue Wool Standards 1 to 3 listed by location.

Wool Standard 3. In this circumstance, the microenvironment of the structure may have led to increased fading of the Blue Wool Standards.

4. CONCLUSIONS

The light levels projected by the modeling software Autodesk-Revit proved to be an asset in responding to anticipated light levels well before object placement. Collecting data prior to and during the exhibition provided a better understanding of conditions within the exhibition space; additional spectrophotometric testing of exposed and unexposed areas of the exhibition objects subsequently acquired by the CI may help create further data around what occurred during the exhibition. Blue Wool was useful as both a qualitative and quantitative tool to understand the amount and kind of light damage that occurred. Although the CI's conservators were operating under a compressed time frame and outside of standard conservation parameters, they were able to quickly create a research project that produced quantitative and visible results showing that light does indeed negatively impact textiles. Although this is essential knowledge for all conservators, the CI team uses these real-life examples to educate curators, designers, and artists as to how their choices impact the art that they are exhibiting. While displaying costume objects under very high light levels is not typically recommended, in this instance the conservators recognized that the lighting program and objects were of equal importance.

ACKNOWLEDGMENTS

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NOTES

[1] A Blue Wool Standard card consists of eight consecutive blue wool cloths, ranging from 1 to 8, in which each cloth (or standard) is approximately twice as colorfast as the one that precedes it, with Blue Wool Standards 1 to 3 showing the highest photosensitivity (International Standard Organization 2014).

[2] CIE Standard Illuminant D65 is a frequently used visible light model that approximates midday light. It has an associated color temperature of 6500 Kelvin.

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AUTHOR BIOGRAPHIES

SARAH SCATURRO is head conservator, Costume Institute, The Metropolitan Museum of Art, where she is in charge of the preservation of all fashion objects and the development of the conservation research program. From 2006 to 2012, she was the textile conservator and assistant fashion curator at the Cooper Hewitt, Smithsonian Design Museum. She is a PhD student at Bard Graduate Center, studying the history and theory of fashion conservation. Address: 1000 5th Avenue, New York, NY 10028. E-mail: sarah.scaturro@metmuseum.org.

CHRISTOPHER MAZZA is assistant conservator, Costume Institute, The Metropolitan Museum of Art, where he provides support for the department's in-house exhibitions and preservation of the costume collection. He holds an MA in Fashion and Textile Studies: History, Theory, and Museum Practice from the Fashion Institute of Technology and an MFA in writing from the University of Alaska. Prior to joining The Met, he was the Andrew W. Mellon Fellow for Advanced Training in Textile Conservation at the Museum of Fine Arts, Boston. Address: 1000 5th Avenue, New York, NY 10028. E-mail: christopher.mazza@metmuseum.org.

A HERRINGBONE STITCH VARIATION FOR USE IN TEXTILE CONSERVATION

MIRIAM MURPHY

ABSTRACT—When stabilizing splits or losses within an unstable area of a textile, it can be difficult to locate stabilizing stitches close to the loss owing to the fragility of the surrounding fabric. Traditional laid-and-couched stitches may not be possible because the addition of the couching stitches through the surrounding deteriorated fabric may cause further damage to the textile. The crossed arms of herringbone stitches can provide more stability; however, their entry and exit points through the stable area of the textile may create long thread spans that can allow the fabric around the split or loss to shift. The addition of running stitches to couch down the herringbone stitch arms where they cross can provide an extra measure of stability.

PUNTADA DE ESPINA DE PESCADO (HERRINGBONE) PARA USO EN CONSERVACIÓN DE TEXTILES

RESUMEN—Localizar áreas para puntada con el fin de estabilizar rasgaduras o pérdidas en áreas inestables de un textil es un reto, debido a la fragilidad de la tela alrededor del área en cuestión. Es posible que puntadas como la "laid-and-couch" no sean opciones debido a que la las puntadas "couching" en el área cercana al textil dañado pueden exacerbar el daño. Las cruces del punto de cruz pueden proveer mayor estabilidad. Sin embargo, los puntos de entrada y salida a través del área estable del textil pueden crear áreas de tensión que eventualemente podrían provocar el movimiento de las áreas que rodean la intervención. La adición de puntada corrida para aplanar la puntada de espina de pescado en donde los hilos se cruzan puede aportar mayor estabilidad.

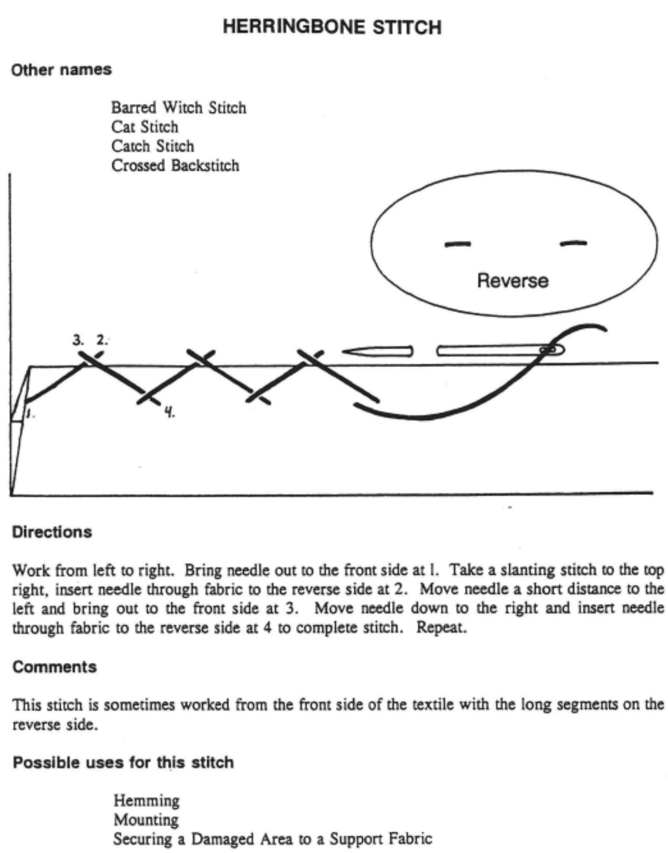
1. INTRODUCTION

When the author treated the jacket of a United States Navy woman's uniform from World War I for a private client, one of its condition issues was a damaged area located in the inner elbow region of the proper left sleeve lining that had caused the fabric to split along both seam and crease lines (fig. 1). The uniform was planned to be dressed for an indefinite period of time, but possibly undressed and mounted again in the future. The client cared only about conserving the visible parts of the uniform and did not want a full stabilization of the shattered area of the lining. However the author was concerned that the splits within the sleeve lining could catch and rip when the jacket was dressed and undressed. It was not known who would be mounting the uniform so it was important to forestall that possibility. Because the area surrounding the splits was brittle, it was not possible to use laid-and-couched stitches to stabilize the splits against an underlay since couching down the laid threads would necessitate piercing the weakened surrounding area, likely causing damage.

2. STITCH SELECTION

The herringbone stitch, as seen in figure 2, is one of the stitches used in textile conservation (AIC, Textile Specialty Group). It was chosen for this treatment to help hold the edges of the loss openings together because the stitch's crossed arms would form a grid that would sandwich the damaged area between it and the

Fig. 1. Jacket sleeve lining, before treatment (Courtesy of Miriam Murphy).



HERRINGBONE STITCH

Other names

Barred Witch Stitch
Cat Stitch
Catch Stitch
Crossed Backstitch

Directions

Work from left to right. Bring needle out to the front side at 1. Take a slanting stitch to the top right, insert needle through fabric to the reverse side at 2. Move needle a short distance to the left and bring out to the front side at 3. Move needle down to the right and insert needle through fabric to the reverse side at 4 to complete stitch. Repeat.

Comments

This stitch is sometimes worked from the front side of the textile with the long segments on the reverse side.

Possible uses for this stitch

Hemming
Mounting
Securing a Damaged Area to a Support Fabric

Fig. 2. Diagram of the herringbone stitch (Grimm 1995, 21).

underlay. However, since the fabric immediately around the fabric splits was too fragile to be stitched, the herringbone stitch arms were too long to adequately stabilize the splits. Wanting to avoid stressing the fragile fabric by removing the stitches, the author sought a solution that would build on the treatment so far. The embellished embroidery stitch work of crazy quilts came to mind.

3. EMBELLISHED EMBROIDERY STITCHES

Embellished embroidery stitches are commonly used to decorate the patch seams of crazy quilts. They are made by layering different embroidery stitches along the same seam line, often using different colors of embroidery floss or pearl cotton, to create more decorative patterns (fig. 3).

4. COUCHED HERRINGBONE STITCH

A commonly used simple combination of stitches in crazy quilt embroidery is the herringbone stitch with a line of running stitches in a contrasting color across the herringbone stitch arm crosses (fig. 4). Couching down the crossing points of the herringbone stitch arms (in this case, with a noncontrasting color) reduced their ability to shift across the damaged area of the sleeve lining (fig. 5). Depending on the condition of the

Fig. 3. Detail of a crazy quilt in the author's collection, circa 1900, showing embellished stitches along patch seam lines (Courtesy of Miriam Murphy).

Fig. 4. Detail of a crazy quilt in the author's collection, circa 1900, showing couched herringbone stitches (Courtesy of Miriam Murphy).

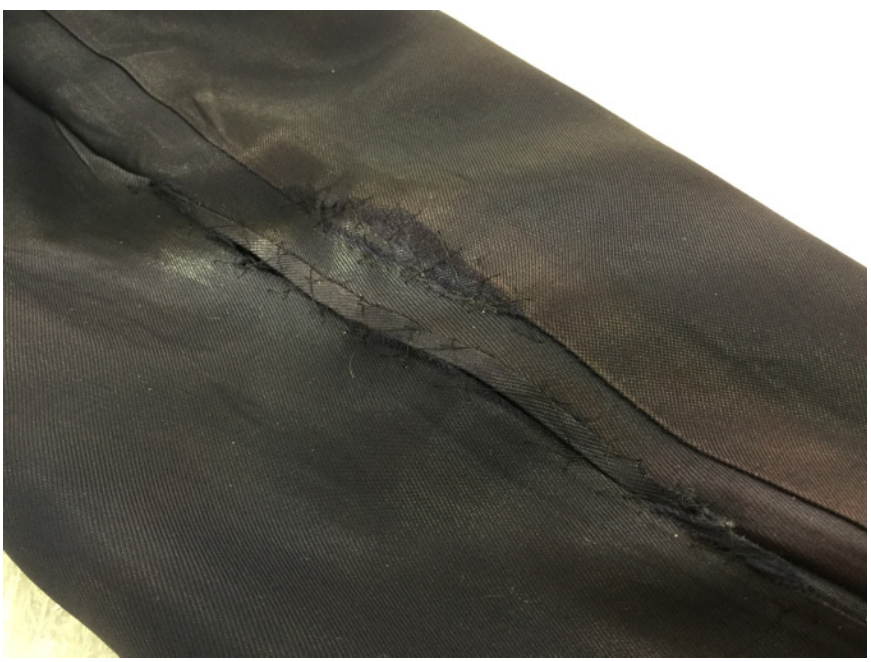


Fig. 5. Jacket sleeve lining, after treatment (Courtesy of Miriam Murphy).

textile's yarn fibers and weave structure, the couching stitch can be short to tightly hold down the crossing point, or a longer stitch across the crossing point, oriented in either the warp or weft direction to mitigate stress to the textile's weaker structural elements.

5. CONCLUSIONS

Couching down the herringbone stitch's arm crosses held the thread spans more closely against the damaged area of the sleeve lining. Because herringbone stitch arms cross at the upper and lower edges of the stitch formation, the added couching stitches were located only along the perimeter of the area that needed stabilization. In this way, the splits were stabilized without causing further damage to the deteriorated area of the fabric. Prior to this treatment the author had never considered using a decorative embroidery technique for the purpose of conservation, and she hopes that sharing this solution will benefit other conservators.

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MIRIAM MURPHY is the associate textile conservator at the Saint Louis Art Museum. Previously, she worked in private practice after having been an assistant conservator at the Costume Institute of The Metropolitan Museum of Art and holding Kress and Smithsonian fellowships at the Smithsonian's Museum Conservation Institute. She received her MA in Fashion and Textile Studies: History, Theory Museum Practice with a focus in conservation from the Fashion Institute of Technology. Address: One Fine Arts Drive, Forest Park, St. Louis, MO 63110. E-mail: miriam.murphy@slam.org.

A FLEXIBLE T-BAR MOUNT SYSTEM FOR TEXTILES

ZOE A. PERKINS

ABSTRACT—A mount system was developed to address the need to quickly rotate flat textiles displayed in permanent exhibition spaces dedicated to textiles at the Saint Louis Art Museum. The system consists of a metal T-bar assembly and a horizontal routed wood slat customized for each textile. The slat can be designed to accommodate a variety of mount attachment systems sewn to the textile, while the flexible T-bar structure minimizes damage to gallery walls or exhibition casework backboards. The system requires access to both metals and wood shop assistance.

UN SISTEMA DE MONTAJE EN BARRAS CON FORMA DE T PARA TEXTILES

RESUMEN—Un sistema de montaje fue desarrollado para solucionar la necesidad de rotar rápidamente textiles planos en espacios de exhibición permanente, dedicados a textiles en el Museo de Arte de San Luis (SLAM, por sus siglas en inglés). El sistema consiste en una barra de metal en forma de T en posición vertical, con una tabla de madera fijada en posición horizontal, misma que es adaptada a cada textil. La tabla puede diseñarse para acomodar una variedad de sistemas de montaje unidos al textil, mientras que la estructura flexible en forma de T minimiza el daño a las paredes de la galería o a las vitrinas de exhibición. El sistema requiere acceso a ambos metales y asistencia de carpintería.

1. INTRODUCTION

Permanent exhibition spaces typically need to accommodate textiles of various sizes. With the mountmaker at the Saint Louis Art Museum, a system was designed by the author consisting of two components: a metal T-bar assembly and a routed wood slat cut to width for each textile. A variety of mount systems can be used to attach the textile. In preparation for installation, the textile is mounted to the customized horizontal wood slat, which can be placed quickly on the T-bar.

2. FABRICATION SPECIFICATIONS

The metal T-shaped bar is made of a vertical ½-in. round rod or stem that is capped with a horizontal flat stock metal crossbar (1/4 × 2 × 30 in.). The rod of predetermined flexible length is drilled and tapped, and screws are countersunk to form a T-shape. The rod fits through a metal collar that is welded to a base plate and taped with four mounting holes. The rod height is adjusted by a setscrew in the collar (fig. 1).

The wood crossbar is 3 inches high by 1/2 inch thick. The width of the slat is customized to the width of the textile. A routed channel along the bottom edge of the wood slat is cut slightly larger than the 1/4 inch wide metal crossbar, thus allowing a snug fit, yet allows the bar to be finessed side to side. The top portion of the crossbar can accommodate staple legs up to 1/2 inch used to attach Velcro or fabric covering that can be used for pinning.

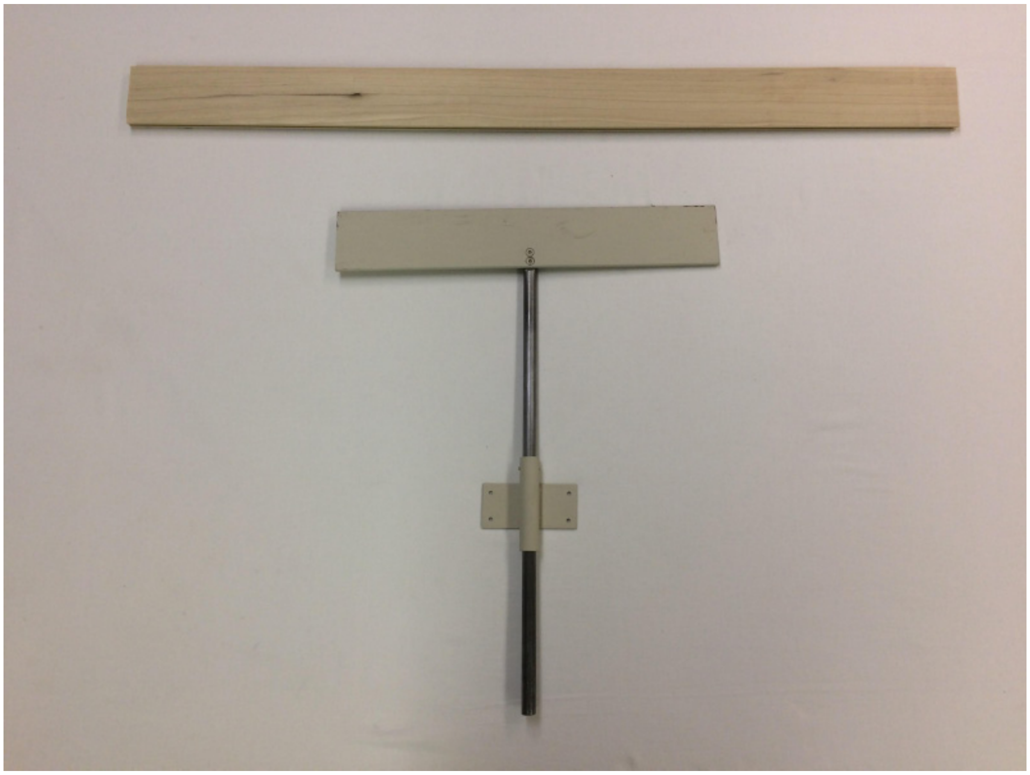

Fig. 1. Metal T-bar and routed wood slat board.

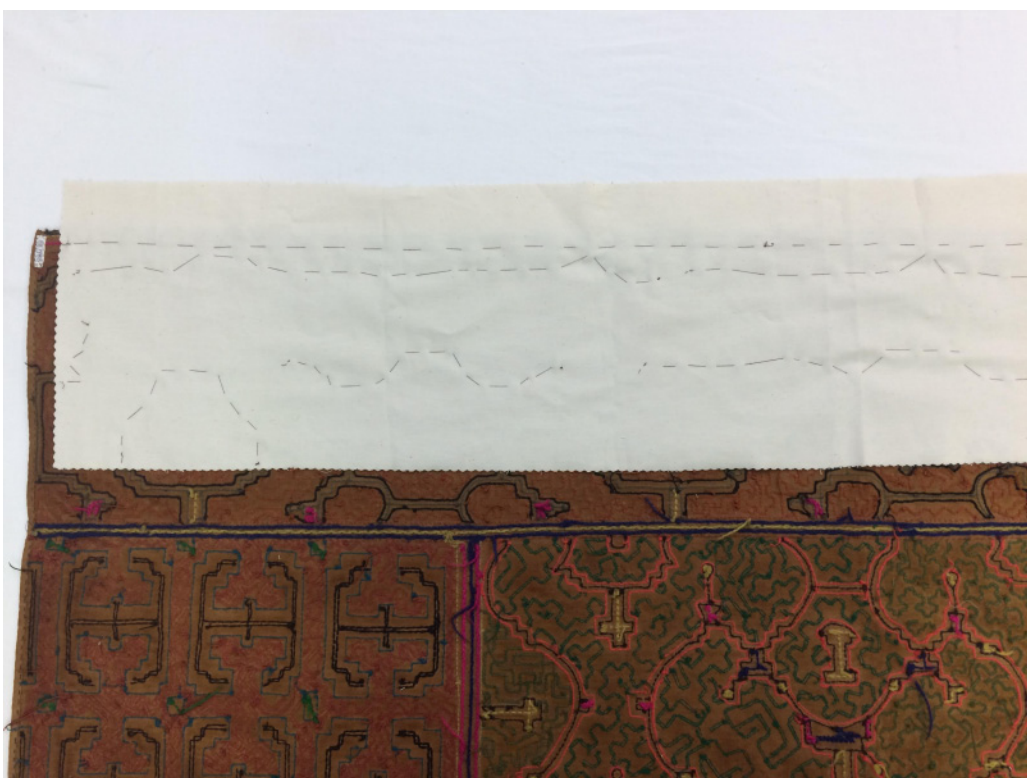

Fig. 2. Detail of fabric mount sewn to back of textile with leveling line sewn along top edge.

Fig. 3. Back of textile with covered slat board positioned on leveling stitch line.

Fig 4. Detail of mount systems showing metal T-bar, cloth-covered wood slat board, and textile mount pinned in position.

3. ATTACHING THE TEXTILE

To use a pinning method, stitch a piece of fabric to the back side of the textile. This fabric must be large enough to extend beyond the top edge of the textile to wrap over to the reverse of the fabric covered slat (fig. 2). In this case, the use of a horizontal guideline stitched below the top edge of the textiles helps to visualize level placement of the textile (fig. 3). Use this line to determine the point in which to turn the mount fabric back at the top edge of the slat, and pin into position (fig. 4).

Upon installation, the pins can be adjusted as needed. Additionally, the crossbar can slide left to right to finesse the proper placement on the wall. Other mount variations include the use of L-brackets screwed to the outer edges of the back side of the T-bar in order to attach round rods for draping textiles. For textiles with irregular, uneven top edges, this system can be used with customized mounting boards cut to conform to the shape of the top edge, then screwed into place on the T-bar and fabric wrapped for a pinning surface.

4. CONCLUSIONS

This mount system is customizable, relatively inexpensive, and easy to produce for myriad types of textiles and exhibition scenarios. Its standardized components can be remixed to quickly mount textiles during gallery rotation.

AUTHOR BIOGRAPHY

ZOE A. PERKINS retired from the Saint Louis Art Museum in 2018 after serving as textile conservator for 39 years. She received her master's degree in Clothing and Textile Science, with emphasis in Historic Textile Conservation from Kansas State University in 1979. Address: 32 Orchard Lane, St. Louis, MO 63122.
E-mail: zoeperkins@charter.net

AN INTRODUCTION TO THE TRIBOELECTRIC SERIES

GWEN SPICER

ABSTRACT—Conservators use materials in their treatments, storage, and mounting selected for their archival and long-term stability, their compatible reaction to the environment, and tradition. Over time, the selections of preferred materials have become well established, encompassing both natural and synthetic materials, woven and nonwoven alike. The phrase "like with like" is often used when materials are selected. This long-held philosophy perhaps need to be reexamined. How materials behave with one another is related to many things, among them topographic friction, cohesion, and the effects of static charge. Each of these factors also influences how materials interact with one another. Could the material selected to be in contact with the artifact also aid in the preservation of an artifact or its support? It turns out that there is a surface phenomenon of electron exchange that occurs when two materials are in contact, which can aid the cohesion of those materials. This phenomenon can lead to either positive or negative results. The degree of electron sharing from one material to another is related to their relative placement on what is called the triboelectric series. Some combinations of materials have improved holding powers versus others.

UNA INTRODUCCIÓN A LAS SERIES TRIBOELÉCTRICAS

RESUMEN—Los conservadores usan materiales para sus tratamientos, almacenaje y montaje de bienes culturales en función de la estabilidad que dichos materiales tienen a largo plazo, su compatibilidad con el ambiente al cual serán expuestos, y tradición. Con el paso del tiempo, las selecciones de materiales adecuados se convierten en prácticas comunes, e incluyen tanto materiales sintéticos como naturales, y tanto tejidos y como no tejidos. La frase "similares con similares" es frecuentemente usada cuando los materiales se seleccionan. Estas filosofías en uso desde hace tiempo quizá deberían ser examinadas. Cómo materiales se comportan con otros está relacionado con muchas cosas, incluídas la fricción topográfica, cohesión, y los efectos de la carga estática. Cada uno de estos factores tiene impacto en cómo los materiales interactúan entre sí. ¿Es posible que el material seleccionado para estar en contacto con el bien también ayuda a su preservación o soporte? Resulta que existe un fenómeno de superficie de intercambio de electrones que ocurre cuando dos materiales están en contacto y se frotan, y esto puede ayudar a la cohesión de ambos materiales. Este fenómeno puede llevar a resultados positivos o negativos. El grado de compartición de electrones de un material a otro está relacionado con el lugar relativo en el cual se encuentra, y se le conoce como "series triboeléctricas" o "efecto triboeléctrico." Algunas combinaciones de materiales pueden incrementar la estabilidad, comparado con otros.

1. INTRODUCTION

Static charge has long been identified as an issue in conservation, especially for fragile and friable materials (Margariti and Loukopoulou 2016). Addressing this concern is usually part of the protocol for framed pastels, charcoals, and friable silks. However, there has been little detailed research into its full role in the field (Commoner 1998). A "charge," to some degree, is present with all materials in contact. What conservators in all specialties and museum professionals need to learn is how to use this to one's advantage or how to lower its risks.

This means reconsidering the use of traditional or new materials when selecting for varied tasks, display, or storage.

2. STATIC CHARGE

Static charge occurs when materials are in contact and then separated without any apparent rubbing or when materials are rubbed together. More static is created with rubbing than with simple contact and separation (Blythe 1974; Sello and Stevens 1984). When materials are in contact, electrical charges develop—which is usually something that a conservator seeks to avoid when working with collections. Electrical charges occur when bonds between electrons, which are established when materials come into contact, are then broken upon separation (Carleton 1962) [1].

All matter is composed of both positive and negative charges equally (Sello and Stevens 1984). The basis of electrostatic charging is a surface phenomenon in which the disruption of the condition of equilibrium is seen in the neutral atom (Commoner 1998). Electrons have a negative charge. When energy is applied to a material system, such as by friction or pressure, a small number of electrons can jump from one material to the other. The material whose atoms gain electrons will become negatively charged with static electricity, while the material that loses electrons will become positively charged. When two materials are in contact, a flow of electrons moves from one to the other, whether it is the same material or between two different types (fig. 1).

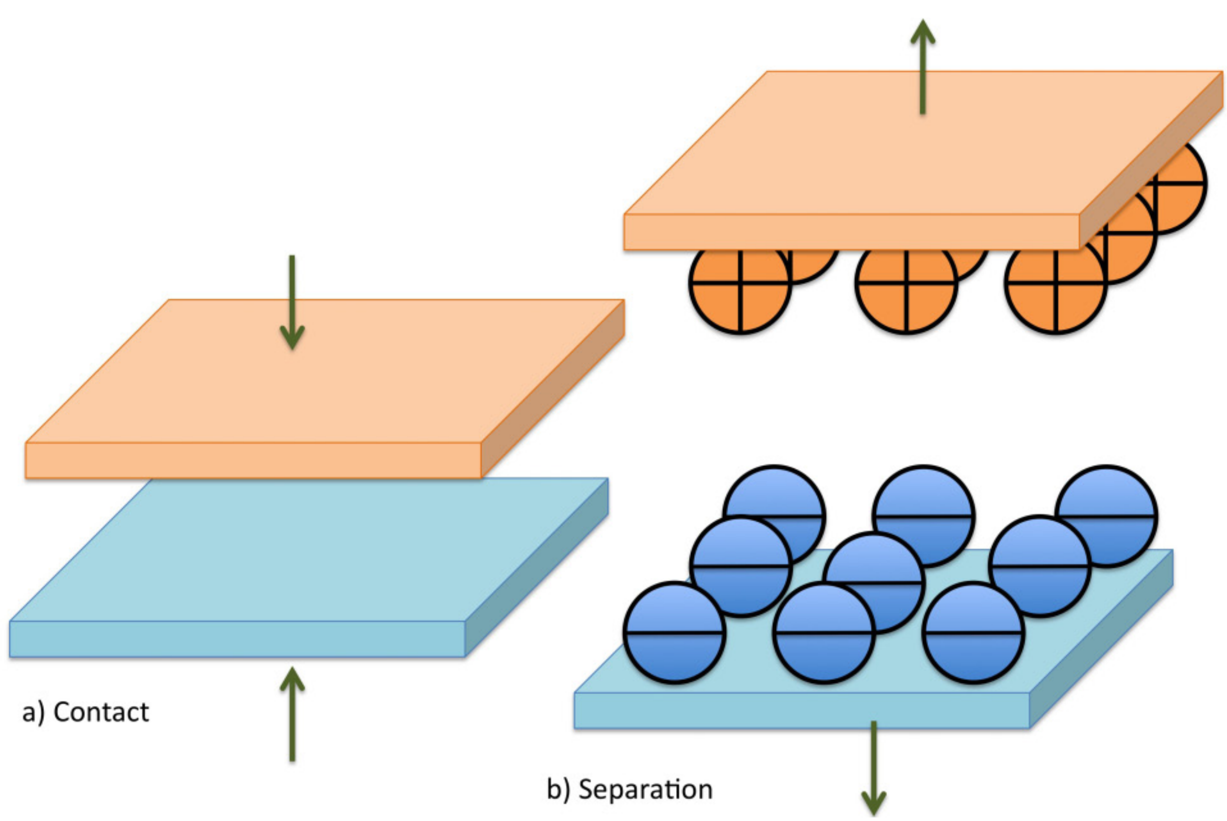

Fig. 1. Schematic of electron exchange when two different materials are in contact and are then separated. The extent of this exchange is based on the materials' placement on the triboelectric series scale (table 1).

3. TRIBOELECTRIC SERIES

Materials that can gain or lose electrons are called triboelectric materials. The order of propensity to gain or lose electrons is called the triboelectric series (Sello and Stevens 1984). The series is based on the conductivity of the individual material. The level of charge is linked to a material's placement in this series (table 1). It is the distance of the two materials from one another on the series scale that increases the charge effect rather than the specific location in the series. Therefore, if two materials in contact are neighbors on the scale, there is less exchange, as with cotton and steel. If they are far apart, no matter where on the scale, exchange occurs.
Table 1, compiled from many sources, shows the ranking of commonly used mounting materials and artifacts.

Table 1. Material Order of the Triboelectric Series

Charge	**Material**	**Notes**
+ + +	Air	
	Polyurethane foam	
	Hair	
	Nylon, dry skin	Dry skin has the greatest tendency to give up electrons and become highly positive in charge.
	Glass	This is why TV screens collect dust on their surfaces.
	Acrylic, Lucite	This is why these materials are not used to frame pastels.
	Leather	
	Rabbit's fur	Fur is often used to create static electricity.
	Quartz	
	Mica	
	Lead	Surprisingly close to cat fur.
	Cat's fur	
	Silk	
	Aluminum	
	Paper	
	Cotton	Best for nonstatic clothes.
	Wool	
NEUTRAL		
	Steel	Not useful for static electricity
	Wood	Attracts some electrons, but is almost neutral.
	Amber	
	Sealing wax	
	Polystyrene	
	Rubber balloon	
	Resins	

(*continues*)

Table 1. Material Order of the Triboelectric Series (*Continued*)

Charge	Material	Notes
	Hard rubber	
	Nickel, copper	
	Sulfur	
	Brass, silver	
	Gold, platinum	
	Acetate, rayon	
	Synthetic rubber	
	Polyester	
	Styrene and polystyrene	Why packing peanuts seem to stick to everything.
	Plastic wrap	Also known as "Cling" wrap
	Polyethylene	
	Polypropylene	
	Vinyl, polyvinyl chloride	
	Silicon	
	Teflon	Teflon has the greatest tendency of gathering electrons on its surface and becoming highly negative in charge.
	Silicone rubber	
- - -	Ebonite	

3.1 TYPES OF MATERIALS AND THEIR LOCATION ON THE SERIES SCALE

In general, proteins tend to be located at the upper part of the series scale, where materials prone to losing electrons and becoming positively charged are located with metals in the lower part; lead and aluminum are exceptions to this rule. Synthetics tend to be located at both far ends; both glass and acrylic are together at the upper end of the series scale.

When treating military wool uniforms, polyester fibers present are very attracted to the surface of the wool fabric. Is it because of the rough surface of the fabric? Then cotton fibers would do the same. But, no, it is just those pesky polyester fibers. The triboelectric series explains it all—the cohesion between the wool and polyester is very strong owing to electron sharing.

A few observations about the location of materials in the series:

- Cellulosic plant fibers are in the neutral section, located in the middle of the table along with wool, and are very close together in the series.
- When mounting paper items, consider using a synthetic material to strengthen the holding power.
- Proteins, such as animal fibers, are located exclusively in the upper, positive section of the table, perhaps because amino acids tend to donate electrons.
- Synthetics are at opposing ends, with nylon and acrylic at the most positive end and polyester, polyethylene, and silicone at the most negative end.

Fig. 2. Polyester fibers attached to wool fabric of a military uniform.

- The topography of materials matters; the more surface area in contact between materials, the higher chance they will exchange electrons.
- Environmental conditions matter; hydrophilic materials at low relative humidity exchange charge more readily than at high relative humidity, while hydrophobic materials are less likely to exchange a charge [2].
- A material may become soiled while it is positively charged because it attracts negatively charged dirt particles in the air.

4. ADHESIONS

The triboelectric effect is considered to be very similar to the phenomenon of adhesion, in which two materials composed of different molecules tend to stick together on contact as a result of a chemical reaction. Adhesion is very similar to a chemical bond in which adjacent yet dissimilar atoms exchange electrons. When one material is physically moved away from the other, the bonding forces appear to the human eye as "friction." One material gains electrons, thereby creating excess electrons, while the other material loses them, thereby creating a deficit of electrons.

Adhesion can be so firm that it can be difficult to remove materials that are adhered to one another (Morton and Hearle 1962). Adhesion can even occur when charged fibers come in contact with uncharged particles.

5. CONCLUSIONS

Many of these observations go counter to our conventional "museum thinking." Other features of the series relate to the preservation of collections and clearly would benefit from more study and attention [3]. For instance, note that the phenomena involving electron exchange are related to light fastness and the pH of materials (Commoner 1998). Conservators routinely regard static as an unavoidable difficulty. From the earlier discussion, the exchange of electrons and the buildup of static charge can sometimes be beneficial; friction can be either an asset or a liability, but abrasion is generally undesirable. Perhaps the conservation field needs to reconsider the phrase "like with like" or at least when consideration of material selection with an artifact is determined.

ACKNOWLEDGMENTS

I want to thank both Mary Ballard, senior textiles conservator, Smithsonian Museum Conservation Institute, and Lucy Commoner, conservator emerita, Cooper Hewitt, for their direction toward static electricity as a plausible contributing factor to a mystery. Thanks also to Marion Billot who performed the careful tests, in a very systematic and scientific manner, while an intern at the Musée du quai Branly, and her advisor Eleonore Kissel, conservator. Ms. Billot's tests confirmed the results of the strong holding power of the polyester ultrasuede within a magnetic system (Spicer 2014).

APPENDIX

Measuring Conductivity

The conductivity or resistivity of a material is listed in Material Safety Data Sheets (MSDS). The unit used is ohms/cm. Below 106 ohms/cm (= 1.06 ohms/m), the material will not build up or hold static. Higher than 106 ohms/cm, the material will tend to create more static. Unfortunately, because companies that are required to produce MSDS manufacture synthetic materials, they therefore omit from these sheets any textile materials made of natural fibers. (An ohm unit is the amount of electric resistance in a circuit transmitting a current of ampere when subjected to a potential difference of 1 volt.)

GLOSSARY OF TERMS

Mostly positive: Materials that tend to give up electrons and are thus positively charged (+); materials that tend to be light sensitive.
Mostly negative: These materials tend to attract electrons (–); materials that tend to be more acidic.
Relatively neutral or not charged: There are very few neutrally charged materials and they do not tend to give up electrons. Some examples are cotton and steel.

NOTES

[1] An electric current is the movement or exchange of electrons from one material to another. All materials are composed of atoms with a surface phenomenon whereby there are an equal number of positive and negative charges (Sello and Stevens 1984). When energy is applied to materials in contact, such as through friction or pressure, a small number of electrons can jump from one material to the other (fig. 1). Both positive

electrons, known as positrons, and negatively charged electrons flow continuously in both directions. The basis of the surface phenomenon of electrostatic charging is that the equilibrium condition of the neutral atom becomes disrupted, allowing electrons to move more freely (Commoner 1998). The material that gains electrons becomes negatively charged while the material that loses electrons becomes positively charged. Unlike magnets, which attract only those materials that can be magnetized, a much larger range of materials can hold an electrical charge. In addition, a charged body can lose some, if not all, of its charge when touched by a neutrally charged body, while a magnet will not lose any of its efficacy from being touched. Since ancient times, it has been known that rubbing certain materials, such as amber, would enable them to lift light objects of certain materials (Feynman 1964), such as bits of papyrus, straw, and dust. In addition, sparks could be created if amber were rubbed long enough. At the time, the attraction was believed to be magnetic. Gilbert's work in the year 1600 determined that lodestone was magnetic and that this was distinct from static electricity produced by rubbing amber. Thus, Gilbert coined the word *electricus*, from the Greek word *λεκτρον*, for "amber," to describe the attraction between small objects that exists after being rubbed. Of course, the story eventually came full circle when later scientists found the link between magnetism and electricity (Feynman 1964).

[2] The presence of moisture in the air limits any charge buildup on a surface. Therefore, the higher the relative humidity of the environment, the less static potential a material will have (Suh et al. 2010). In this way, moisture serves as a ground and reduces the static charge, thereby increasing the conductivity of the material (Commoner 1998). Natural fibers tend to be hydrophilic, or water absorbing, and are more influenced by the environment, whereas most synthetics are hydrophobic, or water resistant, and are therefore less influenced by environmental conditions and more readily build up a charge.

[3] Industries of all types are concerned with the buildup of static electricity, such as those that manufacture finely tuned, sensitive electronics, flammable vapors and dust, and printing materials, to name a few. Hospital operating rooms also work to minimize static electricity.

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AUTHOR BIOGRAPHY

GWEN SPICER is a textile, upholstery, and objects conservator in private practice. She earned her MA in Art Conservation from Buffalo State College, and has since taught and lectured around the world. In her private practice, she assists many individuals and organizations of all sizes with storage, collection care, and exhibitions, and has become known for her innovative conservation treatments. A recent project was overseeing of the inaugural textiles displayed at the National Museum of African American History and Culture in Washington, DC. She has received a Kress fellowship to write a book on the use of magnets in conservation, *Magnetic Mounting Systems for Museums and Cultural Institutions*. She is a Fellow of AIC and the Flag Research Center. Address: 305 Clipp Road, Delmar, NY 12054. E-mail: gwen@spicerart.com.

OLD AND NEW SOLUTIONS TO DISSIPATE STATIC CHARGE FOR PLEXIGLAS PRESSURE MOUNTS

MARY W. BALLARD, ALLISON GENTRY, AND NAMRATA DALELA

ABSTRACT—Textile conservators have recently renewed concerns about the difficulties of opening a pressure-mounted "sandwich" when the antique fabric is silk. The static charge between silk and poly(methyl methacrylate) glazing does not dissipate with moist toweling laid over the top of the sandwich, nor with a static eliminator gun. In the past, one method used was to anticipate the problem by using an antistatic coating, no longer produced. Alternative methods involved anti-cling commercially available aerosols or cationic formulations.

SOLUCIONES VIEJAS Y NUEVAS PARA DISIPAR LA CARGA ESTÁTICA DE MONTAJE POR PRESIÓN EN PLEXIGLÁS

RESUMEN–Los conservadores de textiles han renovado recientemente sus preocupaciones en relación a la dificultad que representa abrir montajes de presión tipo "sándwich" cuando la tela en cuestión es seda antigua. La carga estática entre la seda y el Plexiglás (o cualquier hoja de polimetil meta acrilato) no se disipa ni con una tela húmeda sobre el sándwich, ni con una pistola antiestática. En el pasado, un método usado era anticipar el problema usando una capa protectora antiestática, misma que está descontinuada. Métodos alternativos incluyen aerosoles antiestática y formulaciones catiónicas, disponibles de manera comercial.

1. INTRODUCTION

At an earlier Textile Specialty Group session, two textile conservators spoke to the problem of reopening a pressure-mounted "sandwich" when the antique fabric inside the mount was silk (Giuntini 2012; Sutcliffe, 2012). The authors lamented the recalcitrant nature of static charge between the silk and the Plexiglas: water-dampened toweling did not eliminate the charge, nor did a static eliminator gun. One author suggested that certain individual steps within the actual process of pressure mounting have been altered or lost during the past decades (Giuntini 2012). This short paper describes a minor but significant alteration in the sandwiching operations to address static charge and another post-treatment possibility to control static charge when reopening the sandwich.

2. PRIOR HISTORIES

Decades ago, textile engineers and technologists developed solutions to the creation of static charges during manufacturing operations. These methods were later found to be inadequate for the problems associated with the processing of synthetic fibers and their subsequent performance. *Ciba Review* devoted an entire issue to the phenomenon of static electricity in 1959. The triboelectric series and characterization of static charge were reevaluated during the next decades (Hersh 1975 Sello and Stevens 1984). Textile conservators have had to update their understanding of static charge in response to changes in processing and use (Commoner 1984; Spicer 2018).

OLD AND NEW SOLUTIONS TO DISSIPATE STATIC CHARGE FOR
PLEXIGLAS PRESSURE MOUNTS

When Plexiglas sandwiches replaced glass sandwiches, weight, cold microclimate, and breakability were exchanged for issues associated with static and flexure. One past method used an antistatic coating. For several decades, the textile conservation laboratory at The Metropolitan Museum of Art employed a Larostat product from Pittsburgh Plate Glass (PPG) (Kajitani 1997) (figure 1). A merger of that section of PPG with Badische Aniline Soda Fabrik (BASF) subsequently reorganized the product line.

Apparently, the Larostat 451, a "stearyl dimethylethyl ammonium ethosulfate" [1], was no longer available and a number of other Larostats were discontinued. Larostat 451 had contained a sulfate soap and a liquid amine (Hopwood 1997). In discussing the merits of the remaining Larostat products, the new Larostat FPE (for *F*ood grade *P*oly*E*thylene antistat—described as a "lauric diethanoloamide" with a minor amount of diethanolamine—is said to be "less corrosive than ethoxylated amine based antistats" (BASF n.d., p.1). A dispersion of 0.1% to 0.2% in water was suggested (BASF n.d.). This product remains commercially available as Larostat FPE and is incorporated into polyolefin films; it may also be used as a postproduction surface antistatic agent. This product did not seem particularly useful as a topical spray to the current authors [2].

3. OPENING A PLEXIGLAS PRESSURE MOUNT

Nonetheless, there are ways to deaden the static charge. The simplest one is an anti-cling aerosol used for cat or dog hair and, in the past, women's lingerie (figure 2). The active ingredients are described as denatured alcohol, a hydrofluorocarbon, isobutene, propane, a quaternary ammonium compound, isopropyl alcohol, ammonium acetate, and fragrance. We confirmed our success with the assistance of Tru Vue representatives

Fig. 1. Original sample sent from the Metropolitan Museum of Art to the Conservation Analytical Laboratory, now renamed the Smithsonian Museum Conservation Institute.

Fig. 2. Static guard is one well-known commercial product still available.

and their handheld static voltage measurement device. Its exponential scale was reduced from static charged, to noncharged (10^{13}–10^{8}).

While this method works, it is suggested only for a sandwich with a disposable facing sheet of Plexiglas: the commercial product's formulation or its removal could damage the surface of the poly(methyl methacrylate). It will preserve the condition of the textile but may damage the mount. Other cationics—such as fabric softeners—may also work, with the same limitation.

While the commercial products will require good ventilation, the actual opening does not. In fact, a rush of air flow while opening the sandwich quickly could disarrange and damage the carefully preserved condition of a textile.

4. DISCUSSION OF RESULTS

Coating a finished sheet of Plexiglas with a topical antistatic agent is not straightforward. Despite the assistance of technical representatives—chemists and technologists familiar with the working properties of the range of antistats, a direct substitution was not successful. Perhaps new machinery requirements precluded the use of the earlier product? Perhaps a wetting agent was needed? Topical coatings are rarely composed of a single ingredient; more often they combine numerous ingredients. Yet, even with further effort, would a product designed for a poly(ethylene) or poly(propylene) film function adequately for a poly(methyl methacrylate) sheet if the newer product was designed primarily to be incorporated into the polyolefin film as it was being cast?

Killing the static charge for a specific short-term purpose is more easily accomplished. The choice between saving the glazing or saving the object is relatively simple.

5. CONCLUSIONS

There were materials and methods to cope with the vagaries of materials in the past. Some of these have been lost owing to changes in manufacture, aesthetics, and advances in safety. There are now Plexiglas options that permanently counter static charge. The authors encourage others to plan and to test new solutions to problems. Mock-ups and "dummy trials" remain a wonderful tool in practice, not just for training.

ACKNOWLEDGMENTS

The authors would like to thank Julie Heath and Tru Vue for their assistance in this research and to thank the Smithsonian Museum Conservation Institute for supporting this research.

NOTES

[1] Commercial characterizations of chemical compounds do not follow International Union of Pure and Applied Chemistry (IUPAC) standards.

[2] A dispersion is not a solution; water does not spread easily on Plexiglas. Larostat 451 was manufactured and promoted as an additive to polyethylene food wrapping films, a different use entirely. The authors of this article did not test a range of alternative solvents to water themselves that would be safe for Plexiglas and that would disperse Larostat FPE more successfully.

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AUTHOR BIOGRAPHIES

MARY W. BALLARD, senior textiles conservator at the Smithsonian's Museum Conservation Institute, is a Fellow member of the American Institute of Conservation. Address: Museum Conservation Institute, Smithsonian Institution. 4210 Silver Hill Road, Suitland, MD 20746-2863. USA. E-mail: ballardm@si.edu

ALLISON GENTRY interned at the Museum Conservation Institute, Smithsonian Institution for several months before enrolling at North Carolina State University's College of Textiles, where she received an MSc in Apparel. She now works in Seattle, Washington as material developer for Brooks Running.
Email: allison.gentry@brooksrunning.com

NAMRATA DALELA was a research associate in the Smithsonian's Museum Conservation Institute, where she researched and contributed to a number of projects from 2012 to 2014. She holds a BSc and MSc from Lady Irwin College, Delhi University; she has carried out a variety of teaching assignments, project management, and seminars in India. Most recently, she has been affiliated with textile conservation projects at the Crafts Museum or National Handicrafts and Handlooms Museum, New Delhi, as well as the National Museum, New Delhi. E-mail: dalela.namrata@gmail.com

COMPARISON OF DRY-CLEANING SPONGES USED TO REMOVE SOOT FROM TEXTILES

ALLISON ANDERSON AND MARGARET ORDOÑEZ

ABSTRACT—This tip summarizes a study that compared natural-rubber (e.g., soot sponge) and polyurethane foam (e.g., cosmetic sponge) sponges widely used for dry cleaning textiles that was conducted through the University of Rhode Island Textile Conservation Laboratory. A series of exploratory trials on textiles covered in simulated soot deposits assessed sponge characteristics, efficacy, and potential for damage. The natural-rubber sponges sold for use in conservation failed to outperform polyurethane sponges in all trials. Results suggested that the residue left by natural-rubber sponges makes them unsuitable for use in textile conservation. Further research is needed to determine the long-term suitability of sponges containing alkaline additives.

COMPARACIÓN DE ESPONJAS PARA LIMPIEZA EN SECO, USADAS PARA REMOVER HOLLÍN DE TEXTILES

RESUMEN—Este trabajo resume un estudio que comparó esponjas de hule natural (ej. esponja de hollín) y de poliuretano (ej. esponjas cosméticas), ampliamente utilizadas para la limpieza en seco de textiles. Estas esponjas han sido utilizadas para limpieza de textiles en el Laboratorio de Conservación de Textiles de la Universidad de Rhode Island. Una serie de intentos exploratorios en textiles cubiertos en hollín aplicado de manera intencional fue limpiada con estas esponjas con la finalidad de evaluar su eficacia y el daño que pueden causar. Las esponjas de hule natural, disponibles de manera comercial para uso en el campo de la conservación tuvieron un desempeño inferior a las esponjas de poliuretano. Los resultados sugirieron que el residuo que las esponjas de hule natural deja en la superficie es inadecuado para su uso en conservación de textiles. Se necesita más información para determinar la estabilidad a largo plazo de las esponjas que contienen aditivos alcalinos.

1. INTRODUCTION

Rubber sponges and polyurethane (PU) sponges are both commonly used by conservators when dry cleaning textiles. A published comparison of the characteristics, efficacy, and impact of sponge types to painted canvases did not address garments or other textiles (Daudin-Schotte et al. 2013). This study used textiles with simulated soot deposits to explore the various characteristics of commercially available and conservation-specific sponges, establishing their suitability for textile conservation.

2. METHODS

Materials and methods were chosen through a series of pretests (Anderson 2016). In all pretests and trials, cleaning efficacy was measured as the change in lightness (ΔL) using a spectrophotometer (X-rite model SP62 with Color iQC, v.7).

Sponges were cut into equal-sized 1 cm cubes. Plain-weave cotton fabrics were used as substrates for testing; new fabric was used for the soil-removal tests while 19th century fabric donated to a conservation study collection was used for damage trials. Substrates were soiled using carbon black as an analog for soot; the AATCC Test Method 123-2000, Carpet Soiling: Accelerated Soiling Method (AATCC 2007) was modified by using 2 mm glass balls to minimize damage in the soiling process. To minimize the effects of handling, soiled samples were pinned to foam-core cards and vacuumed at a suction level appropriate for delicate textiles, as determined through pretesting.

Rather than rubbing or rolling the sponges, which can damage textiles by displacing yarns, abrading fibers, and leaving sponge debris, sponges were tamped against the fabric surface in this study. A small-scale test revealed that sponges quickly remove soil before their efficacy reaches a plateau, after which point particulates were redeposited onto the surface of the textile. Sponges removed particulates without redepositing soil between 8 and 16 tamps, after which more tamps with a dirty sponge did not increase the amount of soil removed.

3. SPONGE CHARACTERIZATION

Five sponges were selected for this study to represent the measurable physical characteristics found in dry-cleaning sponges, including composition, structure, and average cell size. Sponges represented those available through conservation supply houses and those marketed for commercial purposes. Two natural-rubber sponges—University Products Dry Cleaning Sponge and Paint USA K-42R Soot and Dirt Remover (fig. 1)—and three polyurethane-foam sponges—University Products Latex-Free Hydrophilic Sponge, Studio 35 Beauty Cosmetic Wedges, and up & up Latex Free Foam Cosmetic Wedges (fig. 2)—were compared.

Sponges were characterized visually based on number of cells in a square centimeter and the average open area of a cell. Composition was further characterized through energy-dispersive x-ray spectroscopy (EDX) analysis that suggested the presence of common sponge additives, either calcium carbonate or aluminum silicate, the presence of which was visible at 1000× (fig. 3). Comparison of these characteristics is found in table 1.

Table 1. Sponge Characteristics

Commercial Name	**Composition**	**Average Cell Size (mm^2)**	**Cells per cm^2**
Paint USA K-42R Soot & Dirt Remover	Natural rubber, calcium carbonate	0.46	132
University Products Dry Cleaning Sponge	Natural rubber, calcium carbonate	0.48	134
Studio 35 Beauty Cosmetic Wedges	PU foam, calcium carbonate	6.7×10^{-3}	8000
up & up Latex-Free Foam Cosmetic Wedges	PU foam	0.031	2300
University Products Latex-Free Hydrophilic Sponge	PU foam, aluminosilicate, titanium oxide	7.8×10^{-3}	6600

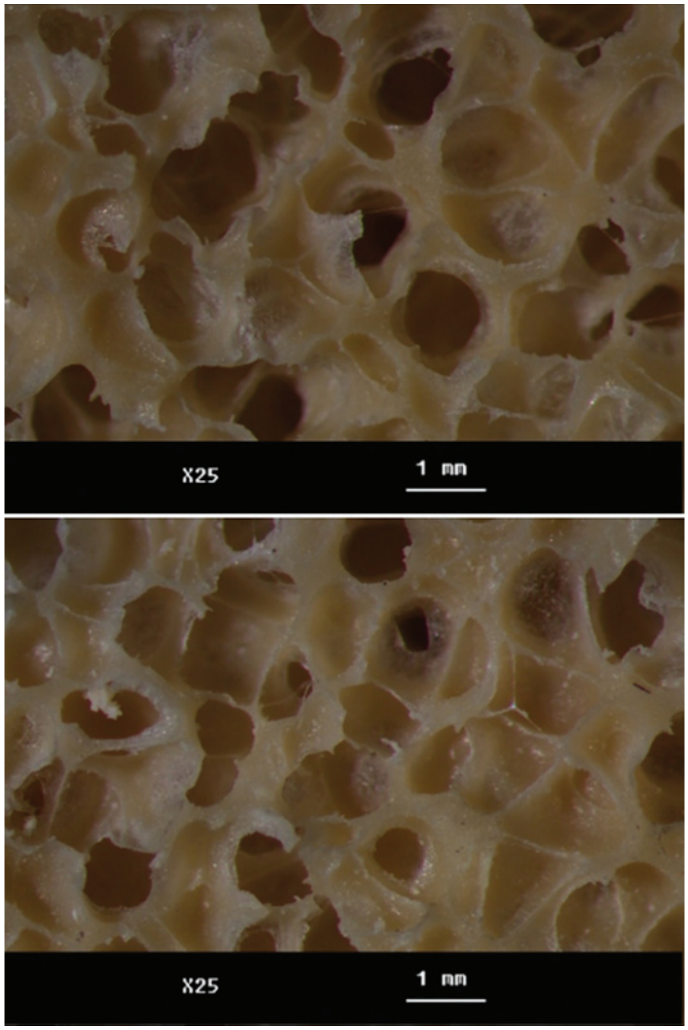

Fig. 1. Natural rubber sponge surface, 25× magnification. University Products Dry Cleaning Sponge (top) and Paint USA K-42R Soot & Dirt Remover (bottom).

4. FINDINGS

A series of trials compared sponge types and brands to determine the most appropriate product for soil removal from the surface of textiles. These trials evaluated cleaning efficiency, damage to the surface of the textile, and sponge residue.

Trial 1 tested the cleaning efficacy of the five sponges, comparing lightness before and after treatment. While the Studio 35 Beauty sponge removed statistically significantly more soil than all other sponges, all PU-foam sponges were not better than the two natural-rubber sponges. Physical characteristics appear to be more important than material in choosing a sponge to remove particulate soil, as the sponge with the smallest cells was the most effective.

Trial 2 tested the number of clean sponge surfaces needed to remove the most soil. As demonstrated in trial 1, the Studio 35 Beauty sponge was significantly better than all other sponges. The slope of the ΔL for the all-PU-foam sponges suggests that fresh sponges may continue to remove soil after the first sponge is

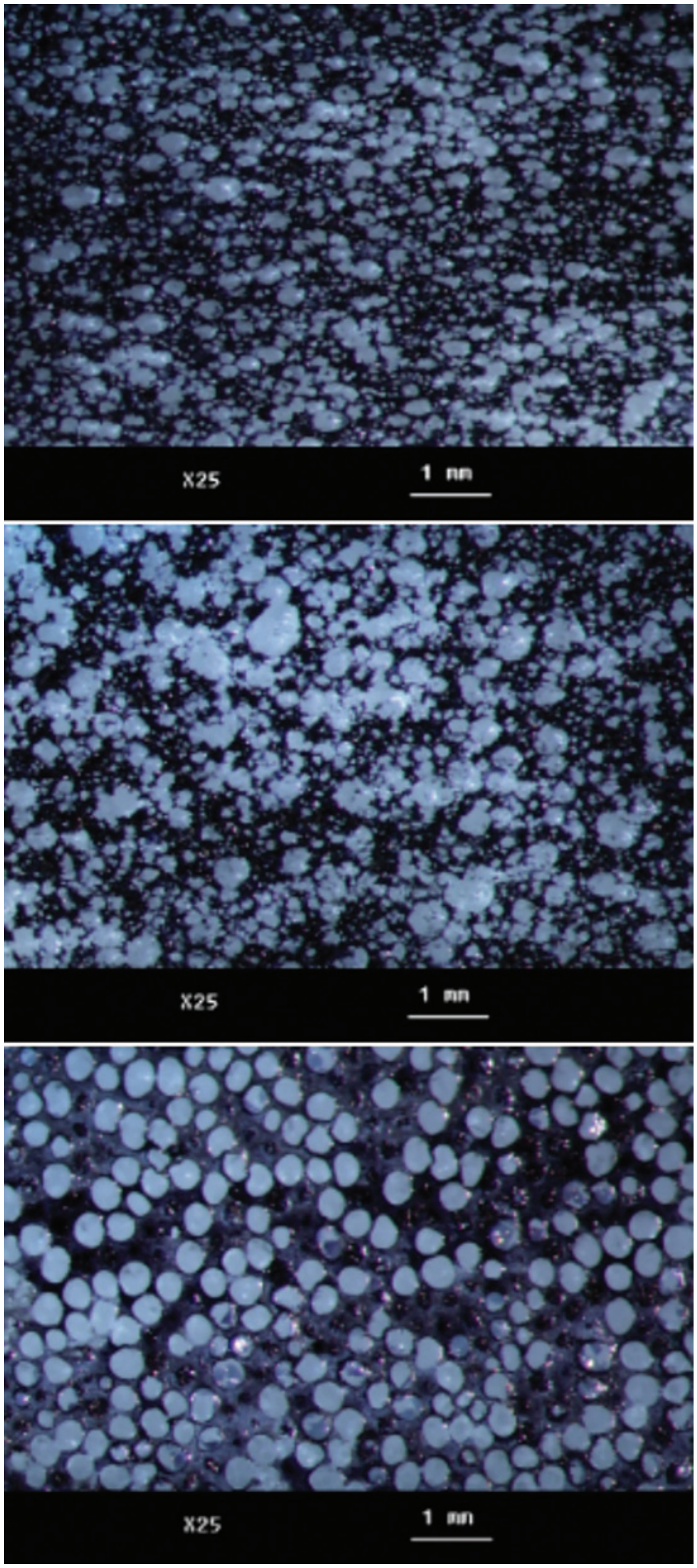

Fig. 2. Polyurethane sponge surface, 25× magnification. University Products Latex-Free Hydrophilic Sponge (top), Studio 35 Beauty Cosmetic Wedges (middle), and up & up Latex Free Foam Cosmetic Wedges (bottom). Sponge surfaces were covered with black ink to make the individual cells more visible.

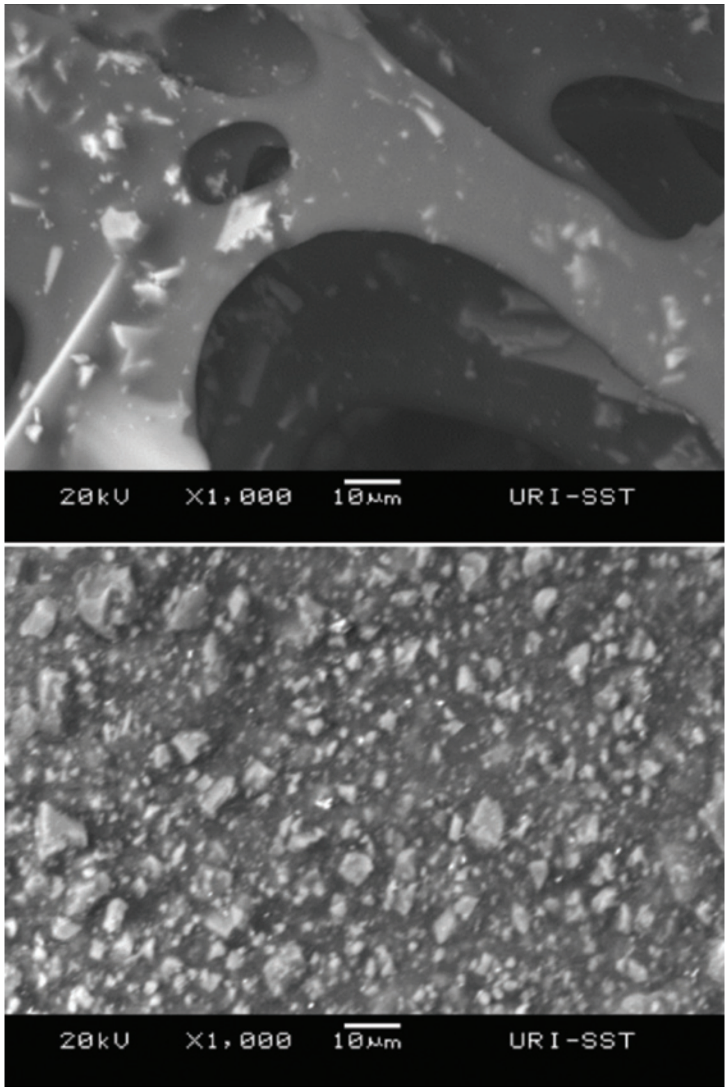

Fig. 3. Sponge surfaces with white structures consistent with calcium carbonate, 1000× magnification. Studio 35 Beauty sponge (top) and University Products Dry Cleaning Sponge (bottom).

exhausted. Data suggested that PU sponges may continue to remove residue after rubber sponges are unable to pick up additional particulates.

Trial 3 evaluated damage to aged textiles through yarn displacements and quantity of fibers dislodged from the yarns, using visual comparison through photomicroscopy. Findings suggested that the tamping action that occurs during sponge cleaning does negligible damage to yarns; all observable differences were less noticeable than those caused by careful handling.

Sponge residue was characterized and measured by tamping sponges onto a clean slide and characterizing the debris left behind. For all sponges, the risk of residue exists and the fragments of sponge or additives redeposited can be as miniscule as soot particulates themselves. Where natural-rubber and PU sponges differed was in the magnitude of particulates deposited on a surface. Within a 20 mm^2 area, PU sponges deposited 30 to 70 particulates, on average, whereas natural rubber produced 500+ particulates; this range of residue is

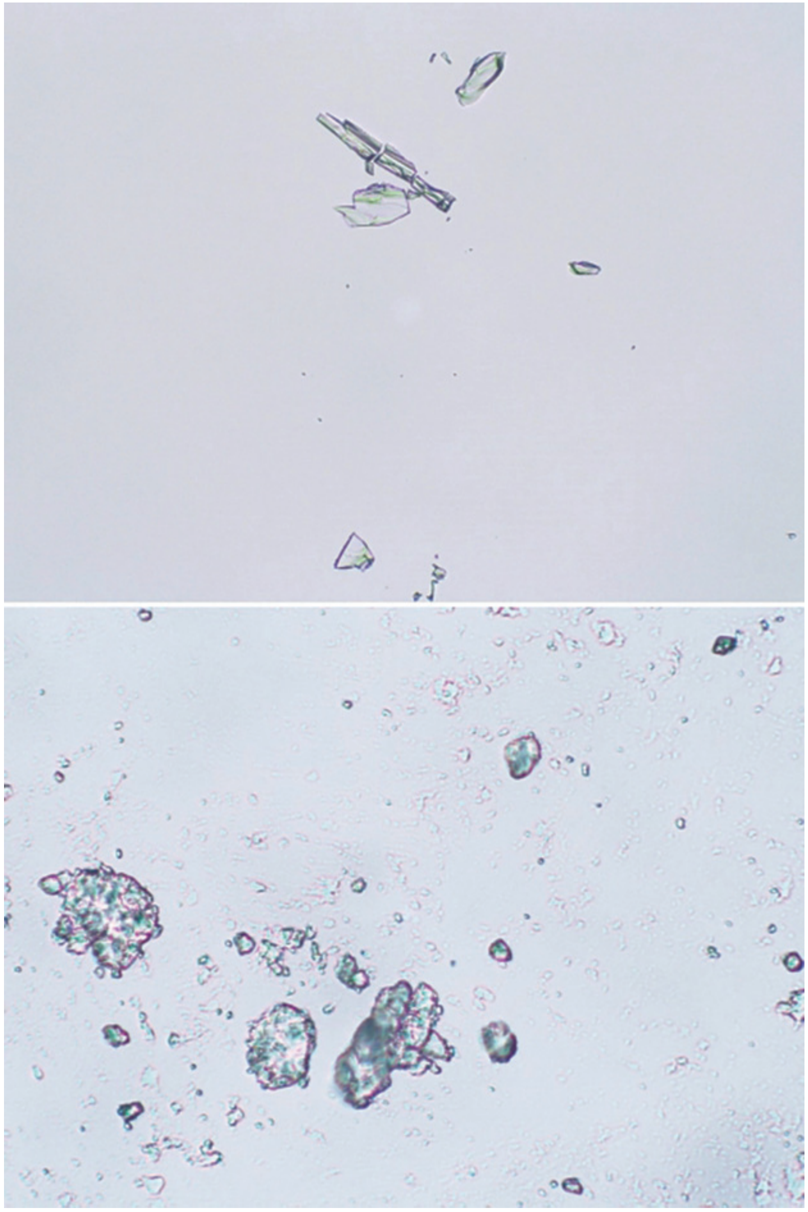

Fig. 4. Sponge debris and additive particulates left behind after tamping. Studio 35 Beauty sponge (top) and Paint USA K-42R Soot & Dirt Remover (bottom).

displayed in figure 4. The size of these particulates makes their removal difficult, if not impossible, raising serious concerns about the quantity of residue produced and deposited by natural-rubber sponges.

5. CONCLUSIONS

Natural-rubber sponges should no longer be used to surface clean any textile. These sponges shed large quantities of particulates, including both sponge material and calcium carbonate additives. While some of these particles might be removed by vacuuming, the strength of suction required to remove them is harsher than recommended for most textiles.

PU sponges may be appropriate for most textiles. Some of these contain and shed small amounts of particulates, consistent with calcium carbonate additives. Sponges that use calcium carbonate or other alkaline fillers may not be suited for use with protein fibers but may still be acceptable for cellulosic fibers.

When using PU sponges, it should be noted that there is a limit to how much soil may be removed. To maximize the amount of soil reduction, clean sponge surfaces should be regularly swapped out after 8 to 16 tamps to avoid redepositing soil onto the textile's surface.

While the results of this study are actionable, further research evaluating the benefits and consequences of using sponges to remove particulate soil as a conservation treatment for textiles is recommended. The methods in this study were exploratory owing to the lack of standardized test methods for evaluating conservation treatment methods. Additionally, this project tested a limited set of materials; continued testing of sponges will be required as product availability changes and manufacturers alter the characteristics of and additives to their sponges.

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SOURCES OF MATERIALS

University Products Dry Cleaning Sponge and Latex-Free Hydrophilic Sponge
University Products, INC.
517 Main St.
Holyoke, MA 01040
www.universityproducts.com

The two commercially available PU sponges tested were store brands purchased at local branches in Rhode Island, while the natural-rubber sponge was purchased at a local hardware store. Corporate addresses are provided below.

up & up Latex Free Foam Cosmetic Wedges
Target Corporation
1000 Nicollet Mall
Minneapolis, MN, 55403
www.target.com

Studio 35 Beauty Cosmetic Wedges
Walgreen Co.
200 Wilmot Rd.
Deerfield, IL 60015
www.walgreens.com

Paint USA K-42R Soot & Dirt Remover
ACE Hardware
2200 Kensington Court
Oak Brook, IL 60523
www.acehardware.com

AUTHOR BIOGRAPHIES

ALLISON ANDERSON completed her Master of Science in Textiles, Fashion Merchandising, and Design at the University of Rhode Island (URI) in 2016 and is currently a research assistant at the Museum of Science, Boston. Address: 100 Bemis Rd., #7, Fitchburg, MA 01420. E-mail: allison.marguerite.anderson@gmail.com

MARGARET ORDOÑEZ, PhD, Professor Emerita, University of Rhode Island, recently retired after teaching graduate textile conservation courses at URI for 29 years. She is continuing to practice textile conservation in her new labs in Tennessee. Address: 21 Bounty Lane, Camden, TN 38320. E-mail: mordonez@uri.edu

A PRELIMINARY EVALUATION OF LINING AND SURFACE PATCHING TECHNIQUES FOR DOPED AIRCRAFT FABRIC

LAUREN GOTTSCHLICH, LAUREN ANNE HORELICK, AND MARK J. WAGNER

ABSTRACT—Doped fabric is ubiquitous on historic aircraft. Traditionally, aircraft dope is made of multiple coats of cellulose derivatives applied over aircraft fabric. As aircraft dope ages, it becomes brittle and shrinks, often cracking or splitting in the process. Restoration practices typically include removal of aged doped surfaces in favor of freshly prepared doped fabric. However, this compromises the authenticity of aircraft surfaces. Lining and surface patching are being explored as alternative treatment options to restoration techniques at the National Air and Space Museum. Tensile testing on an MTS Criterion TM Model 43 universal testing machine evaluated treatments previously employed on two historic aircraft. The lining of doped fabric onto Ceconite 102 (polyester aircraft fabric) using BEVA 371b and BEVA D-8 was assessed using ASTM standard D1002-10 for lap-shear testing. For all samples, the adhesive bond was stronger than the doped fabric. Surface patches using Lascaux 498 HV, 3% (w/v) methylcellulose in deionized water, and 1:1 10% (w/v) sturgeon glue in deionized water/dilute wheat starch paste were assessed using ASTM standard D1876-08 for T-peel tests. Of these adhesives, Lascaux 498 HV had the strongest bond but the weakest, methylcellulose, could have applications for small patches. Further research is necessary.

EVALUACIÓN PRELIMINAR DE TÉCNICAS DE REENTELADO Y PARCHADO PARA TELAS PLASTIFICADAS/LACADAS USADAS EN AERONÁUTICA

RESUMEN—Las telas con algún tipo de recubrimiento (doped fabric) son muy comunes en aeronaves históricas. Tradicionalmente, estas telas se fabrican aplicando derivados de celulosa sobre las telas. Al envejecer, el recubrimiento se torna frágil y encoge, y a menudo se quiebra o rompe en el proceso. Los procesos de restauración típicamente involucran la remoción de las telas envejecidas a favor de telas recientemente preparadas. Sin embargo, esto compromete la autenticidad de las superficies de las aeronaves. El reentelado y el parchado son dos alternativas de restauración exploradas en el Museo Nacional del Aire y el Espacio (National Air and Space Museum). Se hicieron ensayos de tensión por tracción al rasgado en tratamientos previamente usados en dos aeronaves históricas, usando una MTS Criterion TM Model 43. Se evaluó el reentelado del textil tratado con Ceconite 102 (poliéster para aeronaves) usando BEVA 371b y BEVA D-8, usando el estándar ASTM D1002-10. Para todas las muestras, la unión con el adhesivo resultó mucho más fuerte que el textil. Los parches superficiales, elaborados con Lascaux 498 HV, 3% (w/v) metilcelulosa en agua desionizada, y 1:1 10% (w/v) cola de pescado en agua desionizada/almidón de trigo también se evaluaron, usando el estándar ASTM D-1876-08 para "T-peel." De los adhesivos mencionados, el Lascaux 498 HV muestra la unión más fuerte, mientras que el más débil, metilcelulosa, puede tener aplicaciones como parches pequeños. Se requiere más investigación.

AUTHOR BIOGRAPHIES

LAUREN GOTTSCHLICH graduated with a BA from the University of Mary Washington with majors in art history, studio art, and historic preservation. She received her MS from the Winterthur/University of Delaware Program in Art Conservation, majoring in objects conservation and minoring in preventive

conservation. Her graduate internships included placements at the Denver Art Museum, the Royal British Columbia Museum, and the Virginia Museum of Fine Arts. She is currently an objects conservator at the Smithsonian National Air and Space Museum. Address: 14390 Air and Space Museum Pkwy, Chantilly, VA 20151. Email: GottschlichL@si.edu

LAUREN ANNE HORELICK has a BFA in sculpture from the San Francisco Art Institute, a BA in art conservation and anthropology from the University of Delaware, and an MA in archaeological and ethnographic conservation from University of California at Los Angeles (UCLA)/Getty Conservation Master's program. Horelick's research interests include studying the effects of adhesives on cultural materials, diagnostic imaging, and exploring cross-disciplinary adaptive techniques for large-scale technological objects. She is currently an objects conservator at the National Air and Space Museum. Address: 14390 Air and Space Museum Pkwy, Chantilly, VA 20151. Email: Horelickl@si.edu

MARK J. WAGNER is currently the lab manager for the Mechanical and Aerospace Engineering department as well as for the Civil and Environmental Engineering department for the George Washington University—School of Engineering and Applied Sciences. Among other labs, Mark Wagner runs the materials testing laboratory and 3D-print lab. He is the co-inventor of the FLS1 (manual) and FLS2 (motor-driven) portable materials testing frame used for tensile and compression tests of samples in the field. Mark J. Wagner has a BS in Physics from Arizona State University. Address: Science & Engineering Hall, 800 22nd St NW, Washington, DC 20052. Email: qedqcd@gwu.edu

SEM ANALYSIS OF METAL THREADS FROM THE KING'S BED AT KNOLE HOUSE, KENT, UNITED KINGDOM

ERIN MURPHY

ABSTRACT—This poster presents the results of a morphologic and compositional study of four different 17th century metal threads set aside after a 1974 to 1987 wet cleaning. These threads, from the "King's Bed" (at Knole in Kent, United Kingdom) were examined at University College London via SEM/Energy-Dispersive X-Ray Spectroscopy (SEM-EDS) to confirm their elemental composition and morphology. Multiple points were tested and the surface was "mapped" along lines to investigate if the composition varied between bright and dull areas and to detect corrosion products. The thickness of the gold-gilded layer was investigated on cross-sectional samples. Additionally, 10 and 7 kV readings were obtained to help determine the gilded-layer thickness. All four threads were silver; one solid and three with metal foil–wrapped silk cores. The solid silver thread showed tooling striations, indicating manufacturing by drawing, while high gold readings suggested possible gold gilding. The other threads were of cut metal foil wrapped about silk cores. Surface striations suggested different manufacturing methods. The EDS line-mapping tool helped correlate visual evidence with elemental composition. The very thin layers of gold gilding are of interest, as it is possible that the solid silver thread was gilded at one time, which may have been damaged during cleaning.

ANÁLISIS POR MICROSCOPÍA ELECTRÓNICA DE BARRIDO (SEM) DE HILOS METÁLICOS DE LA CAMA DEL REY EN LA CASA KNOLE, KENT, EN EL REINO UNIDO

RESUMEN—Este póster presenta los resultados de un estudio morfológico y composicional de cuatro hilos diferentes del siglo XVII, separados tras su limpieza húmeda entre 1974 y 87. Estos hilos, de "la cama del Rey" (Knole, Inglaterra) fueron examinados por la University College London por medio de microscopía electrónica de barrido - espectroscopía de energía de rayos-X dispersiva (SEM-EDS por sus siglas en inglés) para confirmar sus composición morfológica y composicional. Se colectaron mapas de varias zonas y se examinaron varias zonas con la finalidad de investigar la composición entre las áreas brillantes y opacas, dado que las últimas se pueden asociar a productos de corrosión. El grosor de la capa de dorado se investigó por medio de una sección transversal. Adicionalmente, lecturas a 10 y 7 kV se obtuvieron para determinar el grosor del dorado. Los cuatro hilos resultaron ser plata; un hilo resultó ser de plata sólida y tres de hilos de seda envueltos en el metal. El hilo de plata sólido mostró estriaciones de factura, lo que indica factura por dibujo, mientras las lecturas asociadas a oro sugieren técnica de dorado. Las estriaciones dieron información sobre su factura. Los mapas espectroscópicos de energía dispersiva (EDS por sus siglas en inglés) ayudaron a correlacionar evidencia visual con composición elemental. Las capas finas de dorado son de interés, dado que es posible que el hilo de plata sólida se dorase al mismo tiempo, y éste pudo haberse dañado durante la limpieza.

AUTHOR BIOGRAPHY

ERIN MURPHY is an assistant conservator at the Field Museum in Chicago, Illinois, where she is part of the team renovating the Native North America exhibit. She recently served as the Marshall Steel Senior Intern at the Archaeological Collections at the Colonial Williamsburg Foundation. Erin completed internships at the

Horniman Museum and Gardens in London, the Hirshhorn Museum, the Milwaukee Art Museum, the Arizona State Museum, the Buffalo Bill Center for the West, and others. Erin is a graduate of University College London, where the research for this poster was completed. Address: 525 W Fullerton Pkwy #8, Chicago, IL, 60614. E-mail: emurphy@fieldmuseum.org.

THE CONSERVATION OF TEXTILE MAP LININGS AND SEAL CORDS—WITH A LITTLE HELP FROM BOOK AND PAINTINGS CONSERVATION

SOLANGE FITZGERALD

ABSTRACT—This poster focuses on the adaptation and application of two different conservation techniques, taken from paintings, textile and book conservation. The objects are different from each other in date, format, and condition, both consisting of textiles in the form of linen and silk. Research in different areas of conservation was necessary to help establish an appropriate treatment solution to a 19th century ordnance survey map with a torn linen lining and a 16th century parchment charter with four split silk seal cords. In order to salvage the original lining of the map, an in situ treatment was devised from a method usually applied to damaged canvases in paintings conservation: "the thread-by-thread tear mending technique." The damage associated with the charter's fragile silk cords presented another conservation challenge. The parchment charter and wax seal remained intact but the split threads of the braided cords left the object vulnerable. The treatment involved the addition and securing of new silk threads with adhesives to the split original threads in order to stabilize the whole cord. These cross-disciplinary treatments proved highly successful in making the objects accessible again, while maintaining their historical structure.

CONSERVACIÓN Y REENTELADO DE UN MAPA TEXTIL Y SELLOS DE TELA - CON AYUDA DE CONSERVACIÓN DE PINTURAS Y LIBRO

RESUMEN—Este póster se enfoca a la adaptación y aplicación de dos técnicas diferentes de conservación, tomadas de conservación de pintura de caballete, textil y de libro. Los objetos son diferentes el uno de otro en fecha, formato, y condición, y ambos están elaborados con textiles de lino y seda. Fue necesaria la investigación de diferentes áreas de conservación para poder establecer la solución de tratamiento adecuada para: un mapa de reconocimiento de artillería con el soporte de lino rasgado; y una carta de pergamino del siglo dieciséis con cuatro sellos de hilos de seda. Para poder salvar el soporte de lino, se diseñó un tratamiento local a partir de un método tradicionalmente aplicado a pinturas de caballete: "la técnica de reparación de hilo por hilo." El daño asociado al carácter frágil de la seda presentó retos de conservación adicionales. La carta de pergamino y el sello de cera se mantuvieron intactos pero los hilos rotos del tejido del sello de tela son particularmente vulnerables. El tratamiento involucró la adición y afianzamiento de hilos de seda nuevos, con adhesivos unidos a los hilos originales, rotos. Esto con el fin de estabilizar todo el sello de tela/cordón. Los tratamientos interdisciplinarios resultaron tener un gran éxito, contribuyendo a mantener los objetos accesibles una vez más, manteniendo su estructura histórica.

AUTHOR BIOGRAPHY

SOLANGE FITZGERALD, Accredited Conservator-Restorer (ACR), has worked at the National Archives, Richmond, UK, as a paper and book conservator since 2002. For the past 16 years, she has led and worked extensively on many varied and often challenging book projects. The conservation work within the National Archives collection covers a wide range of materials and includes the repair of parchment manuscripts, maps, and—more recently—textiles. She has published on the less invasive treatments of parchment volumes and

presented her work on cross-disciplinary treatments to map linings and split seal cords. Solange gained ACR status in 2010 and in 2013 became conservation manager of the Collection Care department. Address: The National Archives, Kew, Richmond, Surrey, TW9 4DU. E-mail: solange.fitzgerald@nationalarchives.gov.uk

CONSERVATION TREATMENTS APPLIED ON SEVERELY DAMAGED, DECOMPOSED SANDALS OF KING TUTANKHAMUN

SAFWAT MOHAMED AND HADEEL KHALIL

ABSTRACT—This study discusses the conservation of a pair of decomposed sandals of King Tutankhamun, considered one of a kind and made of three principle materials: leather, gold, and papyrus. The sandals were discovered in 1922 by Howard Carter inside the tomb of Tutankhamun. Subsequent conservation treatments damaged them, resulting in the sandals being categorized for study rather than exhibition. A full deterioration map was made for the sandals using digital photography and AutoCAD. Some microbiological test swabs were obtained to test the sandals in addition to other analysis: FTIR for identifying previous conservation materials and XRF for recognizing the metal type used in the manufacture of the sandals. The mechanical cleaning and consolidation of each fragment was then undertaken. In order to prevent new damage, the reassembly of the fragments was tried first in Photoshop and each pair of matched fragments were marked with a unique symbol. The pieces were adhered with Klucel G and supported with dyed black Japanese paper. A layer of acid-free cardboard was used to support the sandals from the bottom without adding adhesive. The conservation treatments extended the lifetime of the sandals and stabilized their condition.

TRATAMIENTOS DE CONSERVACIÓN APLICADOS A SANDALIAS DEL REL REY TUTANKHAMUN SEVERAMENTE DAÑADAS

RESUMEN—Este estudio discute la conservación de un par de sandalias del Rey Tutankhamun, consideradas únicas y elaboradas de tres materiales principales: piel, oro, y papiro. Estas sandalias fueron descubiertas en 1922 por Howard Carter dentro de la tumba de Tutankhamun. Tratamientos subsecuentes de las sandalias resultaron en su daño, lo que las llevó a ser objetos de estudio, y no de exhibición. Se realizó un mapa de deterioro usando fotografía digital y AutoCad.Las sandalias se analizaron por espectroscopía infrarroja por transformada de FTIR, para identificar materiales usados en su restauración previa, XRF para identificar el metal usado en las sandalias, así como exámenes microbiológicos. El proceso involucró limpieza mecánica y consolidación de cada fragmento. Para prevenir daño nuevo a los fragmentos, el reensamblaje primero se hizo en Photoshop y luego cada fragmento se marcó con un símbolo único. Las piezas se adhirieron con Klucel G y reforzadas con papel japonés teñido de negro. Una capa de cartón libre de ácido se usó para dar soporte a las sandalias sin añadir adhesivo. Los tratamientos de conservación extendieron la vida de las sandalias y estabilizaron su condición.

AUTHOR BIOGRAPHIES

SAFWAT MOHAMED is a conservator and assistant of the head of organic materials lab in the conservation center of the Grand Egyptian Museum. Address: Alexandria Desert Rd, Remaya Square, Al Haram, Giza Governorate, Egypt. E-mail: safwat1alsayed@gmail.com.

HADEEL KHALIL is a conservator at the special project lab in the conservation center of the Grand Egyptian museum. Address: Alexandria Desert Rd, Remaya Square, Al Haram, Giza Governorate, Egypt.