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This volume contains papers given at the Objects Specialty Group (OSG) session of the 2010 AIC Annual Meeting in Milwaukee, Wisconsin, and makes up the 17th Volume of OSG Postprints. The theme of the Annual Meeting was “The Conservation Continuum: Examining the Past, Envisioning the Future.” For the OSG program, the call for papers requested papers that focused in on a particular aspect of the meeting’s overall theme: “Treatment Revisited.”

In the autumn of 2009, there was a flurry of discussion on the OSG-L about complicated issues in contemporary art—topics ranged from preservation of lemons to potential substitutes for syllabub in an artwork. These lively discussions led to the development of a joint OSG/Electronic Media Group (EMG) lunchtime session called “Case Studies in Contemporary Art.” I joined forces with EMG chair Christine Frohnert and program chair Fletcher Durant to plan the session. Gwynne Ryan, who was the Chair of the Program Committee of the International Network for the Conservation of Contemporary Art, North America (INCCA-NA) and committee member Kendra Roth were involved with planning the luncheon, and helped us arrange to have INCCA-NA board member Jay Krueger introduce and moderate the session.

The OSG session began with the OSG/EMG joint luncheon on Wednesday May 12, 2010. Andrew Smith presented the first paper of the day which described the treatment of an Anish Kapoor powder-pigment sculpture. Mr. Smith discussed the difficulties with these extremely fragile objects and the process he developed to re-apply pigment to the surface without introducing binding mediums. Tin Ly described the installation and maintenance of an artwork consisting of 3 lasers pointed at a low vantage point across a large area of grass in a public park. The final presentation at the luncheon was given by Anne Turner Gunnison who described how a team of conservators and scientists determined the appropriate preventive conservation measures for a large mobile composed of brightly colored plastic luggage. The first two papers in this volume come from the OSG/EMG Joint Luncheon, “Case Studies in Contemporary Art.”

Following the luncheon, the first two papers of the OSG session continued with the contemporary art theme, with a focus on revisiting past treatments. Robert Krueger presented a new approach to maintaining water features and eliminating re-occurring biological growth outbreaks in a Noguchi fountain. Next, Objects Conservator Margo Delidow and Paintings Conservator Cynthia Albertson presented their research and collaborative treatment approach of a Claus Oldenburg soft sculpture. The remaining presentations on Wednesday were devoted to re-evaluating previous treatments. Mina Thompson and Conor McMahon reviewed the history of conservation practices in the Museum of New Mexico System. Katrina Posner discussed the issues related to interpreting the original surface of two bronze Henry Moore Sculptures in the J. Paul Getty Museum’s collection. I then presented recent research examining pinning materials for marble sculpture; the aim of which was to re-think the conventions of sculpture repair techniques and to take a less invasive approach. The final paper of the day was presented by Suzanne Hargrove who spoke about the treatment of David Smith’s 2 Circle IV, the painted surface of which had undergone several campaigns of treatment over the years.
The second part of the OSG session took place on Friday May 14, 2010, and continued with papers looking back on old treatments, or considering new ways of looking at treatment techniques, with a focus on archaeological and ethnographic materials. Kathleen Garland began with a discussion of the examination and treatment of an Egyptian limestone relief with a long and varied treatment history. J.P. Brown presented his work with Escal barrier film to create micro-environments for unstable archaeological metals. Paul Mardikian then illustrated the innovative techniques he used to recreate individual tools from the remains of a cluster of tools that had fused together in a marine environment. After the refreshment break, the session continued with Dana Senge who presented an overview of past treatments of waterlogged basketry from the Pacific Northwest. Finally, Renee Stein described how she used 3-D prototyping to create fragments to help reconstruct a fragmentary Greek kylix. Unfortunately the authors Smith, Hargrove, Mardikian, and Stein were not able to submit their talks for publication in this volume, I expect their research will be published in another format.

It was an honor to serve as the OSG program chair in 2010. I would like to thank all of the speakers for presenting their work in Milwaukee, with special appreciation to the authors who contributed to papers represented in this volume. The help of the EMG officers, Christine Frohnert and Fletcher Durant, as well as INCCA-NA members Gwynne Ryan and Kendra Roth, was indispensable in pulling together a very successful luncheon. I would also like to thank Jay Krueger for moderating the luncheon. I owe a debt of gratitude to my fellow officers who helped guide me through the planning process: Chair Helen Alten and Treasurer Julia Lawson. For her patience and perseverance in helping to pull together the OSG Postprints, I am especially thankful to Chris Del Re.

Carolyn Riccardelli, OSG Program Chair 2010
ABSTRACT

To validate the digital and electronic technology of the 21st Century, the Broward County Public Art & Design (PAD) Program commissioned an ambitious light-based artwork to add to its public art collection. Can such a project be considered “permanent” artwork with a minimum of 15 years lifespan of daily eight hours operation? How well can a laser artwork be preserved and maintained by a public art program? What are the unique challenges and rewards? “Broward Light Project: Emerald Laser Lawn” by Dan Corson, a recipient of the 2008 Public Art Year in Review, was installed in early 2007 in an open plaza of downtown Fort Lauderdale, Florida. Combining laser technology and computer software programming, this interactive artwork consists of three lasers projected at low vantage point across the lawn of a 1.8 acre plaza. It has fascinated the public by its constant mutation of nine different light sequences and patterns. However, within one year of its operation, the light installation encountered a major setback when one laser malfunctioned. A lengthy process of restoration ensued. I will discuss the roles that the artist and conservator play in the long term preservation of the artwork through collaboration with a fabricator, a computer software designer and a local service provider in this complicated restoration process.

1. INTRODUCTION

Established in 1976, the Broward County Public Art & Design Program has commissioned and acquired 234 titled artworks. The program has allocated two percent (2%) of the county capital construction project for commissioning artists who provide design expertise and create artworks within a broad range of medium and expression. The program focuses on the enhancement of urban design through the commissioned works of art which create a “sense of place.” As a result of the dynamic interaction between selected artists and interested constituent groups, 167 portables (artworks of traditional media, such as painting, sculpture, photography, drawing and so on, that can be removed and relocated easily) and 67 integrated art projects were acquired and implemented.

Among them, eight light-based projects have been commissioned, covering a wide range of media from solar energy to Light Emitting Diode (LED). Some examples are illustrated: Florida Current, by Keith Sonnier, was installed in 2001 at Terminal 4 of the Fort Lauderdale-Hollywood International Airport. The neon artwork, powered by static transformers, measures 245 running feet across the back walls of the Baggage Claim area.
Solar Time Plane, by Dale Eldred, installed in 1986 at the Broward County Main Library in downtown Fort Lauderdale, incorporates solar diffraction grating material on the surface coating. The sculpture presents a constant shifting spectrum of colors that underlines the interactive complexities of time and relative optical movement.
*Calypso and Waves*, by Tobey Archer, installed in 1998 at Terminal 2 of Port Everglades, utilizes neon and fiber optic to illuminate a 26,000 square feet of interior space.

![Fig. 3. Tobey Archer, Calypso and Waves, 1998, Port Everglades (Courtesy of Broward County Public Art & Design Collection)](image)

*Luminous Portals*, by James Carpenter, installed in 2005 at the Rental Car Center of the Fort Lauderdale-Hollywood International Airport, combines the use of computerized and interactive LED lighting with various glass finishes creating an animated interaction between six portals and moving passengers.

![Fig. 4. James Carpenter, Luminous Portals, 2005, Rental Car Center at Fort Lauderdale-Hollywood International Airport (Courtesy of Broward County Public Art & Design Collection)](image)
Fig. 5. Huizenga Plaza, Laser Artwork layout plan (Courtesy of City of Fort Lauderdale)
2. FROM CONCEPT TO REALITY

In 2006, to celebrate 30 years of Broward County’s Public Art & Design Program, a light-based project was approved by the Broward Cultural Council. Artist Dan Corson of Seattle, WA was selected to receive this commission to create a permanent installation.

The City of Fort Lauderdale and the Downtown Development Authority, in an unusual act of cooperation, partnered with the Broward County Commission, and together they supported this multi-dimensional project. Dan Corson took up the challenge to find a suitable site. He selected Huizenga Plaza, a 1.8 acre of open space in downtown Fort Lauderdale for this experimental light-based project. Corson stated:

Lasers moving through the grass allow us to experience in a new way something that is ubiquitous in the American Landscape - Lawn. Turf or sod is the largest irrigated crop in the United States. It is everywhere. Illuminating the lawn with coherent radiation, allows us to re-see with new eyes what is normal and all around us. Moving light simulates (and stimulates) the growth of the lawn, the flooding of the fields, the sparkle of the dew on the grass. The kinetic patterns on the lawn animate the grass for people to explore and play with the light. (Broward County Cultural Division 2007)

Installed in early 2007, this light-based artwork drew people out in the evening, like a magnet. With nine pre-programmed sequences of light patterns lasting for ten minutes each, the laser artwork has captivated children and adults alike.

Fig. 6. Laser pattern A (Courtesy of Broward County Public Art & Design Collection)
Fig. 7. Laser pattern B (Courtesy of Broward County Public Art & Design Collection)

Fig. 8. Laser pattern C (Courtesy of Broward County Public Art & Design Collection)
Fig. 9. Laser pattern D (Courtesy of Broward County Public Art & Design Collection)

Fig. 10. Laser pattern E (Courtesy of Broward County Public Art & Design Collection)
3. THE MAKING OF LASER ARTWORK

With his fully-developed concept of a laser artwork, artist Dan Corson collaborated with Jeff Silverman, chief designer and owner of Nth Degree Creative, a laser production company from Everett, WA, for the fabrication of this project. Mr. Silverman designed and custom-built the following items:

- **Laser system**: consisted of three laser units; each unit is a 2 channels, 300mw, rated IIIB green DPSS (Diode Pumped Solid State) projection system, with beam split, rated by CDRH (Center for Devices and Radiological Health) and various accessories. This laser system has a CDRH variance for safety compliance and testing. The three laser units, encased within a custom-made powder coated stainless steel box which was locked and bolted down to concrete floor, were installed under a park bench situated at one end of the open plaza.

- **Safety system**: a custom “scan fail safe circuit” (to avoid hurting eyes) for all three laser units; and a “Proximity Detection” device for the laser to shut down as needed when the device detects a moving object five feet from the laser system.

- **Custom digital three channels Pangolin controller** (which is electronic equipment that contains programmable hardware and a circuit board to produce a laser show used in the entertainment industry for designed Light show) with built-in timer: runs a pre-programmed sequence of nine light patterns, housed in an A/C facility twenty feet away from the laser system.

- **Computer and monitor**: control the pre-programmed light sequence. The computer is housed in the same A/C facility, operated with its dedicated power supply and power back-up.

- **Three motion detectors**: located at different areas in the Plaza, to detect motion of a passer-by which activates the laser artwork and starts the pre-programmed sequence of nine light patterns.

The three laser systems mounted below the park bench are controlled from within the laser equipment vault to produce the various laser patterns projected out to the lawn at a low angle. These three laser systems are fed electronically with information provided by a computer which programs the three channels Pangolin controller, both housed in a nearby air-conditioned facility.

The laser systems are integrated as a whole where the start and stop operation is caused by approaching visitors triggered the three motion detectors to “start”, along with a disengage sensor or safety system to “stop”, located in front of the laser system. Within two years of its operation, the light-based installation encountered a major set-back when one unit of laser system was malfunctioned and shut down. A lengthy process of restoration ensued.
Fig. 11. Laser System (Courtesy of Broward County Public Art & Design Collection)

Fig. 12. Laser Location (Courtesy of Broward County Public Art & Design Collection)
Fig. 13. Laser Safety System (Courtesy of Broward County Public Art & Design Collection)

Fig. 14. Pangolin Controller (Courtesy of Broward County Public Art & Design Collection)
Fig. 15. Laser pre-programmed sequence (Courtesy of Broward County Public Art & Design Collection)

Fig. 16. Computer and monitor (Courtesy of Broward County Public Art & Design Collection)
4. CONSERVATION PROCESS

After informing the artist of the occurrence (whose one-year warranty on the artwork had expired), the artist recommended that the malfunctioned laser unit be shipped back to the laser designer and fabricator, Jeff Silverman of Nth Degree Creative, for technical diagnosis to determine the course of restoration.

Due to a proactive measure to prevent this kind of unfortunate incidence, the Broward County Public Art & Design Program requires artists who work in digital, electronic and light-based media to secure and train a local/regional service provider. The latter would learn about the technical components of the artwork directly from the artist while the artwork was installed. This local service provider would assist in emergency repair and related maintenance need. With that provision, his service was engaged to de-install the malfunctioned laser unit which was shipped to Mr. Silverman.

After a lengthy process of testing in his lab, Mr. Silverman reported that the cause of the problem was indeed a non-functioning and burnt laser diode which would need to be replaced with a new unit. Dan Corson agreed with the assessment and the laser unit was restored by Mr. Silverman and returned one month later to be re-installed at its proper location. Then, the restored unit was tested by the local service provider Eduardo E. Carpriles of United Laser Artists, Miami FL, coached by long distance call from Mr. Silverman; and re-calibrated to integrate with the other two laser units to form a seamless whole.

From the time of de-installation to its resumed operation, it took three months to complete the restoration. The laser artwork has been performing smoothly and perfectly.

Fig. 17. Laser unit uncovered (Courtesy of Broward County Public Art & Design Collection)
5. CONCLUSION

Broward County Public Art & Design Program has been encouraging artists to experiment with new media for their commissioned project. However, a proactive approach for long term preservation has forged a Conservation Review process before a new project is approved by the Public Art Selection Committee. This preventive Conservation Review would continue through design development into fabrication and installation phases, to ensure that technical details of the project would not be overlooked in the process. Furthermore, a detailed cataloging form was provided by the artist and design team to complete the full documentation of the project. The Broward County Public Art Conservation Program is funded by a 15% of the 2% public art allocation, accounted for an average of 25 conservation projects each year.

According to a survey conducted in 2006 by the Public Art Network of the American for the Arts, there are 341 public art programs in operation in 46 states. The majority (90%) of these programs do not have funding set aside for maintenance and long term preservation of their collection. Yet, these programs represent a sizable portion of public artworks that would require the service of conservators of all disciplines in the future.

The advancement of digital and electronic art in the public art arena further complicates the situation. Are there conservators trained in this field? What kind of role should the software designer and electronic technician play in the conservation of these new media? It is with high hopes that future conservators would be able to meet the challenges to maintain and preserve the legacy of so many artists and public art programs created around us.

ACKNOWLEDGMENTS

Mary A. Becht, Director, Broward County Cultural Division; Dan Corson, public artist; Claire Garrett, Project Manager, Broward County Cultural Division, Public Art & Design Program
APPENDIX 1. CONSERVATION REVIEW REPORT OF THE CONCEPTUAL DESIGN FOR EMERALD LASER LAWN PROJECT

PUBLIC ART AND DESIGN PROGRAM
CONSERVATION REVIEW OF PROPOSED DESIGN

Date: May 15, 2006
Artist: Dan Corson
Project Name: Broward Light Project: Green Laser Lawn
Project Location: Huizenga Park, Fort Lauderdale
Project Manager: Claire Garrett
Reviewed by: Tin Ly, Conservation Manager

Project Lifespan
- Temporary (1 to 5 years)  X Midspan (5 to 15 years)  _ Permanent (more than 15 years)

Remarks

Dynamic LED Effects
Public Art & Design Program will pay for the 5 sensors at the “medallions zone” with programmed sequence of LED light patterns and colors. Maintenance of LED is provided by DDA (Downtown Development Authority of Fort Lauderdale).

Green Laser Lawn: maintained by County PAD program
A painted stainless steel box, housing the green diode laser light system, is secured under a bench. Laser system: 300 mw, rated IIIB green DPSS diode projection system, with a digital 3 channels Pangolin controller to control each scan set. The laser projection starts at 18” from ground level, aiming down gradually to the center of open field of lawn. This system is unique and fabricated by Nth Degree Creative of Everett, Washington.

Precautionary measures: a custom “scan fail safe circuit” for all 3 scan sets of laser (avoiding hurting eyes), and a “proximity detector” for laser shut down as needed when the device detects an object 5’ away from the system.
This laser system will have a CDRH variance application for safety compliance study and testing. Lifespan: 10,000 hours of operation, with average of daily usage from 8pm to 12am, resulting in a lifespan between 3 to 10 years. Artist gives a one year parts and labor warranty.
Installation method: to be determined as location may differ from the proposed one.

Project will be further reviewed for conservation during design development phase
- Laser design and fabrication may differ from the proposed one pending on the CDRH variance application process for laser safety compliance
- Installation method

G:\PUBLIC ART & DESIGN\CONSERVATION\Administration\Conservation Review\Dan Corson-Green Laser Lawn.doc
APPENDIX 2. SAMPLE OF CATALOGING FORM

EXHIBIT C

BROWARD COUNTY PUBLIC ART AND DESIGN
CATALOGING FORM

NOTE: Please add attachments to provide comprehensive information for the following:

I. Artist Information
   A. 1. Name:

      2. Name you want to use on label and PR materials, if differs from above:

   B. Date of Birth:

   C. Place of Birth:

   D. Address, e-mail, web site:

   E. Phone: Business: Home:
      FAX:

   F. One paragraph biography of artist:

II. Work of Art
   A. Title:

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B. Medium:

C.1. Dimensions in inches or centimeters:
   H: W: D:

2. Image with frame (if any):
   H: W: D:

D. Frame Description:

E. Inscription, marks:

F. In case of portable and multiple artwork, note on artist preference for display (ex: sequential series, installation height, spacing, etc.):

G. Artwork with electronic components used:
   - Name of item:

   - Manufacturer info (address, telephone, fax, e-mail):

   - Supplier info (address, telephone, fax, e-mail):
H. Artist's statement:

III. Fabrication Information

A. Material(s) used in Artwork:

B. Material Finish:

C. Materials used in the presentation of the project (maquette):

D. Fabricators (name, address, phone, fax, e-mail, web site):

E. Fabrication method (attach diagrams or drawings):

F. Architect/Engineer (name, address, telephone, fax, e-mail):

IV. Installation

A. Installation executed by (name, address, phone, fax, e-mail, website):

B. Installation method (attach diagram of substructure, footings):

C. Date of Installation:

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V. External Factors

A. Describe physical positioning of the artwork:

B. Describe existing environmental factors which may affect the condition of the artwork:

C. If the Artwork is site-specific, describe the relationship of the Artwork to its site:

VI. Maintenance (attach schedule of maintenance for specific items: light bulb, electronics etc.)

A. Short-term:

B. Long-term:

C. Note desired appearance of the artwork:

VII: Digital copies for use in repair of sound art and graphic reproduction:

<<Insert Artist's complete name>>

Authorized Signature for Artist ____________________________ Date ___________

Print name and, if applicable, title above of Authorized Signature for Artist

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REFERENCES


Broward County Cultural Division, Public Art & Design Program. 2007. Cataloging Form, 2007. 1. Di; H. Artist’s Statement

TIN LY has worked as a visual artist and art conservator in Broward County, Florida, for the past thirty years. A recipient of many awards and fellowships (including twice from the Florida Arts Council and twice from the South Florida Cultural Consortium), he joined the Broward County Cultural Division in September of 1999 as Conservation Manager of the County’s Public Art Collection. Ly has conserved artworks for the Charles Saatchi Collection in London UK, Martin Margulies Collection in Miami FL and Ludwig Museum in Koln, Germany, among others. Ly is a Duane Hanson specialist.

With the Broward County Public Art Collection, he has managed over 90 some major conservation projects of artwork in diverse medium, from traditional to contemporary, interactive electronic to digital, such as artwork by James Carpenter, Alice Aycock, Alice Adams, Jody Pinto, Dan Corson, Mags Harries/Lajos Heder, Michele Oka Doner, Yaacov Agam, Keith Sonnier, Ralph Helmick, Jim Sanborn etc…

He has presented at:
- 2001: “Conservation and Maintenance of Contemporary Public Art”, organized by the Cambridge Arts Council, Boston MA
- 2010: “Case Studies in Contemporary Art”, co-organized meeting between INCCA-NA and the OSG and EMG specialty groups at the American Institute for Conservation (AIC) Annual Meeting, Milwaukee WI

Address: Broward County Cultural Division, Public Art & Design Program, 100 S. Andrews Avenue, 6th floor, Fort Lauderdale, FL 33301. Phone: (954) 357-7331
PREVENTIVE CONSERVATION AND IDENTIFICATION OF PLASTICS OF A RECENT ACQUISITION AT THE NATIONAL MUSEUM OF THE AMERICAN INDIAN

ANNE TURNER GUNNISON, SUSAN HEALD, JIA-SUN TSANG, YOONJO LEE, AND JENNIFER GIACCAI

ABSTRACT

In 2009, the National Museum of the American Indian (NMAI) acquired contemporary artist Brian Jungen’s Crux (as seen from those who sleep on the surface of the earth under the night sky) [26/7253], a large mobile comprised of five animals made of plastic luggage, and a wooden rowboat. Mr. Jungen’s work is often characterized by his use of mainstream consumer goods.

The installation of Crux in the main rotunda of the museum made it necessary to determine appropriate preventive conservation parameters for materials not often found in NMAI’s collections. FTIR, Py-GC-MS, micro-fader testing, and spectrophotometer technologies, were used at the Smithsonian’s Museum Conservation Institute, the National Gallery of Art, and at NMAI to identify and characterize the plastics present and determine an appropriate exhibit environment for Crux.

Of equal importance to the analysis was the opportunity to consult with Mr. Jungen about his perspectives on the long-term preservation and aesthetic expectations for Crux. Mr. Jungen is well aware of the potential for degradation of the materials with which he chooses to work. While consultations with Native constituent community groups are already standard practice in the NMAI conservation department, working with contemporary artists and their materials, which requires a slightly different approach, is a newer development.

1. INTRODUCTION

In the spring of 2009 NMAI, acquired Brian Jungen’s Crux (as seen from those who sleep on the surface of the earth under the night sky), seen in figure 1, a mobile comprised of a wooden rowboat and five large animals, made of plastic luggage. That fall, the museum installed Crux and Strange Comfort, an exhibit of twenty-four of Brian Jungen’s pieces. This was the first solo exhibition of a contemporary artist at the NMAI Mall Museum since it opened in 2004 and it was the first time Mr. Jungen, who is of Swiss-Canadian and Dunne-za First Nations heritage, had exhibited his work at a Native American museum. Mr. Jungen is known for his use of mainstream consumer goods, such as golf bags, trash bins, and perhaps most famously Nike Air Jordan shoes, which he transforms into Native Pacific Northwest Coast inspired masks. As NMAI curator Paul Chaat Smith writes in his essay “Money Changes Everything”: “Brian Jungen turns objects inside out. By deconstructing them, he changes not only the things themselves, but the ways we think about what they used to be, and what they’ve become. He begins with objects that are ordinary, useful, and comforting. When he’s through, they are unique, expensive, and useless” (Smith 2010).

They also offer some conservation challenges. This paper will discuss aspects of the acquisition of the mobile Crux, its refurbishment by the artist, as well as consultations with Mr. Jungen, preventive conservation, and materials analysis. Part of this research was undertaken for Anne Gunnison’s research project as an Andrew W. Mellon fellow in conservation. Ms. Gunnison served as the assistant to Susan Heald, textile conservator at NMAI and the conservation liaison for the Strange Comfort exhibit and installation. Jia-sun Tsang, senior paintings conservator at the Smithsonian Institution’s Museum Conservation Institute (MCI) assisted on aspects of this project as she has done considerable research into plastics. The
conservation, refurbishment, and installations were truly collaborative projects and included not only NMAI and MCI conservators and fellows, but conservation scientists from MCI and the National Gallery of Art, as well as NMAI exhibit design, collections, registrar, and curatorial staff and contracted engineers, and perhaps most importantly, the artist himself.

Fig. 1. Crux (as seen from those who sleep on the surface of the earth under the night sky). Collection of the National Museum of the American Indian. 26/7253. (Photograph by Anne Gunnison)

2. BACKGROUND

Crux was originally constructed and installed in an abandoned factory building on Cockatoo Island in Sydney Harbor, for the 2008 Biennale of Sydney. The animals, a life-sized crocodile, emu, shark, sea eagle, and possum, represent figures in constellations developed by Indigenous Australians. They were fabricated from purchased Samsonite and Antler brand luggage. Natural polymers, such as horn and beeswax, are prevalent in the collections of NMAI. While modern synthetics, like polyesters, are represented in textiles, such as modern pow-wow regalia, this is the first large piece of contemporary art composed of plastic materials in the NMAI collections.

3. REFURBISHMENT

After the piece was acquired, the artist wanted to change certain aspects of the animals, namely the crocodile and emu. He also wanted to incorporate a large wooden rowboat, which was originally on the floor in the Biennale, into the mobile. The rowboat was originally used by the artist to transport materials to Cockatoo Island from the mainland.
Crux arrived at NMAI in May 2009, followed closely by the artist at the end of the month. After the animals and rowboat were unpacked, the next order of business was to find green, blue, and black Samsonite F’Lite upright hardside plastic suitcases in the greater Washington, DC area so that Mr. Jungen would have the raw materials needed to make the changes. Working with Robert Patterson, an exhibits specialist and mountmaker, Mr. Jungen deconstructed the suitcases to make components for the crocodile and emu. To make the crocodile less flexible, Mr. Jungen and Mr. Patterson created an internal support system with aluminum tubing, as seen in fig. 2. The crocodile was partially deconstructed to create access points through which the internal support was fed. The head was taken apart; the upper and lower jaw had been attached, but Mr. Patterson welded a steel support structure, comprised of a steel plate and four steel rods welded to the plate, which would hold the crocodile’s mouth open, to provide a clear view through the mouth. The support was secured with bolts to the plastic wall of the back of the head, the plastic wall of the body, and an arc welded steel “H” form in the interior of the body, which was attached with steel angle and bolts to the aluminum tubing internal armature. The bottom jaw was secured to the bottom two rods of the support with bolts. The top jaw rests on the two top rods. Mr. Jungen made the crocodile’s tail more substantial with pieces of plastic luggage cut from the newly acquired black and green F’Lite suitcases. The pieces were secured to the internal armature with aluminum tubing and bolts.

Fig. 2. An internal support structure was added to the crocodile (Photograph by Anne Gunnison)
Modifications were also made to the legs of the emu. The legs were attached at the top to the suitcase wheels with only one point of connection, which was causing disfigurement and whitening of the plastic material. On each attachment, a small piece of rectangular aluminum flat sock was attached at two points to the leg, and one point to the wheel. The metal was covered with pieces of luggage of the same color to hide the aluminum plate. Additional pieces of new blue F’lite luggage were added to the legs and attached to the lower leg with bolts. Mr. Jungen expressed dissatisfaction with the emu’s head. The head was removed, and a new head, which had been previously made at the Sydney Biennale, was attached and a piece of luggage was added to the neck to make it more substantial. A large piece of blue F’lite luggage was also attached to the front breast of the emu.

4. CONSULTATION

During the artist’s tenure at the museum, his time was in high demand. However, conservation and collections staff sat down with him to discuss his ideas about the future preservation and maintenance of *Crux*. Mr. Jungen is aware that the materials he uses in many of his pieces may degrade and fade or darken, and expressed a desire to mitigate the fading on *Crux* by displaying the piece for only a year.

At NMAI, interviews with Native artists and constituent groups, and the refurbishment of ethnographic objects in the collections by community representatives, are not new practices. While the museum is new to exhibiting fine art by contemporary artists, instituting protocol for interviews with these artists and working with them to modify their art is rooted in established practice. Many articles have been written by NMAI conservation staff regarding these practices, a list of which can be found at: http://www.nmai.si.edu under Collections and Research.

Distinguishing characteristics between Native community and contemporary artist consultations are found in the interviewees themselves: Brian Jungen makes decisions about Brian Jungen’s contemporary art, purchased and owned by the museum; community representatives make recommendations for ethnographic objects, held in trust at the museum for
their community as a whole. While the dynamic of ownership may be different for each circumstance, the practice of stewardship of all objects by the museum, whether defined by the wishes of a contemporary artist for his own work, or an invested community for their cultural heritage, is of high importance. NMAI’s Collections Management Policy states: “Beyond the basic professional tenets of preservation, NMAI also operates under the principle that it acts as the steward rather than owner of collection items in its care, and that preservation should be undertaken in consultation and collaboration with representatives of Native communities…” (National Museum of the American Indian 2008). This policy could be seen to extend to the preservation of contemporary work in consultation and collaboration with contemporary artists.

5. LIGHT MONITORING & INSTALLATION

While the light levels of the proposed exhibit space for Crux—in the main rotunda of the museum, where there is a sky-light, called the Oculus, and in front of a wall of north-facing windows—had already begun to be monitored, the artist’s concerns about fading acted as the guide in determining and suggesting effective methods of mitigation.

As noted in the book Plastics: Collecting and Conserving, light is “one of the most detrimental factors in a plastic’s long term stability. Visible light, and especially ultraviolet, can induce damaging photochemical changes. Light effects are cumulative, with each excessive exposure contributing to deterioration.” (Pagliarino and Shashoua 1999, 92-93) These changes include increasing brittleness and color change. Increasing brittleness may lead to structural failure, which for a piece like Crux, could possibly end in disaster. To mitigate light-inflicted damage to plastic objects, light levels should be approximately 50 lux. The recommended UV light level should not exceed 75 microwatts/lumen (Pagliarino and Shashoua 1999).

HOBO data loggers were hung from the ceiling of the north side of the main rotunda of the museum, in front of the windows where Crux was to be hung to monitor visible light levels from both the windows, as well as from the Oculus. The north-facing windows had consistent and sustained high visible light levels, which were more than twenty-four times higher than recommended levels, indicating that Crux would be prone to cumulative damaging exposure. While light from the Oculus could reach up to 14,800 lux, these spikes occurred only very briefly during the day, and thus would not be likely to have a profound effect on the piece. The Oculus also had a UV film in place, whereas the north-facing windows did not. A spot reading indicated UV levels at 190 microwatts/lumen from the north-facing windows, which far exceeded the recommended levels.

As a result of this light study, it was recommended that UV and visible light blocking film be placed on the north facing windows. 3M Scotchtint Night Vision Window film, which comes in various shades, which block different amounts of visible light, and all block 99% of UV light, was recommended. Because of aesthetic concerns about the film, the type which transmits 45% of visible light was installed. It was only installed on the top bank of windows, the ones in front of which the mobile would hang, because of end-of-the-fiscal-year restrictions.

With this preventive measure in place, the piece was ready to be hung. Mr. Jungen wanted the rowboat to become part of the mobile itself, hung upside down, the keel facing the ceiling, and animals hanging from the boat. Mr. Patterson, other members of the exhibits team, and a contracted engineer engineered the installation, doing trial runs to correctly balance the animals using fork lifts, weights, and human strength in the NMAI exhibits shop. In September 2009, the piece was installed. It hung nearly perfectly balanced; an approximately four pound
bag of #2 lead pellets had to be placed on the back of the crocodile to achieve the final equilibrium.

6. ANALYSIS

While perhaps taking preventive conservation measures was sufficient, it was also worthwhile to undertake further investigation of the plastics that comprise Crux, to identify their types, which were initially believed to be ABS plastic, and perform color change and fade tests on the samples. When Crux arrived at NMAI, a box of cast-off materials, included identification tags from the luggage. This helped determine what types of luggage Mr. Jungen had used. The Design Center Coordinator at Samsonite luggage was contacted to request any materials information they could provide on the luggage, but there was no response.

6.1 FTIR & PY-GC-MS

Ms. Tsang and Ms. Gunnison worked with Jennifer Giaccai, a conservation scientist at MCI to identify the plastics. Samples of the luggage were taken from off-cuts produced by the refurbishment of Crux, pieces from the sea eagle were procured in the packing material, and small samples were cut from the possum and the shark. Ms. Tsang, Ms. Giaccai and Ms. Gunnison first examined the plastic samples with FT-IR. The samples were then further analyzed by Pyrolysis-GC-MS (Py-GC-MS) by Ms. Giaccai.

The crocodile, emu and sea eagle luggage samples showed the same infrared spectrum, indicating that all were made from polypropylene or a mixture of polypropylene and polyethylene. High temperature Py-GC-MS of the samples was similar for these same samples. The peaks were mono- or polyunsaturated hydrocarbons, characteristic of polypropylene. The most prominent peaks were from cyclopropane, isobutene and dimethylheptene, all degradation products of polypropylene. There were no unsaturated hydrocarbon peaks suggesting the presence of polyethylene, therefore it appears that these luggage samples from the crocodile, emu, and sea eagle are composed only of polypropylene.

Low temperature Py-GC-MS of the samples showed small amounts of phthalate plasticizers. The samples had been stored in plastic sample bags, so plasticizer could have been transferred from the plastic bag to the samples. In addition most samples also contained squalene, which is found in lubricants and some hand creams. Its presence could be a part of the luggage manufacture, creation of the work, or as contamination from the sample storage bags or handling.

The infrared spectra of the samples from the shark and possum all showed the presence of the same polymers—acrylonitrile (likely ABS) and polycarbonate—but with different ratios of each polymer.

Squalene was present in both the red possum and the sample from the black luggage used in the shark. It was not observed in the sample from the gray luggage from the shark. As with the polypropylene samples, it is possible that the plasticizers were contamination from the plastic bags used to store the samples.

The major peaks from the high temperature pyrogram of the possum indicated that the plastic is composed of both ABS and polycarbonate, while the major peaks from the high temperature pyrogram of the black shark sample are from polycarbonate with the exception of one polystyrene peak. Minor peaks show the presence of acrylonitrile and ABS monomers,
indicating that ABS is a component of the black shark plastic, but there is less present than the possum; polycarbonate appears to be the main polymer component.

The pyrogram from the gray shark sample also showed both ABS and polycarbonate peaks, but between the higher-ABS ratio of the possum sample and the higher-polycarbonate ratio of the black shark sample. This is consistent with the IR results where the acrylonitrile peak was largest for the possum sample and smallest for the black shark sample.

As noted in the book *Conservation of Plastics*: “Due to lack of resources, these ‘high-risk’ materials [which is defined by the author, Yvonne Shashoua as cellulose nitrate and acetate, poly (vinyl chloride), polyurethanes, and rubbers] have been the focus of research projects looking at how to prolong the useful lifetime of plastics, at the exclusion of others. Polyester, polyethylene, and polypropylene plastics are increasingly showing signs of degradation in museum collections and are expected to be the focus of conservation research projects in the near future.” (Shashoua 2008, 229). Shashoua references the study “Lights Out! The Conservation of Polypropylene Wall Tapestries” by Thea B. van Oosten et al. In this study, the issue is raised that polypropylenes can be sensitive to the effects of UV and the photo-oxidation process of polypropylene is described: “Polypropylene is highly sensitive to UV, which is responsible for the radiation induced polymer photo-oxidation… which causes development of surface cracks, discoloration, darkening and a… gradual loss of mechanical properties and, ultimately, embrittlement” (van Oosten et al. 2008, 97-105). Of course, not all polypropylenes are the same, and vary batch-by-batch, manufacture by manufacture. Further testing of these effects on *Crux* need to be pursued, but efforts were made to filter out any UV light in its display area.

### 6.2 MICROFADE TESTING

In an effort to gauge what type of fading one might expect from some of these plastics in *Crux*, Dr. Christopher Maines, a conservation scientist at the National Gallery of Art, was asked to test samples of the plastics from the crocodile, emu, and sea eagle from *Crux* with a microfade tester, or MFT. The MFT detects light-sensitivity and light-fastness of the materials. A light source, tenths of a millimeter in diameter, filtered of UV and infrared light, is directed at an area on the surface of the samples, without leaving visible evidence of the test on the object. The reflected light from the surface of the object transfers through a spectrophotometer, which measures the color change and fading over a period of a several minutes. The results are compared with the fading and light-fastness of ISO Blue Wool Standards.

While the data from the MFT was apparently quite noisy, Dr. Maines believed that there were trends that were quite clear: the light-fastness of the samples could be considered no worse than Blue Wool 3 and were most likely less sensitive than that. Because of the general noise level of the data, Dr. Maines could not give any further evaluation beyond general evidence of light sensitivity.

### 6.3 SPECTROPHOTOMETER

Samples of plastics for color change testing were created to be placed at various locations around the museum. Though all the plastics could not be represented, larger pieces leftover from the refurbishment of *Crux* were cut to approximately 2 inch by 1 inch. As can be seen in figure 4, half of each of the plastic sample was covered in aluminum foil. One was placed in the area where *Crux* is hung, one on the floor directly above in the museum’s Resource Center, also facing the north-facing windows, and one, outside, on the director’s terrace, facing east. All were
left for a 4 to 6 month period. The samples on the director’s terrace survived the two foot snow drifts of the DC blizzards of 2010, but the one in the display area fell over at some point face forward; it grew a surprising amount of mold, as a result of condensation.

Yoonjo Lee, an Andrew W. Mellon Fellow in conservation at NMAI, was pursuing research into the use of the spectrophotometer and she tested these samples with a portable Minolta CM-2600d spectrophotometer. The spectrophotometer measures the spectral reflectance from or the transmittance through materials as opposed to a colorimeter, which directly measures CIE colorimetric coordinates under standardized conditions. Before testing, the samples were gently cleaned with water to remove dirt, which would affect the readings. The unexposed side, under the aluminum, was measured three times and averaged to produce colorimetric coordinates. Areas on the exposed side, which did not have the aluminum foil cover, were tested in the same way. The two average measurements were then compared for color differences.

Figure 5 is an example of the results, this one from the green luggage sample on the director’s terrace. The negative L* represents a darkening of the material, a* represents a shift towards red, and b* represents a shift towards blue, and the delta E*ab, the overall change. Because they fell over and possibly because of the UV filtering on the windows, the samples in the display area showed negligible amount of change. The samples from the director’s terrace and the Resource Center showed similar trends. Most of the samples from the director’s terrace showed slightly more color difference than the samples in the Resource Center with some exceptions. In general, the results indicated a slight, non-visible shift, which tends towards darkening of the plastics.
6.4 TENSILE STRENGTH

Dr. Marion Mecklenberg, a Senior Research Scientist at MCI, was asked to examine the animals in *Crux* to determine whether he foresaw any problems with the hanging mechanisms imparting too much stress and strain on the plastics. His main concern was the stress imparted on the tail of the possum. There was a small hole drilled in the tail, through which the possum was hung when on display. Dr. Mecklenberg determined the maximum stress, the force applied to the sample divided by the cross-sectional area, on the possum tail is 640 PSI, or pounds per square inch. He believed the possum would be able sustain this stress because the allowable tensile strength for a polycarbonate-ABS blend plastic is 5040 PSI.

7. BLOGGING

During all of this testing and installing, Ms. Gunnison wrote posts for the NMAI blog (blog.nmai.si.edu), at the wishes of the curator. The blog was written from the conservation perspective, in order to engage the public and create greater awareness of *Crux, Strange Comfort*, and the conservation issues they present. The Czech avant-garde counter-culture rock group Plastic People of the Universe, the hi-top fade haircut sported by 1980s hip-hop star Kid of Kid-N-Play, and Dannon Yogurt’s decision to stop using plastic lids were all invoked to discuss a range of issues including plastics preservation, microfader testing, and the importance of consultations with contemporary artists.
8. CONCLUSIONS

The acquisition, exhibit, and the artist’s tenure at the museum during installation provided opportunities for consultation, collaboration, and examination as Mr. Jungen’s work became part of the exhibit and the museum’s collection. While more materials testing can be performed to understand and anticipate changes that may occur to Crux, appropriate preventive conservation measures were taken and the artist’s desire to only display Crux for limited amounts of time will be heeded. Change is expected to occur to these materials, but it cannot be expected of Mr. Jungen, who acknowledges and recognizes the long-term instability of his chosen materials, to change the materials he works with. These commercially made and obtained materials, the shoes, the trash bins, the luggage, are the crux, if you will, of Mr. Jungen’s art. As Paul Chaat Smith writes: “Some artists paw through dumpsters for their art, an interesting and honorable strategy… Jungen simply buys what he needs, in the same way and at the same stores that you and I frequent…True, before long they go under the knife, drill, or table saw, and through this creative destruction they increase in value exponentially, but they all begin as ordinary items on a shopping list” (Smith 2010). So it is the conservators’ job, to understand these materials, to mitigate the changes that could occur, so that these ordinary items on a shopping list retain their value as the art objects they have become.

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Oriel Instruments
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Four Hour Day, Inc
214 N. Greene Street
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Edmund Industrial Optics
101 East Gloucester Pike
Barrington, NJ 08007-1380

Minolta Spectrophotometer
Konica Minolta Sensing Americas, Inc.
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A NEW APPROACH TO MAINTAINING WATER FEATURES AND REDUCING BIOLOGICAL GROWTH

ROBERT KRUEGER

ABSTRACT

This study focused on Fountain, by Isamu Noguchi in the Nelson-Atkins Museum of Art. The difficulty in finding an acceptable way to control algae without endangering the artwork was the impetus for this investigation. The result lead to an alternative to the standard algae control products by focusing on the water chemistry and making simple improvements to the fountain’s mechanical system. This paper follows the changes made to the fountain and some of the rationale behind the approaches taken.

1. INVESTIGATING ISAMU NOGUCHI’S 1987 FOUNTAIN

In 2008 Isamu Noguchi’s 1987 Fountain was investigated in the Nelson-Atkins Museum of Art in Kansas City to resolve a problem with reoccurring algae on the basalt elements of the fountain. A literature study of algaecides found they all have the potential for undesirable side-effects. Standard water chemistry tests conducted over an 11 month period revealed the condition of the water was causing the artwork to slowly dissolve. This study lead to a focused examination of the water and its constituents, as well as the layout of the fountain’s mechanical system, in order to find a maintenance procedure that will insure the longevity of the sculpted elements and reduce the potential for algae growth.
The system was comprised of a holding tank with the capacity to hold the fountain’s entire water supply, a distiller set up to automatically provide water to the system when needed, a circulation pump, supply and return plumbing, a particulate filter, a UV sanitizer and of course, the carved basalt artwork. Most of the system was housed in the basement, with the artwork in the first floor gallery. From the large polymeric holding tank the water went through the pump which pushed the water, via plastic supply pipes, to the sculptural elements of the fountain. After flowing across the sculpture the water traveled through a bead of white granite and then gathered in a stainless steel catch basin. The basin funneled the water to a plastic return line through which it traveled to the mechanical room below. Before returning to the holding tank it passed through a 20 micron particulate filter and then it was exposed to a UVC germicidal lamp. A plumbing bypass diverted the water around the particulate filter and the UVC lamp to allow the filter to be replaced without having to turn the fountain off.

After studying the mechanical system the water was analyzed. The fountain’s water was tested using a standard lab thermometer and a Taylor Water pool and spa water chemistry test kit K-2006, available from most pool supply stores. The test results from the Taylor tests showed that there was more than algae to be concerned about. The Saturation Index portion of the test indicated a problem.

The saturation index is an overall indicator of water condition. It takes into account all measurements taken using the Taylor test kit and determines whether the water is corrosive or if mineral scale will form. This is important because both conditions will damage the artwork. If the Saturation Index indicates a measurement of more than 0.5, then scale will form on the artwork and other surfaces. If the Saturation Index is –0.5 or lower, then the water is corrosive and will attack the artwork and other surfaces.

The tests on the Noguchi fountain showed the water was corrosive with a saturation index of –2.1. Rather than treating the algae and the corrosive water separately, every aspect of the water chemistry and mechanical system was evaluated and considered.

The fountain’s water supply is provided by the distiller. Distilled water is very pure and lacks the minerals normally found in tap water and when the water from the distiller was tested it was found to be acidic.

Water molecules are commonly thought of as containing two hydrogens and one oxygen. In general it is fine to think of water in this way, but a balanced ratio of two hydrogens for every oxygen is pH neutral and not acidic. To understand how pure water can be acidic, the water has to be looked at differently. Water is actually made up of variations of H$_2$O, such as H$_3$O$^+$ and OH$^-$. There are also three isotopes of hydrogen and three isotopes of oxygen, but for the sake of simplicity these can be ignored for now. When water has more H$_3$O$^+$ than OH$^-$ it is acidic (Seager and Slabaugh 2000). This condition increases the water’s ability to dissolve and hold dissolved solids.

It is normal for water to contain dissolved solids in suspension. In many parts of the country these dissolved solids are seen as they accumulate on the water fixtures in homes. The white crusts left behind are from the dissolved minerals suspended in the water. When water contains high concentrations of dissolved minerals it is considered hard water. Water low or lacking in dissolved minerals is considered soft. The treated water from the distiller is soft.

Saturation is another term used to describe the amount of dissolved solids in water. Water that is unsaturated is soft and has the ability to hold more dissolved solids. Supersaturated water is very hard and the dissolved solids will fall out of solution and form scale. Water that is saturated holds the dissolved solids in solution without depositing excess or dissolving solids.
Mineral saturation is the goal in fountains to prevent the leaching of minerals from the basins, plumbing and artwork (Smethurst. 1988).

There are several approaches that can be taken to remove the biological growth. The most common method for removing biological growth is to add chlorine to the water. When chlorine is added to water it forms hypochlorous acid. The formation of hypochlorous acid is considered the most germicidal of the chlorine compounds. The current belief is that the chlorine penetrates the cell wall and then attacks the enzyme group within, resulting in the death of the organism (White 1992). Chlorine can have undesired affects, for example, leaving the gallery smelling like a swimming pool. Chlorine and other halogens such as bromide can deteriorate the mechanical systems and the artwork in contact with the chlorinated water or vapor from these waters (Butler and Ison, 1976).

Copper and silver are commonly used to control biological growth in water. Some studies have shown that for particular growths, a combination of silver and copper work better. Copper acts as an algaestat rather than an algacide, retarding or preventing growth, but not actually killing established algae. Silver is an algacide for pink algae, but otherwise is a better bactericide (Young and Lisk. 1972). Pool supply companies caution that the use of metallic algacides can cause staining on hard surfaces.

Other algae killing additives were considered, but to avoid possible undesirable side-effects, a preventative approach of using a water supply that cannot support life was explored. The nutrients required in large quantities for algae to grow are carbon, nitrogen, phosphorus, sulphur and iron (Waite 1984). These nutrients are absorbed by plants in a fixed stoichiometric ratio. Limiting any one of them will limit algae’s ability to grow. Phosphate is used in the formation of cell walls and is a crucial part of the DNA backbone structure (Seager and Slabaugh 2000). Limiting phosphate from the water will therefore limit organic growth (Waite. 1984). This should be easily accomplished because the water from the distiller does not contain phosphate.

Ensuring the water is phosphate free will prevent future growth, however limiting phosphate will not kill living organisms; it will just limit the organism’s ability to reproduce. The system is fitted with a germicidal UVC lamp which will kill the algae. The lamp emits energy at a wavelength of 253.7nm. The germicidal effect happens between the wavelengths of 205 and 265nm. When the UVC radiation penetrates the organism it disrupts unsaturated bonds, causing a lethal biochemical change (Huff et al. 1965).

2. RECOMMENDED CHANGES

When this study began, the fountain’s mechanical system allowed water to be sent through the bypass so the particulate filter could be changed. When the water went through the bypass, algae from the fountain entered the tank, contaminating the water. Even when the sculpture was completely cleaned of all algae, the contaminated tank water re-introduces algae to the sculpture.

Recommendations were made to the engineering department to re-plumb the mechanical system. The recommendations included moving the particulate filter and UVC Water Purifier to the supply side of the system. Because UVC is very easy to block, even by small particulate matter in the water, the recommendation included a request to change from a 20 micron to a 5 micron filter as guided by the Sanitron® Ultraviolet Water Purifier Owner’s Manual. Two filters can be installed in parallel, so that the water can be sent through a second stand-by filter while the first filter is changed. The installation of gauges was suggested on either side of the
particulate filter so changes in pressure caused by a clogged filter could be monitored to determine when the filter needed to be changed.

Fig. 2. As installed (Drawing by R. Krueger)

The UVC emitting lamp within the purifier has a limited life. As the lamp ages, the amount of UVC being produced in the germicidal range diminishes. The lamp emits some visible light, however this cannot be used as an indicator of effectiveness. Even when the lamp is no longer producing germicidal radiation, visible light is still emitted. A monitor was suggested for the water purifier that will indicate when the lamp needs to be replaced.

Recommendations were made to the conservation department to monitor and test the water weekly and to adjust the water chemistry when needed. If the water is soft, calcium can be added until the water is properly saturated. If the pH is low, sodium bicarbonate can be added. Sodium bicarbonate will increase the pH, and also buffer against changes in the pH. Phosphate levels also need to be monitored using a phosphate test kit. If for any reason the water becomes supersaturated, the pH is too high, or if phosphate levels rise, water can be drained from the holding tank and replaced with distilled water. Since distilled water has a very low pH, no phosphate, and is lacking in minerals, this will effectively lower the pH, phosphate, and calcium levels within the water.

Studies have shown that bleach or chlorine will kill most biological growth, but in some cases, as a stress survival response, organisms will go into reproductive mode as they are dying, producing spores that are immune to chlorine (Bacišková 2006). Alcohol vapor is also an effective method for killing algae, but if the concentration of alcohol is too low, the stress response will produce spores that will later re-introduce the growth. Oddly, 100% alcohol will produce the same response. If a slightly dilute solution of alcohol is used everything is killed, even the spores. To kill the algae on the surface an alcohol solution was recommended, followed by a thorough cleaning using a brush, triton X-100 and distilled water for the final rinse.

As a part of this study the alcohol treatment was performed. The sculpture was wrapped in plastic sheeting to form a vapor chamber. A solution of 90% ethanol in distilled water was
made. Cloths were saturated with the solution and placed within the plastic vapor chamber. The white granite directly under the sculpture was also treated within a vapor chamber. After 24 hours of treatment the chamber and cloths were removed. Although the algae are dead, they still contain all the nutrients needed for new algae to grow. The entire sculpture was vacuumed after the alcohol treatment to remove the remaining dead algae. This treatment successfully killed the algae, however a white fungus began to grow on the sculpture after the treatment. It was believed that the fungus was living off traces of the dead algae. Dr. Johanna Bernstein at Rutgers analyzed a sample and confirmed that the white growth was a fungus.

After the system is re-plumbed it was recommended that the sculpture be thoroughly cleaned to remove any trace of algae. The white granite bed below the sculpture and the catch basins under the granite will also need cleaning. It is impossible to remove all traces of the algae, but the dead algae will be slowly removed by the particulate filters and by the occasional replacement of water in the system when adjustments are made to lower the pH, phosphate levels or calcium.

As an interesting side note, Brad Masuen, the museum’s engineer, initially estimated the recommended changes would cost between $10,000 and $20,000 and because of the fine filtration requirements needed for the particulate filters he saw that the ongoing costs of filter replacements would also be prohibitive.

After the system was re-plumbed Mr. Masuen reported the changes cost only about $3,000 including the engineer’s labor costs. After the first couple of weeks of frequent filter changes, the new filters require less frequent changes than before the system was re-plumbed. Since the filters now require less frequent changes, the overall cost of maintenance was lowered, making the recommended changes cost effective. One factor that increased the usable life of the new filters is the water is now pumped through, rather than relying on gravity as before. Because of the higher water pressure the filters can now hold more particulate before clogging. Another reason why the filters are lasting longer is because of the careful monitoring of the water.
chemistry. Without the re-occurring outbreaks of algae, the filters are not being clogged with dead algae as before.

3. CONCLUSION

This case study is an example of new approaches to maintaining fountains. Most fountain mechanical systems are not set up this way. Every water feature needs to be evaluated to find the best maintenance plan for its associated artwork. This approach was proactive; addressing the fountain with a reasoned approach was more beneficial than reacting to problems. The approach presented for this fountain will likely extend the life of the artwork, and save the museum money and time.

The distiller is an advantage for Noguchi’s Fountain. If the system was not supplied by a distiller, another solution would have to be found. Chelating agents are available which will remove phosphate from the water. The chelating agent combines with the phosphate and falls out of solution. If this were done in this fountain the precipitate would then have to be removed from the holding tank shortly after treatment because changes in pH or temperature can cause the phosphate to be re-released into the water.

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ABSTRACT

In 1962 Claes Oldenburg created a body of work for his first one-man show at the Green Gallery, New York. Oldenburg and wife Patti Mucha used a portable sewing machine, heavy weight canvas, cardboard boxes, foam, and acrylic paint to create his first giant soft sculptures in the shape of a hamburger, an ice-cream cone and a giant piece of cake. Floor Cake (Giant Piece of Cake) entered the collection of The Museum of Modern Art (MoMA) in 1975 and has been very heavily exhibited. The object has 15 square feet of painted cotton canvas, three square feet of which are intended to rest directly on the floor. The historical maintenance of this work, while on view, was to mechanically readjust the interior stuffing by fluffing the layers. The results of life in a busy museum environment have left Floor Cake with cracking and paint loss, abrasions, tears and punctures, and extensive surface soiling. With two previous treatments already on record, conservators at the Museum of Modern Art were confronted with the re-treatment of forty-seven year old, 5 x 9 ft. Floor Cake (Giant Piece of Cake). This paper investigates the effects of past treatment and explores the practical application of surface cleaning acrylic paint with Oldenburg’s Floor Cake as a case study.

1. INTRODUCTION

Surface cleaning of acrylic paintings has been discussed in the art and conservation literature since the 1960s but has gained widespread interest and momentum across the scientific and conservation community in the last decade. The Modern Paints project initiated in 2002 was a collaboration between the Tate Modern, London; the National Gallery, Washington D.C.; and the Getty Conservation Institute (GCI), Los Angeles, CA. Building on this research, in 2006 The Modern Paints Uncovered Symposium brought together over 250 conservators, scientists, and artists from around the world to share among other things their understanding of acrylic paint and its treatment. As part of GCI’s initiative to integrate current research into the field, a colloquium titled Cleaning of Acrylic Painted Surfaces: Research into Practice (CAPS) was held in the summer of 2009. This gathering facilitated a dialog on the application and evaluation of new treatments, and aimed to guide future research on acrylic painted surfaces. The Modern Paints project’s most recent results have been presented at the American Institute for Conservation’s annual conference in 2009 (Keefe et al.) and 2010 (Phenix et al.). GCI in collaboration with Dow Chemical Corporation has used their High Throughput System (HTP) to test the cleaning ability of numerous aqueous systems with parameters like pH, conductivity, surfactant type and concentration, chelator type and concentration, and variations of these solutions. HTP utilizes swab-bearing mechanized arms to systematically clean manufactured dirt on painted mock-ups, giving scientists and conservators extensive results on potential protocols for cleaning acrylics.

Sculpture and painting conservators at Museum of Modern Art (MoMA) collaborated from the onset of this project to study all of the current available research and treatment methods. They observed that there is a lack of recent publications from conservators on cleaning treatments for acrylic paintings or painted objects. Acrylic paints are, in a word—complex. They have various compositions of acrylic binder, pigment, wetting agent, dispersing agent, thickener, freeze-thaw stabilizer, coalescent, biocide, pH buffer, and defoamers. Within the acrylic binder, among other components there is an emulsifier or a surfactant that remains in the film upon

AIC Objects Specialty Group Postprints, Vol. 17, 2010
drying, which can then migrate to the surface affecting the optical clarity of the paint film. Due to their low $T_g$ and the plasticizing effect of surfactants, acrylics become soft and flexible when above room temperature. Dust and grime can then become embedded in the surface. If the readily water soluble surfactant is removed the optical clarity is returned and the acrylic film becomes more firm, reducing the attraction of dirt to the surface (Hayes et al. 2007). There is a wealth of published information regarding the formulation and properties of acrylics, and this paper brings several together in the bibliography for the object conservators’ reference.

Conservators at the MoMA sought to study Floor Cake’s previous treatments and to find a practical re-treatment including cleaning and consolidation for the acrylic painted object with the intention to share the results with both the conservation community and the general public.

Fig. 1. Claes Oldenburg Floor Cake 1962 before treatment in the gallery in 2009 (Photograph by Delidow)

2. OBJECT HISTORY

The Swedish born Claes Oldenburg moved to New York City in 1956 to become an active member in the artistic community. His first New York exhibition took place in late 1958 when a selection of his drawings was included in a group show at Red Grooms' City Gallery (Umland 1998, 68–69). In the winter of 1961, Oldenburg opened a “Storefront” on the Lower East Side of Manhattan that featured a wide variety of every day materials rendered in plaster covered muslin finished with glossy paints. The sculptures included undergarments and food items such as slices of blueberry pie. In 1962 in a subsequent incarnation of The Store at the Green Gallery, New York, Oldenburg and wife Patti Mucha used a portable sewing machine, heavy weight canvas,
cardboard boxes, foam, and acrylic paint to create artworks for Oldenburg’s one-man show. In operation from 1960 to 1965 the Green Gallery was located at 15 West 57th Street in New York City, presenting the work of artists such as Tom Wesselmann, James Rosenquist, and Donald Judd in addition to Oldenburg (Mucha 2002, 79-87). The Green Gallery featured Floor Cake (Giant Piece of Cake) (fig. 1), Floor Cone also in the collection at MoMA, as well as Floor Burger now in the collection of Art Gallery of Ontario. Similar to The Store but in this instance on a much larger scale, the artist filled the gallery with super sized sculptures of food and household items.

3. CONDITION

Measuring 5 feet wide by 9 feet long and 5 feet high, Floor Cake is constructed out of five separate “cake” layers, and two smaller forms sewn to the top (fig. 2). Each layer is sewn from heavy weight cotton canvas duck. Oldenburg and his wife used upholstery techniques including details such as fabric covered zippers to finish the openings (fig. 3). The layers were painted by alternating dark brown paint with white to represent “chocolate cake” and “icing” and then filled with foam and cardboard boxes. Attached to the top layer are two smaller sewn and stuffed forms; MoMA has referred to the long cylindrical topping as the sprinkle, while the dark ochre dollop is known as the chocolate drop.

![Fig. 2. Floor Cake 1962 deconstructed in the conservation lab at MoMA (Photograph by Albertson)](image-url)
Overall, this popular piece of painted cake is in remarkable shape for a forty-seven-year-old soft sculpture that has been heavily exhibited in the museum, across the United States, and around the world. As any courier knows, an object is moved multiple times during the course of exhibition travel—from packing and trucking, to palletizing and flight. In the 21st century Floor Cake has made its way to Paris, Bonn, Berlin, and as far away as Japan. US tours included venues in Washington DC, Richmond, Dallas, Los Angeles Chicago, Worcester, Toledo, Denver, San Diego, and Omaha. Like Floor Cake, Floor Burger has also been immensely popular and thus heavily exhibited. Colleagues at the Art Gallery of Ontario shared their concerns about the condition of Floor Burger, as there are many paint losses, most often along creases in the fabric support. Aside from vacuuming and dusting, Floor Burger has not been previously treated (Phillips, 2009) (fig. 4). Floor Cone in MoMA’s collection was also never treated and has not been exhibited as heavily and does not show the wear and tear that Burger and Cake show (fig. 5).
The sculpture has a total of 15 square feet of painted cotton canvas, three of which are intended to rest on the floor. *Floor Cake*’s life in a busy museum environment has resulted in extensive surface soiling, cracking and paint loss (figs. 7, 8). The thinner or single applications of paint are in good condition, although there is notable paint loss to the upper-most layer where the most handling and manipulation occurs. The thicker or multiple layered areas of paint are cracked throughout. The maintenance history of this work has indicated that the interior stuffing was adjusted by “fluffing” the layers. Undoubtedly this has contributed to some of the mechanical failure seen in the paint layers. There are also minor abrasions and small tears and punctures. Upon visual inspection the chocolate drop appears to be an oil based paint exhibiting chalky white efflorescence.
The Cake’s stuffing is degrading as evidenced by overall compressed and sagging layers. Comprised of polyurethane foam and cardboard boxes, it was amusing to learn that the cardboard boxes are, rather whimsically, three different sizes of ice cream containers (fig. 9). When asked about his choice of filling materials, Oldenburg commented that an ice cream shop was close to his studio and it was what he had available to him at the (Oldenburg, 1998). While the foam is discolored and brittle in some instances, most of it remains soft and flexible. Without preventative measures, the foam most likely will eventually disintegrate leaving nothing to fill the Cake.
An archival image of *Cake* in 1975 depicts the drop and the sprinkle in a different location from what was seen during the condition examination (fig. 10). As a likely explanation for this alteration, MoMA’s oral history and object files revealed that in *Cake’s* early days of its travel. The crate was not large enough to house the cake completely assembled. Therefore the toppings had to be detached for transit. Through the course of our examination original tether locations for the drop and the sprinkle were located and the toppings moved back to their 1975 location (figs. 11, 12).
4. ANALYSIS

It was suspected that Oldenburg was using acrylic paint for the Cake layers as well as an oil-based paint he may have had left over from The Store. Analysis with FTIR confirmed that Oldenburg used at least two different types of paint for Cake: a paint with a polyvinyl acetate binder for the icing on the upper cake layer, as well as an alkyd paint with an oil component for the chocolate drop. The chocolate drop is painted with a thick layer of high gloss ocher paint, not observed elsewhere on the sculpture. Additionally, a chalky white bloom has developed on the surface of the drop. This same bloom has been observed with similar paints that Oldenburg used
with his painted plaster objects from the Store (Ordonez, Twilley 1998). The spectra, revealing an oil based paint, explained the white bloom or efflorescence seen on the drop as oil paints contain free fatty acid deposits that can migrate to the surface of works (Schilling, Khanjian, Carson 1997, 71–78).

Paint samples were taken from the light and dark Cake layers as well as the chocolate drop and sprinkle (fig. 13). The polished cross sections were quite surprising. Within all of the samples there is evidence of a white ground preparation layer. The object went through many iterations best illustrated by the “chocolate drop” as what appears to possibly be flavors of cherry, lime, and orange before the upper most layer of dark ocher brown. The sections reveal an extremely painterly quality to Oldenburg’s application of layers. Curatorial records from both the Art Gallery of Ontario and MoMA indicate that Oldenburg stated that he painted Floor Burger and Floor Cake with latex and liquitex. Liquitex is a brand name for an artist grade paint made from an aqueous acrylic emulsion (Rhoplex AC-33 in 1962), while latex is a common generic name used for house paints during the 1960s. By 1962 latex would have an acrylic, styrene butadiene, or polyvinyl acetate binder. FTIR results from the samples taken were consistent with the presence of a latex paint on the cake layers, as well as an alkyd paint with an oil component on the chocolate drop. Additional sampling and testing may have revealed another type of binder.

Fig. 13. Composite of cross sections imaged at 125x (Photographs by Elizabeth Nunan)
5. STUDYING PAST TREATMENT

There is no recorded history of cleaning Floor Cake prior to 1998. However, MoMA oral history indicates it may have been cleaned twice before. The 1998 condition reports notes that the Cake was soiled in areas that rested on the floor and along the entire top of the upper layer. The 1998 treatment included overall dusting and vacuuming and then only the top layer was cleaned. The filling was removed and the canvas was cleaned with a 2% solution of tri-ammonium citrate in de-ionized water, applied with a brush and cleared twice with de-ionized water. After drying with blotters, the filling was then replaced. To aid in determining the course of the 2010 treatment, it was necessary to understand the possible effects of the previous treatments.

5.1 ANALYSIS OF PAST TREATMENT

Analysis was performed to determine if the previous cleaning solution had left residue, and to ascertain if the process had weakened the canvas fibers thus contributing to cracking and paint loss. During examination it was noted that several canvas fibers were standing proud of the paint surface. A number of fibers were extracted from the upper layer of cake that had been previously treated, as well as from the untreated lowest layer (fig. 14) Scanning Electron Microscopy/ Electron Dispersive Spectroscopy (SEM/EDS) was used to attempt to locate residue of tri-ammonium citrate from the upper layer of Cake (fig. 15). This technique would reveal nitrogen if ammonia from the cleaning solution had clung to the canvas fibers. SEM did not reveal any nitrogen. The surfaces of the fibers were also analyzed with Attenuated Total
Reflection Fourier Transform Infrared (ATR-FTIR). There were no significant differences in the spectra between the fibers extracted from the treated upper layer of cake versus the ones from the lower untreated layer. These fibers were compared to control fibers soaked in 2% Tri-ammonium Citrate solution. The spectra from the soaked fibers were noticeably different from that of the treated and untreated fibers (fig. 16). Testing has not detected residue from the 1998 cleaning, suggesting that either the TAC was cleared or that the methods used could not detect the trace amounts.

6. TREATMENT

In looking for new treatment approaches for acrylics, conservators must consider the inherent problems associated with cleaning acrylic paint such as water sensitivity and the solubility of additives after surfactant migration (Ormsby et al. 2009, 186–195). The GCI CAPS Colloquium held in 2009 was closely studied when developing a cleaning strategy. Dry cleaning has been considered one of the safer methods for surface cleaning acrylics, therefore testing on Floor Cake began with grated eraser crumbs and dry cleaning soot sponges to observe the dirt reducing capability of these techniques (fig. 17). Most dry methods were effective, but not all were appropriate for the large expanse of Floor Cake’s painted surface (table 1). The grated erasure crumbs became too easily lodged in the interstices of the cracked paint. Rubber soot sponges, very gentle and highly effective, were the most successful of all of the methods tested (fig. 18).
Fig. 16. FTR-ATR Spectra of canvas fibers extracted from upper layer and lower layer versus control fiber. Sample prepared by authors and analysis provided by Chris McGlinchey.

Fig. 17. Dry cleaning materials used for testing grime removal (Photograph by Delidow)
To understand the nature of the grime the methods shared at the GCI CAPS Colloquium were explored and tested. Working with MoMA paintings conservator Michael Duffy, a colloquium attendee, pH and conductivity testing was conducted on the surface of the layers of the cake. Each of the five layers was tested in three separate locations. The pH was tested with a Horiba twin Micro pH meter and Whatman Filter Paper discs, while conductivity was measured with the Horiba B-173 Micro Conductivity Meter (fig. 19). The average pH of all these locations was 6.2, while the conductivity was .33 m/s (table 2). While initial cleaning tests with neutral water and saliva both on hand rolled cotton swabs exhibited effective moisture cleaning, it was felt that working with a tailored pH would prove to be the most gentle and effective. The Modular Cleaning Program was used to assist with developing an aqueous cleaning solution. The MCP was developed by paintings conservator Chris Stavroudis in conjunction with Professor Richard Wolbers, of Winterthur. The testing of different combinations of surfactants, chelators, and buffers with the computer program was ideal for recipe preparation, allowing for quick alterations to the cleaning solution (fig. 20). Different formulas at pH’s ranging from 6 to 7 were tested to determine what was most effective. Additionally, conservators experimented with methods of application by comparing the PVOH sponge to hand rolled cotton swabs (fig. 21). Ultimately the PVOH sponge was selected as the best tool for both application of solution and for clearance due to the smooth minimally abrasive surface and its great absorption.4

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**Table 1. Dry cleaning tests and results**

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staedtler Mars Plastic Eraser</td>
<td>Removes very little dirt—too aggressive</td>
</tr>
<tr>
<td>Staedtler Mars Plastic Eraser crumbs</td>
<td>Removes a fair amount a dirt</td>
</tr>
<tr>
<td>Dry Cleaning Sponge</td>
<td>Removes some dirt—too aggressive on fragile paint</td>
</tr>
<tr>
<td>Groom Stick Molecular Trap</td>
<td>Removes some dirt—too aggressive on fragile paint</td>
</tr>
<tr>
<td>Di water</td>
<td>Slight change</td>
</tr>
<tr>
<td>Absorene</td>
<td>No apparent change</td>
</tr>
</tbody>
</table>

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Fig. 18. Gently wiping wedges of soot sponge over paint surface (Photograph by Albertson)
### Table 2. Conductivity measurements of layers (Drawing by L. Davis)

<table>
<thead>
<tr>
<th>Layer</th>
<th>pH</th>
<th>Conductivity - mS/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>6.57</td>
<td>.49</td>
</tr>
<tr>
<td>A2</td>
<td>6.3</td>
<td>.70</td>
</tr>
<tr>
<td>A3</td>
<td>6.6</td>
<td>.31</td>
</tr>
<tr>
<td>B1</td>
<td>6.5</td>
<td>.26</td>
</tr>
<tr>
<td>B2</td>
<td>6.25</td>
<td>.85</td>
</tr>
<tr>
<td>B3</td>
<td>5.8</td>
<td>.24</td>
</tr>
<tr>
<td>C1</td>
<td>6.3</td>
<td>.38</td>
</tr>
<tr>
<td>C2</td>
<td>6.3</td>
<td>.25</td>
</tr>
<tr>
<td>C3</td>
<td>6.3</td>
<td>.30</td>
</tr>
<tr>
<td>D1</td>
<td>6.26</td>
<td>.146</td>
</tr>
<tr>
<td>D2</td>
<td>6.08</td>
<td>.104</td>
</tr>
<tr>
<td>D3</td>
<td>6.25</td>
<td>.189</td>
</tr>
<tr>
<td>E1</td>
<td>5.8</td>
<td>.27</td>
</tr>
<tr>
<td>E2</td>
<td>5.9</td>
<td>.196</td>
</tr>
<tr>
<td>E3</td>
<td>5.6</td>
<td>.22</td>
</tr>
</tbody>
</table>

Fig. 19. Collecting samples for pH measurements (Photograph by Delidow)
Cleaning emulsions discussed at the GCI CAPS Colloquium were also explored. A 3” x 3” square on the bottom of the lower layer of cake was used to test cleaning with Velvesil FX Gel. Velvesil is a decamethylocyclpentasiloxane that comes in powder form. Velvesil was introduced as a solvent medium to aid in the reduction of paint swelling and leaching of surfactant, by allowing small droplets of emulsified water to be suspended and to act as cleaning cells into which water soluble grime can be held (fig. 22). Velvesil was diluted with a silicone solvent and emulsified with a small amount of water. However, upon gel clearance, grime removal was far less obvious as compared to aqueous solution tests, with either a swab or a sponge. While this may be a very useful tool for cleaning tensioned acrylic paintings, a gel application was not a great fit for this treatment. It seemed impractical to be able to adequately clear a gel from such a highly irregular un-tensioned surface. The possibility of staining areas of bare canvas and in areas where the paint layer was particularly thin was also a concern.
After testing, the chosen aqueous solution was derived from the Modular Cleaning Program (MPC). Stock solutions were prepared in 500 ml bottles in addition to several bottles of pH 6.5 water clearance solution. Initially, the Cake’s filling was removed with the belief that a flat surface would provide control with the cleaning. However after the first layer, the stuffing was kept inside to provide a measure of support for the paint film. The canvas and paint have a crack and crease memory after being together for nearly 50 years. Additionally, keeping the stuffing inside the layers kept the wear and tear overall to a minimum. The final treatment method selected, began with dry cleaning with soot sponges, where the paint was less cracked. The cleaning solution was then applied to wedges of PVOH sponge and the wedges gently patted and wiped over the surface. The solution was cleared two times with pH 6.5 water on clean sponge wedges. This method was able to remove approximately 30% of the dirt and grime from the surface, an acceptable result as further dirt removal would require a more aggressive treatment. The drop and sprinkle were removed from the cake for the treatment and the fatty acid bloom reduced with saliva on rolled cotton swabs (fig. 23).

Over the years the polyurethane foam has lost volume resulting in a deflated Cake. Different fillings were investigated to search for a material that is archival and light weight. Since a large majority of the foam is soft and intact additional stuffing was added to the original foam—instead of totally replacing it. After consultation with colleagues in textile conservation, a 1 lb. density Ethafoam was chosen and contained in muslin bags (Britton, 2010) (fig. 24). With this method, supplemented materials would be kept together and easily distinguished from the original, allowing for easy removal in the future. This supplemental stuffing was archival, efficient, and low cost. Bags were inserted into the deflated layers of Cake, placing the stuffing in key areas to support vulnerable parts (fig. 25).
Fig. 23. During treatment image of cleaning of chocolate drop (Photograph by Albertson)

Fig. 24. Small cut Ethafoam sections in muslin bags (Photograph by Delidow)
Fig. 25. Authors inserting the supplemental stuffing (Photograph by Delidow)

Fig. 26. Consolidation of fragile areas with Lascaux (Photograph by Albertson)
Fig. 27. Before and after treatment details of the chocolate drop (Photographs by Albertson)

Fig. 28. *Floor Cake* after treatment (Photograph by Albertson)
The treatment was completed with additional minor consolidation where there was a high risk of paint loss (fig. 26). 81012 Lascaux Medium for Consolidation was chosen for its low viscosity and matte appearance upon drying. Areas of frayed or broken canvas fibers were consolidated using a combination of sturgeon glue and wheat starch paste, which is common in canvas tear repair. Minor filling was completed on the toppings with Becker’s Latex spackle followed by integration with watercolors (fig. 27). *Floor Cake* was reassembled on a trolley in the conservation lab. The toppings were reattached with heavy weight cotton thread to the upper layer of *Cake* in their 1975 acquisition documentation locations (fig. 28).

7. CONCLUSION

The current research on the cleaning of acrylics indicates that the reduction of water contact or reduction of time in contact with the surface will minimize paint swelling and removal of surfactants, which is of particular importance for newer untreated surfaces. *Floor Cake* is nearly fifty years old and has been cleaned with aqueous solutions twice before, so conservators were not overly concerned with surfactant removal. Our analysis of earlier treatment could not detect the presence of tri-ammonium citrate residue, suggesting that proper clearance of chelating agents is possible. Utilizing a combination of dry and wet cleaning techniques, grime was extracted with minimal mechanical action. This project brought sculpture and paintings conservation together and took advantage of the Modular Cleaning Program, not typically used in objects conservation. Whether using aqueous solution/gel or dry based methods to clean acrylics, each must be carefully adapted by conservators to reflect the needs of complex art objects.

New conservation guidelines for movement and installation of *Floor Cake* will ensure the use of gloves and no longer advocates adjusting the layers by “fluffing”. A conservator should be present during installation to make adjustments to the interior components and from inside or beneath the canvas, rather than manipulating the paint layer from the surface. In addition the use of stanchions or a platform is strongly recommended to keep visitors from touching or accidentally kicking the sculpture. Over the course of the year that *Floor Cake* spent in conservation, blog posts were made providing treatment strategies and updates to encourage the conservation and scientific community to share thoughts and insight, as well as to share the treatment progress of this iconic pop sculpture with the general public.6

ACKNOWLEDGEMENTS

The authors are sincerely grateful to the following people: Claes Oldenburg, Anny Aviram, Jim Coddington, Michael Duffy, Roger Griffith, James Hamm, Chris McGlinchey, Elizabeth Nunan, Greg D. Smith, and Lynda Zycherman.

NOTES

2. Acquisition records from MoMA Department of Sculpture and Painting files, 1975 indicate that Oldenburg stated he was using latex and Liquitex on his 1962 soft sculptures.


4. PVOH sponge Cross-linked polyvinyl alcohol sponge. For more information on sponges see Albertson, Cynthia. “Surface Cleaning: Analysis of Sponge Abrasion on Paintings”, Art Conservation Department at Buffalo State College, Poster AIC 2008.

5. Prepared Stock Solution derived from testing with the aid of the Modular Cleaning Program. The pH was targeted at 6.5 and the conductivity 0.33 m/s. 500 mL distilled water, 5.2 grams of Bis-tris, 4.8 g of citric acid, 0.5 g of Brij 700, 2.3 mL sodium hydroxide (10%), 0.4 mL of hydrochloric acid (10%), pH 6.5 with sodium hydroxide (10%).


REFERENCES


**FURTHER READING**


SOURCES OF MATERIALS

Dry cleaning sponge: vulcanized rubber sponge
  Talas
  330 Morgan Ave
  Brooklyn, NY 11211

PVOH sponge Cross-linked polyvinyl alcohol sponge.
  Peregrine Brush ad Tools
  1211 S. 60 W.
  Wellsville, UT 84339
  www.brushesandtools.com

Brij 700 Brij
  ICI Organics, England
  Trademark for a series of nonionic surfactants that work well in both alkaline and acidic solutions. They are composed of polyoxyethylene ethers of higher aliphatic alcohols.
  Available from Fischer Scientific

Bis-tris
  Bis-tris- 2-bis(2-hydroxyethyl)imino-2-(hydroxymethyl)-1,3-propanediol.
  Available from Fischer Scientific

Velvessil FX Gel
  Sample-O.454KG 84786, 10043-11-5 Boron nitride 17955-88-3 Caprylyl Methicone
  443892-05-5 Silicone Gel 541-02-6 Decamethylcyclopentasiloxane
  Momentive Performance Materials
  Waterford, NY 12188
  (518) 237-3330

Ethafoam Polyethylene foam, 1”, 2” 4” planks, 2.0 lb density
  Masterpak
  145 East 57th Street
  New York New York 10022
  service@masterpak-usa.com

Cotton Drawstring Muslin Bags
  15” x 12” Rose Garden Creations.
  www.amazon.com

White 100% cotton heavy-weight thread
  Coats and Clark
  P.O. Box 12229
  Greenville, SC 29612-0229
  www.coatsandclark.com
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PLASTER, PLIACRÉ, AND PAPER

MINA THOMPSON AND CONOR McMAHON

ABSTRACT

Established in 1909, the Museum of New Mexico ranks among the oldest museums in the Southwest. It also has one of the longest histories of planned and institutional conservation, beginning in 1935 conserving early Puebloan wall murals to early staff and consultants such as Per Guldbeck and Rutherford Gettens in the 1950s. This paper traces the history of conservation and conservation practices in the Museum of New Mexico System, from its inception as a single museum for Southwestern art by Edgar Lee Hewett to its current incarnation of seven divisions under the New Mexico State Department of Cultural Affairs. Evolving practices and trends of artifact restoration and preservation are discussed using case studies of archaeological ceramics and Spanish Colonial santos. Analyses of treatment materials, supplemented with archival documentation, uncover past treatment philosophies, some of which are remarkably modern. Retreatment and reexamination of these artifacts, as well as efforts to preserve the intangible aspects of cultural materials, have greatly influenced present-day treatments, including choices made in recent years toward less toxic and more easily reversible treatments of these two collection types.

1. INTRODUCTION

Established in 1909, the Museum of New Mexico ranks among the oldest museums in the Southwest. It also has one of the longest histories of planned and institutional conservation. This paper traces the history of conservation and conservation practices in the Museum of New Mexico System, from its inception as a single museum for Southwestern art to its current incarnation of seven divisions under the New Mexico State Department of Cultural Affairs. Evolving practices and trends of artifact restoration and preservation will be discussed using case studies of archaeological ceramics and Spanish Colonial santos. Materials analysis and archives research reveal past treatment philosophies, some of which are remarkably modern. Retreatment and reexamination of these artifacts, as well as efforts to preserve the intangible aspects of cultural materials, have greatly influenced present-day treatments, such as using less toxic and more easily reversible treatments of these two collection types.

2. EDGAR LEE HEWETT AND THE MUSEUM OF NEW MEXICO

It is probably safe to say that museums themselves are the first act of preservation, and the Museum of New Mexico, founded in 1909 by Edgar Lee Hewett was no exception (fig. 1). His mentor, pioneer archaeologist Adolf Bandelier, instilled in him a passion for both past and present indigenous cultures of the Southwest, and he spent the rest of his life building institutions and academic departments to commemorate them. Over his lifetime, Hewett created and simultaneously directed six institutions and academic departments, all of which he oversaw simultaneously.

The first institution he created was the School of American Archeology in Santa Fe in 1907. The purpose of the school was to train future archaeologists to work in the Americas, as most schools focused on the Old World sites and cultures. Early field school students include now-legendary archaeologists Sylvanus Morley, Neil Judd and A.V. Kidder, as well as several women, which was highly controversial at the time (El Palacio 1981).
Fig. 1. Edgar Lee Hewett, ca. 1912, as Director of Museum of New Mexico, and the School for American Archaeology. Photograph by Jesse Nusbaum. (Courtesy of the Palace of the Governors Photo Archives (NMHM/DCA), #007339)

From their prolific summer excavations, there quickly became a need to house their numerous finds. In order to prevent the artifacts from being absorbed into east-coast institutions, Hewett and the New Mexico Territorial government founded the Museum of New Mexico, which was housed in the Palace of the Governors on the Plaza (fig. 2):

Critical to the founding missions of the school and the museum (which separated from each other in 1959) was also the encouragement and preservation of contemporary Southwestern Native American cultural material. New artifacts were acquired, and studios were even offered to craftsmen to encourage their work. The museum's collections – often the archaeological pottery - inspired contemporary makers either to revive old designs or create new ones (SAR 2007). Maria and Julian Martinez of San Ildefonso Pueblo are perhaps the most famous of this program, who were hired by Hewett to recreate pottery found on archaeological excavations that were no longer known, and from which they were inspired to create their own unique styles that are still coveted today.

In the coming decades, the Museum of New Mexico grew from a single museum located in the Palace to a group of museums and institutions that include: the Museum of Art, founded in 1917 and located across the street from the Palace; the Laboratory of Anthropology, which opened independently in 1931 but merged with MNM in 1947; the Museum of Indian Arts & Culture, built in 1987 to house the Laboratory of Anthropology’s growing collections; the Museum of International Folk Art, which opened in 1953 as the first folk art museum in the country; six State Monuments, and the Office of Archaeological Studies. The most recent
addition is the New Mexico History Museum, which houses the artifact collections of Palace of the Governors—the first museum site and the oldest public building in continuous use in the United States.

Nearly every one of these museums, which are collectively called the Museum of New Mexico System, has its own history of preservation, whether in its founding mission or through staff and consultants who helped actively conserve their collections.

Fig. 2. An early photo of the facade of the Palace of the Governors along the Plaza, as it appeared when it first housed the Museum of New Mexico. The Palace was renovated the following year into its current “Santa Fe Style” by Jesse Nusbaum. Photograph by Jesse Nusbaum, ca. 1911. [Courtesy of the Palace of the Governors Photo Archives (NMHM/DCA), #061537]

3. A BRIEF HISTORY OF CONSERVATION AT THE MUSEUM OF NEW MEXICO

Milestones in the museum system's conservation history can be marked as follows:

- The museum itself was founded to preserve ancient and contemporary cultural material of the Southwest. This is perhaps best represented in its pottery restoration, which will be discussed later.
- The first major, complex conservation treatment occurred during the Kuaua excavations between 1935 and 1938. During this collaborative project between the Museum of New Mexico, SAR and the University of New Mexico (UNM), intact kiva murals dating to the 1500s and earlier were discovered, and, quickly after began to separate from their adobe structure. The murals were faced and supported in plaster, removed and taken to a laboratory at UNM for preservation. Painstaking *strappo* conservation techniques revealed 17 layers of elaborately painted walls, which were mounted into 76 individual
support systems. The Kuaua murals are the most complete cycle of Puebloan murals with a continuous theme in existence (Munzenrider 2004).

- Consultations with Rutherford J. Gettens began in 1935, in which Jesse Nusbaum, director of the Laboratory of Anthropology, describes in great detail the Lab’s wholesale pest eradication methodology with Carboxide gas, the brand name at the time for ethylene oxide gas (Nusbaum 1935). Gettens continued his association with the MNM for the next several decades, most notably in his identification of pigments used by Spanish Colonial artists and later in a treatment consultation on one Kuaua mural fragment in the mid-1950s (Gettens 1950).
- E. Boyd, in 1951, becomes the first curator and conservator of the newly created Spanish Colonial Art Department in MNM. She and protégé Alan Vedder conserve artifacts and also help to revive traditions with local santeros, much in the same spirit as Hewett’s founding missions for Native American cultural material.
- In 1953, the Museum of International Folk Art opens. At that time, the museum was state-of-the-art, with climate control, a conservation lab, and fumigation chamber, which used hydrogen cyanide gas to fumigate the museum’s founding collections.
- Per Guldbeck, the founder of conservation for Parks Canada, served as the first curator/conservator at the Folk Art Museum until he headed out to Cooperstown in what must have been the late 1960’s. His years here working on diverse cultural material provided the foundation for his book written in 1972, *The Care of Historical Collections: A Conservation Handbook for the Nonspecialist*.
- In the mid-1950’s F. DuPont Cornelius, paintings conservator at the Metropolitan Museum of Art, retires and moves to the Southwest, treating many paintings for the Museum of New Mexico system and consulting with staff on other conservation treatments.
- In 1979 the first program-trained conservator, Claire Munzenrider, was hired. She worked here until her retirement in 2006, and had senior staff in the 1980s and 1990s that included Bettina Raphael, Landis Smith and Dale Kronkright. All of these projects and individuals formed and informed conservation practices here at the Museum of New Mexico, and continue to influence treatments and approaches to the same materials today.

4. CASE STUDIES

Archaeological ceramics of the Southwest and Spanish Colonial santos are perhaps the two most common collections types requiring treatment in the Museum of New Mexico System, and therefore provide ample opportunity for comparing past and present treatment philosophies and materials.

4.1 CONSERVATION OF ARCHAEOLOGICAL CERAMICS OF THE SOUTHWEST: PAST AND PRESENT

The Museum of New Mexico was one of six institutions in the early twentieth century to sponsor archaeological excavations in the Mimbres Valley, which is located in Southwestern New Mexico. Archaeologist Wesley Bradfield excavated the Cameron Creek River site from 1923 to 1928. This project occurred in part to “keep up with the Jones’ ” on an institutional level, and, in part, to acquire stunning Mimbres classic bowls (dating to 1000 – 1130 AD) with a
reliable provenance. Even in the early twentieth century, the Mimbres valley was being ravaged by looting, and to this day there are only a handful of scientifically excavated Mimbres sites (Turnbow 2005). The Museum of New Mexico's Cameron Creek artifacts, with Bradfield’s copious field notes and excavation reports, remain a highly studied and significant collection of Mimbres cultural material.

Because of their continued value, in 2004 the conservation department was asked to remove highly discolored restorations present on many of the Mimbres Classic bowls. After consultation with and ultimately approval from the Museum's Indian Advisory Panel, the work began.

As is evident in figures 3 and 4, the staining from the restoration materials is quite disfiguring. Materials analysis and research among multiple museum archives revealed that the bowls had in fact been restored by Museum of New Mexico staff and soon after transport from the excavation site (Thompson and Elliot 2006). There appeared to be only one restoration campaign that utilized materials commonly available in the early twentieth century. UV-VIS examination of a cross section of the restoration materials, in addition to microchemical testing and FTIR analysis revealed the following information:

1. sherds were adhered with cellulose nitrate adhesive,
2. cracks and losses were filled with Plaster of Paris,
3. joints and fills were covered in a still yet-to-be identified material, though it is likely cross-linked copal resin or, in some cases, polyvinylacetel resin used in paleontological samples, and
4. all cracks and fills were inpainted and overpainted with linseed-oil paints – probably store-bought but modified in-house for color matching.

The Cameron Creek bowls are the only collection at the museum with this kind of staining, so it is likely that the oil migration did not take too long to become noticeable. Just as oil is absorbed into raw canvas, so it was absorbed by the porous earthenware. While linseed oil can be relatively easily removed with certain organic solvents, the fact that up to 30 bowls had to be treated in a small conservation lab with limited exhaust capabilities and by multiple conservators made it critical to come up with a less toxic alternative for paint removal. After numerous testing campaigns, paintings conservator Claire Munzenrider suggested what became the best solution: an ammonium bicarbonate poultice as described in Mora, Mora and Philipot's book, Conservation of Wall Paintings (1984). Our resulting formulation was 10 ml of 10% ammonium bicarbonate in deionized water added to dampened paper pulp (from cotton rag blotters) mixed with a 15g of 4% 4M methyl cellulose to give the mix a smoother consistency. The poultice was applied over mulberry tissue and left for 20 minutes to one hour. The poulticed area was then rinsed with deionized water and ethanol.

The staining, in most of the bowls, was successfully reduced (fig. 5). Perhaps the more significant benefit to removing the restorations was the uncovering of paint-polish strokes, use-wear marks, and, on one occasion, a kill hole. Such markings, noticeable in figure 5 as the small pock-marks in the slip near the kill hole, highlight the intangible aspects of the bowls and help to elucidate the mysteries surrounding these bowls that have persisted for the last century.

Though losses in archaeological ceramics would not usually be filled, the pre-existing plaster fills were stable. Removing them from all of the bowls was determined to be a lower priority and, frankly, too time-consuming. The conservation team instead toned plaster fills to the slip color with acrylic emulsion paints, taking special care not to replicate any lost imagery for a very specific reason: in the past, restorers' designs have been unintentionally mistaken for
original imagery and published as such. The museum and conservation team could not risk this happening again.

Fig. 3.

Fig. 4. Before treatment (fig. 3) and UV/VIS (fig. 4) illumination of the same bowl from the Cameron Creek excavations, highlighting the extent of restoration. Catalog number 20216/11, Museum of Indian Arts & Culture/Laboratory of Anthropology Collections. (Photographs by Larry Humetewa)
It is easy to understand why these bowls were originally restored so extensively. Firstly, such treatments were not uncommon in the early twentieth century. Mimbres bowls were prized for both their reliable provenance but also for their unparalleled aesthetic qualities. Most importantly, it was these early-excavated Mimbres bowls that provided the basis for Mimbres pottery dating and classification that is still used today. “Complete” bowls made the images easier to read and therefore classify.

Today, conservation treatments of Native American cultural material are often relatively minimal. It is consistent with modern practices not to fill losses, and rarely to replicate lost designs. When fills are deemed necessary for structural stability, however, today’s conservation team often uses a two-part epoxy putty in lieu of plaster. These essentially fake sherds are tacked into position with small amounts of adhesive, which helps to diminish the relative strength of the epoxy over the earthenware. One can even paint them prior to adhering them in place, thereby minimizing risk of paint transfer to the original material (figs. 6, 7).
4.2 SPANISH COLONIAL SANTOS

In contrast to treatments of archaeological materials, basic philosophies for treating Spanish Colonial art mirror those of today, though the choice of materials has altered.

4.2.1 E. Boyd

Elizabeth Boyd White was known as E. Boyd, or, simply, E (fig.8). After moving to Santa Fe in 1929 to paint, she quickly developed an appreciation for the simple, painted wooden saints (*santos*) ubiquitous in churches and homes in New Mexico. Yet knowledge about the
devotional works was hard to find. Santeros (the saintmakers) and their collective knowledge were rapidly disappearing, mainly as a result of mid-nineteenth century Bishop Lamy's distaste for this “primitive” style. Boyd made it her life's work to study the aging religious artifacts. She inventoried Spanish Colonial devotional works state-wide, and, through careful study of local archives and church records, she was also able to date many works and even attribute them to santeros (Loomis 1964).

During her work, Boyd found the santos in such states of disrepair that she took it upon herself to learn how to restore them. While she never apprenticed formally, she knew where to seek help. Archives research shows numerous technical studies bulletins, treatment recipes and collaborations with conservators (Boyd 1951-1959). In the late 1940's, she and artist Cady Wells contacted Rutherford Gettens to perform the first pigment identification of Spanish Colonial santos. In 1951, he published his research in El Palacio, the quarterly publication of the Museum of New Mexico and the oldest museum magazine in the country (Gettens and Turner 1951, 13-28). Boyd's and Gettens' relationship continued on both professional and friendly levels, with letters describing the chemical makeup of gypsum to inquiries about the fine retablo (a two-dimensional santo) Boyd was procuring for Gettens and his wife in the late 1960s (Gettens 1958 and 1964).

![Fig. 8. Image of E. Boyd in 1958 cleaning a retablo in her office in the Palace of the Governors. [Photograph by Charles Herbert, courtesy of Palace of the Governors Photo Archives (NMHM/DCA), #15368]](image)

4.2.2 Early Conservation of Santos

It wasn't until 1951 that Boyd was officially hired as curator of Spanish Colonial Art at the Museum of New Mexico. She, and her protégé Alan Vedder, who worked by her side beginning in 1955 and continued after her death in 1974, had quite modern treatment
philosophies towards the conservation of *santos*. In a book written in homage to Boyd entitled Hispanic Arts and Ethnohistory of the Southwest, Vedder (1986), in his contributing essay, describes in great detail his and Boyd's philosophies and materials used to treat a fine *reredo* by José Raphael Aragón from a *penitente* in Vadito dating to around 1830. He states:

> Trying to achieve a final product that was exactly like the original work at the moment it was finished was not the goal to be strived for. The pieces were old, had been used and were worn, and that should be evident. (223)

He elaborates upon materials in an interview late in his life, stating that flaking paint and losses were filled with layers of gesso, and “inpainting was done only in the areas of loss” using “[watercolors] with the same pigments as those used by the *santero*” (Giffords 1988).

Boyd and Vedder rather extensively used a mix of waxes from Plenderlieth's seminal treatise, *The Preservation of Antiquities* (1934) to resaturate and protect the flaking, fragile surfaces. They used a light touch when applying the wax mixture; applying it diluted with turpentine and topically only (other contract conservators dipped the works in the wax). Boyd also recognized the need for reversibility, stating in her treatment records and interviews that the wax could easily be removed with turpentine should changes be necessary (Loomis 1964).

### 4.2.2 Today’s Approaches to Treatment

Today the Conservation Department's approaches to the treatment of Spanish Colonial art are similar, though our treatment materials have changed. Wax, gesso and watercolors are no longer used. Instead, flaking paint is consolidated with isinglass (a close relative to Boyd’s and Vedder’s gesso), as it reacts well with the hide glue binder in the original paint and gesso layers. With some experimentation, the conservation team has ultimately found that masking losses with toned mulberry tissue, a technique introduced by senior conservator Maureen Russell and used by many institutions for similar purposes, is generally the best loss compensation technique for Spanish Colonial *santos*. *Santos* are highly complex artifacts: they have varying degrees of inherent vice, such as insufficiently cured wood, too little binder, and were often housed in environments with great fluctuations in relative humidity and leaky roofs. They often also have numerous campaigns of restoration or repainting by their caretakers. These campaigns of care speak to the object’s past and its cultural significance, and it is important to preserve that information as completely as possible.

By tacking down the edges of the tissue with methyl cellulose (or other appropriate adhesive), the tissue becomes a Band-Aid, and there is no need for filling. The tissue fills are very easily reversible, and the tissue has enough give to move with the material as necessary in today’s more stable museum environments, and hides conspicuous damage, as seen in figure 10.
Fig. 9. The *reredo* by José Raphael Aragón, ca 1830, before treatment on the left. On the right, the same *reredo* after treatment by Alan Vedder. Museum of International Folk Art, FA.1960.24.1. (Photographs by Alan Vedder, courtesy of MOIFA)

5. CONCLUSION

Trends in conservation and restoration will continue to change, much as they have done in the past several decades. This is one of the reasons why conservators document their work, justify their decisions and strive for complete reversibility. It is for this reason that conservators and museums must retain their documentation, which hopefully explains decisions made and avenues not chosen. It has been many of these small notes and papers that have provided the insight into past treatments here at the Museum of New Mexico – and its shared history with other institutions and legendary conservators, such as Rutherford Gettens. Because of this research and what is likely available but difficult to find at other institutions, the authors of this paper have two ideas:

1. Museums around the nation often share artifacts from the same collections or sites. There are Cameron Creek bowls with the same dark stains at least four museums in the United States. Rarely, however, does documentation of such transfers exist. Wouldn't it be useful to establish an online database in which museums and/or conservation departments can share records - either on discreet collections or perhaps even treatments?

2. It is difficult to find information on many early conservators. Wintherthur has its oral history archives – perhaps this could be expanded to include digital copies of archival papers and images, such as the personal letters between Boyd and Gettens?

There is one trend that should not change, though documentation of it should always be maintained. The Museum of New Mexico's consistent focus, most notably through Hewett and Boyd, on working with contemporary populations to encourage, if not revive, their artistic traditions is very impressive and inspiring. Later museum directors and conservators have carried on this tradition of collaboration, evident with the Museum of Indian Arts & Culture's Indian Advisory Panel and Ms. Munzenrider's internships for santeros in the conservation laboratory.
Yet it is easy to lose sight of the importance of collaboration when time is short. In Santa Fe, the Museum of New Mexico System Conservation Department is profoundly lucky to live amongst the people whose art we safeguard in our museums. We need to maintain the tradition of collaboration Hewett began 100 years ago.

Fig. 10. Detail of Entierro (Christ interred) from Mora by José Benito Ortega. Image on the left shows a detail of the coffin before treatment, the dark drip-marks from previous water damage. On the right, the same area after treatment with toned mulberry tissue. 2007.32.91, Collection of the New Mexico History Museum/Palace of the Governors. (Photographs by Mina Thompson)

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NOTES

1. The School of American Archaeology was renamed the School of American Research in 1917 to reflect the broadening spectrum of its mission, namely, a greater anthropological approach that included twentieth century cultures. SAR was renamed again in 2007 to the School for Advanced Research.

2. The Indian Advisory Panel was founded in 1987 and consists of 15 to 26 members at a given time who represent 29 pueblos, tribes and nations in the American Southwest. The IAP is regularly consulted on exhibits, collections issues and programs at the museum; but it was essential to gain their consent for the Mimbres treatment project because about 60% of the bowls are funerary items subject to repatriation under NAGPRA. While most culturally sensitive artifacts from MIAC/LAB’s collections have been repatriated in the past 15 years, the Mimbres funerary bowls from Cameron Creek excavations remain at the museum because there are no existing lineal descendants or tribes with recognizable cultural affiliations to the Mimbres. The project was presented to the IAP by Chris Turnbow, the Assistant Director of MIAC/LAB at that time and curator of the project, as a means of removing disfiguring staining and modern restoration materials applied to the Black-on-white bowls. Through the proposed treatment, the original designs of the bowls would appear more clearly and images invented by early restorers would be removed. Most importantly, the bowls would return to a state more closely resembling the condition in which they were originally placed in the ground. On the basis of these statements, the project was approved.

3. Archaeologist Wesley Bradfield does not identify this bowl as being associated with human remains, and therefore both the Indian Advisory Panel and the staff of the Museum of Indian Arts & Culture/Laboratory of Anthropology have allowed its image is allowed to be published. Staining on other bowls associated with human remains often has even more pronounced staining.

4. The authors are grateful for subsequent discussions with George Wheeler, Director of Conservation at the Historic Preservation Program and Columbia University. Dr. Wheeler alerted the authors to the danger of high pH solutions on ceramic, something that was overlooked in 2005 when the treatments occurred. The pH of the ammonium bicarbonate is measured at 8.5 – 9.0, and should be used with caution. Ammonium bicarbonate may have been the best solution given the constraints of the project and the invasiveness of previous treatments, but, the potential damage incurred on silicates from the relatively high pH deems the treatments risky.

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Turnbow, C. 2004 – 2005. Personal communication. Archaeologist and Deputy Director of the Museum of Indian Arts and Cultures/Laboratory of Anthropology, Santa Fe, NM.


**SOURCES OF MATERIALS**

Ammonium carbonate  
Sigma Chemical Co.  
www.sigma-aldrich.com

Blotters (100% unbuffered cotton)  
University Products  
www.universityproducts.com

Methyl cellulose (4000 centipoises)  
Sigma Chemical Co.  
www.sigma-aldrich.com

Mulberry tissue (30% kozo/70% pulp)  
University Products  
www.universityproducts.com

Polyfix (calcium carbonate-bulked spackle with polyvinyl alcohol binder)  
Conservation Support Systems  
www.silcom.com/~css/

Golden acrylic emulsion paints  
Golden Artist Colors, Inc.  
New Berlin, NY, USA  
(607) 847-6154  
supplied by:  
Artisan’s,  
Santa Fe, NM

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HENRY MOORE’S BRONZE FORM AND LARGE FIGURE IN A SHELTER: INTERPRETING THE ORIGINAL SURFACE

KATRINA POSNER

ABSTRACT

Henry Moore’s final two sculptural series—Bronze Form and Large Figure in a Shelter—were fabricated in 1985-6 by welding together cast-bronze elements. The abstract shapes were likely polished to a high shine after assembly to give a uniform golden appearance. Many of these sculptures, which are now installed throughout the world, have undergone restoration treatments that have addressed the environmental impact on such fragile surfaces – darkening and modulation of the bright color. As it is likely that Henry Moore did not see the completed sculptures in these series before he died, to what aesthetic should the modern conservator refer? This paper will look into the history and context of these sculptures as well as investigate the process for determining their future treatment.

1. BACKGROUND

At the end of his lifetime, the English artist and icon Henry Moore undertook the realization of two final monumental outdoor bronze series: Bronze Form (in an edition of 6 plus the artist’s copy) and Large Figure in a Shelter (in an edition of 1 plus the artist’s copy).

These nine sculptures, which were all sand cast in sections and welded together at Morris Singer Art Founders outside London between 1985 and 1986, represent both the culmination of Moore’s artistic concepts that had been percolating for decades, as well as what can best be described as a significant departure from the artist’s aesthetic norm.

Research into these series was initiated by the fact that it is apparent that the Getty’s version of the sculpture is in need of treatment. The sculpture, which was a gift to the Getty Museum, was installed at the Getty Center in May 2007. It was untreated prior to installation due to time constraints and the need for research into its original appearance. At some point prior to its acquisition by the museum, the sculpture was coated with a clear acrylic-urethane. This coating, which has been compromised due to years of outdoor exposure, is breaking down and is no longer protective. The lack of a cohesive coating is causing uneven darkening, as well as deep pitting and associated corrosion.

While there are other more minor aesthetic issues that will be addressed, the impetus for a near-future treatment will be to remove the coating and reapply something more protective. Two other Moore sculptures – *Draped Reclining Mother and Child* (JPGM 2005.117.2) from 1983 and *Seated Woman* (JPGM 2005.117.3) from 1958 – were also a part of a 28-piece gift of modern outdoor sculpture in 2005 from the recently deceased film producer Ray Stark and his wife, Fran. Their collection now comprises the Fran and Ray Stark Sculpture Garden at the Getty Center. *Draped Reclining* and *Seated Woman* were installed after their treatments that involved removing their accumulated coatings followed by the reapplication of wax. The *Bronze Form*, however, was installed untreated pending future research into the original and subsequent surfaces.
2. PROCESS

Fortunately, Henry Moore’s creative and working processes are well documented. Many of his large sculptures find their origins in his drawings and/or were inspired by the pieces of flint, bone and shell he found along the seashore. Working maquettes made from plaster, bronze, lead and even silver often initiated the three dimensional stage in his process.

![Fig 3. On the left is the piece of flint found by Moore that ultimately inspired the Bronze Form and Large Figure series. The other pieces in the series show the progression, in plaster, to the final Bronze Form figure. (Photograph by Katrina Posner)](image)

Frequently, sections of realized sculptures were modified and re-oriented to become passages in new works; his process was a series of overlapped and interlocking themes, where he revisited past ideas to engender new designs.

These overlaps are truly evident in the Large Figure and Bronze Form sculptures, which were two separate series, made from the enlargement of the last of Moore’s middle-sized Helmet Head sculptures - Helmet Head Number 6- from 1975. One version of this sculpture is currently located at the National Gallery for Foreign Art in Sofia, Bulgaria.

In the mid-1980s, an enlarged model made from expanded polystyrene was created from the Helmet Head to make Large Figure in a Shelter and Bronze Form. According to Chris Boverhoff (2010), a representative of Morris Singer, the polystyrene would have been subsequently skimmed in plaster and then cut into the sections for sand casting. After polishing the surface of the metal to what Boverhoff described as a “sateen” finish, the sculptures would have then been waxed, without he believes, the prior application of a chemical patina.
Moore assigned Bernard Meadows to oversee the fabrication process for these sculptures at the Foundry. Meadows, who was Moore’s assistant from 1936 to 1940 (Mitchinson 1998) and went on to have a successful art career of his own, returned to Perry Green in 1980 as a Trustee of The Henry Moore Foundation, and was appointed director in 1983. As Moore was quite ill during the fabrication of these final series, Meadows stood in for the artist during their casting and, according to past and current employees at the Foundation, was instrumental in the decision to leave the surfaces of the sculptures a polished, bright and unpatinated golden hue. According to several current Henry Moore Foundation employees, it is very likely that Moore never saw any of the completed sculptures from this series.

James Copper, the Foundation’s current sculpture conservator who trained under Moore’s longtime assistants – John Farnham, Malcolm Woodward and Michel Muller – corroborated Boverhoff’s statement that the surfaces were left unpatinated (Copper 2010). He went on to note that the decision, again presumably made mostly by Meadows, was an unpopular one. It seems
that it was a major departure from the standard palette for the artist’s outdoor works to date. Incidentally, according to the Foundation’s current archivist Michael Phipps (Phipps 2010), the three assistants refused to work on the pieces at the time, saying they would allow them to “go green” after Meadows passed on, which was in 2005.

3. HENRY MOORE AND PATINAS

While Moore was indeed creating bright gold sculptures in the later part of his career, their surfaces were generally given washes of dilute patinating chemicals—either Liver of Sulphur or Ferric Nitrate. Applied cold, these salts were used to help define the form of a sculpture where the gold was made to go slightly darker in recesses and interstices, generally remaining bright at the edges. Moore likened this interplay of lights and darks to the tension seen in a clenched fist—lighter areas where the skin is stretched tautly over the underlying bone structure (Pullen 2010). These variations in color would be both intensified and animated by sunlight.

In the writings of and interviews with Henry Moore, it is apparent that he considered the application of patina to be an indispensable step in the generation of his art. Moore’s understanding of the chemistry of oxidation is elucidated in the interview he gave to Mervyn Levy for his Studio International article, “Henry Moore: Sculpture Against the Sky” in 1964: “I work out and apply all patinas myself. The chemical composition is largely determined by the climactic conditions in which the particular work is going to be set…Different things will happen to the patina of bronze according to the kind of atmosphere in which it is gradually weathered.” He goes on, “My own patina is, of course, a preliminary to the one which nature will herself supply in time” (Wilkinson 2002, 236). In her article, “Preserving the Artist’s Intent: Henry Moore’s Monumental Sculptures,” presented at the 1987 AIC Conference in Vancouver, conservator Linda Merk-Gould describes the time she spent working with Moore and his assistants at the studio in Perry Green. She addresses the concept of “appropriateness” in the use of protective coatings for Moore’s outdoor works, acknowledging that there are some who have argued that applying a coating disallows the sculptures from reacting to their environment, thereby contradicting the artist’s intent. However, she writes, his monumental sculptures with gold patinas were coming back from the Noack Foundry (Fine Art Foundry Hermann Noack, Berlin, Germany) with a polyurethane-like coating, indicating to the author “an acknowledgement of how quickly the monumental golden patina sculptures darken outdoors” (Merk 1987, 73).

As Merk-Gould notes, the statements made by Moore about the natural weathering of his pieces were “made during the time period when the majority of his sculptures were patinated green or brown” (Merk 1987, 69). Indeed, the attempt to categorically describe Moore’s intent for his patinas is met with contradictions that were initiated by the artist himself. In “Gilding The Lily: The Patination of Henry Moore’s Bronze Sculptures,” Julie Summers, then Deputy Curator at The Henry Moore Foundation, writes: “Moore never fully resolved the problems and contradictions in his own attitude towards his outdoor pieces. On the one hand, if he was pleased with the result after patination he might advise that nature should be allowed to take its course and the sculpture carry on patinating naturally, as dictated by the elements. On the other, he might take preventive action to maintain a certain colour to prevent oxidation taking place and the patina ‘going wrong’ ” (Summers 1995, 145). Preventive action, presumably, meant the application of a coating, and “going wrong” can be interpreted as whether the color change interfered with the visual interplay and balance of the form.
Moore’s method, namely, what he wanted for his sculptures and how he perceived the place coloration would take in their future, has been well-dissected. However, what we have with these final series is an issue that predates the concerns about longevity. The Large Figure and Bronze Form sculptures were not patinated; therefore, how do we approach their treatment?

It would be useful at this point to introduce the purpose and function of The Henry Moore Foundation. It was established in 1976, while Moore was still alive, to keep the artist’s collection together and accessible to the public after his death (Mitchinson 1998). There are those who were present at its inception who are still working there today, and it is clear that both the institutional knowledge and spirit of Henry Moore is carried through these people. Throughout the conversations with current employees it was never indicated that the Foundation aims to have the final word in all Moore restorations, though their understanding of Moore’s process and desires is undeniable.

The three main assistants who continued to restore sculptures at the Foundation and around the world after Moore’s death – Farnham, Woodward and Muller – are no longer working. However, as mentioned, they trained current conservator James Copper. Thus, although there is still a connection to the original source through his predecessors, it will soon become impossible to argue that decisions for maintenance and treatment are based on first-hand knowledge.

In terms of the artist’s intent and the preservation of his memory, there are broader philosophical issues at hand than merely who was present when he was working. What is at the crux of this discussion is that the sculptures were uncharacteristically left unpatinated. They are, arguably, the product of another artist – Bernard Meadows – whose own aesthetic preference was for smooth, highly polished, unpatinated bronze. This presents an ethical question in and of itself- just because the past and present believe the pieces were inappropriately finished, is it permissible to change their original state for the future? And if so, is that where the artist’s intent, for these pieces at least, lies: at the point of patination?

Finally, where do conservators stand? This is a summary of the possibilities for treatment:

- Restore the pieces to their originally unpatinated state. If so, let them darken or keep them bright?
- Continue with the practice to which the Foundation subscribes, of applying washes of Liver of Sulphur or Ferric Nitrate, as the assistants have, and presumably Moore would have, done. And if so, let them darken or keep them bright?
- Or, dispense with the periodic re-patinating scheme altogether, keep the surfaces as they are and either a) lacquer them to hold them relatively steady or b) apply wax only to the surfaces with the intention of allowing them to darken slowly.
4. THE SERIES

As mentioned, there are nine sculptures in the two series, Large Figure in a Shelter and Bronze Form, listed here with their edition numbers and current locations.

*Large Figure in a Shelter*, 1985-6 edition of 1 +1 (artist copy)
0/1: The Henry Moore Foundation, Perry Green, Much Hadam, England.
1/1: Parque de los Pueblos de Europa, Guernica, Basque Country, Spain.

*Bronze Form*, 1985-6 edition of 6 + 1 (artist copy)
0/6: The Kawamura Memorial Museum of Art, Chiba, Japan.
1/6: Frederick Meijer Gardens and Sculpture Park, Grand Rapids, United States.
2/6: A.P. Møller - Mærsk Group Headquarters, Copenhagen, Denmark.
5/6: Private Collection, Japan.

In discussions with those at the Foundation, I was able to garner treatment information about those of the sculptures that were restored by their employees and these will be reviewed below. It is interesting to note that, clearly due to the reactivity of the bright surfaces, these sculptures were all treated for the first time within a few years of their fabrication.

Large Figure, 0/1 in Perry Green piece was installed in 1988. The surface coloration is currently quite modulated, stemming primarily from the fact that the Incralac has been seriously compromised and is flaking heavily.

Conservator James Copper said that he treated the interior form several summers ago by sanding down the surface and applying a wax coating without a patina (Copper 2010). Copper plans to treat the piece during Summer 2010 by sanding down the surface of both sections with a disc sander, applying a thin wash of Liver of Sulphur, and waxing the surface. Based presumably on his training by Farnham and others, Copper is among those who considers Bernard Meadow’s choice to keep the surfaces unpatinated anathema to Moore’s aesthetics. Further, by using only wax and not lacquer, it is his intention that the surface will continue to darken, or self-patinate, with time.

The *Bronze Form* artist’s copy (0/1) is at the Kawamura Memorial Museum of Art in Chiba, Japan. Mr. Kozo Kumamoto, a conservator at Hakone Open Air Museum sent this description of his process, which was developed during the first restoration of the sculpture that was performed in 1990 with Michel Muller, one of Moore’s assistants. Kumamoto restored the piece again in 2006 using the same process.

1. Take off the Incralac completely with paint stripper.
2. Grind down the surface of bronze with disk sander to make the surface rough.
3. Apply Potassium Sulphide to the surface of bronze with a brush - starting at the top and lighter part and emphasizing the under-cut and lower part with a darker and more concentrated solution of the chemical.
4. Using Scotch-Brite pads, gently even out the gradation of color. And finally, spray apply the Incralac coating (Kumamoto 2010).
Bronze Form, 2/6, in Copenhagen, was treated by John Farnham of the Henry Moore Foundation in 1988, two years after it was fabricated and, presumably, after it had darkened significantly. Notes from the Moore Foundation describe his process: the polished area at the top, front and sides were lightly burnished with an orbital sander to brighten the areas. Two coats of beeswax were applied and the surface was polished. He recommended waxing four times a year and a light abrasion of the polished parts with a pumice powder should they get too tarnished (Phipps 2010).

Fig. 5. Large Figure in a Shelter 0/1, current condition at Henry Moore Foundation, Perry Green. LH 652c. © The Henry Moore Foundation. All Rights Reserved. / ARS, New York / DACS, London (Photograph by Katrina Posner)

5. BRONZE FORM AT THE GETTY CENTER

Ray Stark bought Bronze Form 4/6 in 1986, just after it was cast, and it was sent directly from the Morris Singer Foundry to his home near Santa Barbara. It arrived damaged, and the Stark’s conservator wrote the following about its condition: “Numerous dirty hand prints overall, gauges in the metal along several of the edges, copper corrosion from moisture and chemical action, damage to the patina where the packing material stuck to the surface of the sculpture, runs from dripped chemicals. Overall,” she wrote, “it appears as though there has been abusive handling”
Reg Woolf, a representative from Morris Singer, traveled to California to address the issues and his treatment was as follows: “Completely sand down the sculpture to remove grease and discolourations, wash down and repatinate, wax and polish” (Woolf 1987).

Chris Boverhoff said that Woolf would have used an orbital sander to take the surface down to fresh metal followed by the application of patina, likely Liver of Sulphur. There are subsequent notes from Stark’s conservator that the sculpture was coated both with Incralac and wax, and recent analysis found the aforementioned acrylic urethane.

What is interesting about the treatment of these four pieces is that in each case, Foundation and/or Foundry representatives oversaw restorations that did not attempt to return the sculptures to their originally bright, unmodulated and unpatinated state.

As previously mentioned, the impetus for this research is the impending treatment of the Getty’s piece, which will involve removing the current acrylic urethane coating, reducing the extant corrosion, and potentially mitigating and integrating the surface anomalies of past treatments and damages. Though the balance of the treatment is still being discussed, it will likely not involve the application of a patinating chemical to the surface. And while the application of a wax coating seems to be most relevant in keeping in line with Moore’s wishes, it is a decision that would require a significant amount of staff time—rewaxing and polishing every few months to ensure the continuity and protection of the coating. Although this aspect is still being discussed, it is likely that the surface coating will be one akin to Incralac.

6. FUTURE CONSIDERATIONS

Derek Pullen, Head of Sculpture Conservation at Tate was consulted during this research process for his breadth of understanding and experience with Henry Moore and his works. His perspective is invaluable, as his consideration of Henry Moore and his aesthetic legacy goes back 25 years. Indeed, Alan Bowness who was then the Director of the Henry Moore Foundation, phoned Pullen on the event of Moore’s death to seek his opinion as to whether they could ethically keep the two final series moving through the Foundry, as not all of the sculptures were complete when he died (Pullen 2010). Ultimately, it was decided that the series would be finished as planned.

Pullen has argued for the development of a shared language between curators, art historians and conservators. Akin to the nomenclature of geology, which describes visual and structural minutiae in material, he argues for a language that describes the visual surfaces of modern sculptures – both those as they were originally finished and how surfaces have been transformed since – could be useful in the consideration of modern art. Jargon, he points out, has a place. It is a means of getting the “meaning across quickly between experts and interested parties” (Pullen 2010). Perhaps that is a step for the 21st century.

In this murky realm of an artist’s intention, it is important to keep in mind both the passage of time and the fluctuating concerns of those involved – both directly and peripherally—in a sculpture’s preservation. And while we as conservators are quite attuned to, reliant even, on facts and analytical results, outdoor works demand that we employ a certain amount of fluidity in our approach to their maintenance. It is, as always, important to keep our eyes and ears open to the collective story.
ACKNOWLEDGEMENTS

The research into these series was facilitated by colleagues throughout the world, and I am indebted to them for their help with the process. I would like to thank the staff at Henry Moore Foundation for opening their collective memories and current thoughts to this line of inquiry. Thanks also to Chris Boverhoff and those at Morris Singer Art Founders for an invaluable visit. I am grateful to the many conservators and professional colleagues who shared their thoughts and approaches to the care of Henry Moore’s sculptures. In particular: Carolina Izzo, Kozo Kumamoto, Katy May, Derek Pullen and Cameron Wilson. And finally, thank you to my ever-colleagues in Decorative Arts and Sculpture Conservation – Brian Considine, Jane Bassett, Arlen Heginbotham and Julie Wolfe.

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AN EXAMINATION OF PINNING MATERIALS
FOR MARBLE SCULPTURE

CAROLYNRICCARDELLI, GEORGE WHEELER, CHRISTINA MUIR,
GEORGE SCHERER, AND JOE VOCATURO

ABSTRACT

The use of pins or dowels in repairing stone has been common since ancient times. Conventional wisdom in art conservation suggests that repair materials such as pins or adhesives should have similar properties (such as strength and modulus) to the substrate. Stainless steel continues to be the most commonly used pinning material even though it has a much higher elastic modulus than that of marble. When planning the repair of a sculpture that will remain in a controlled museum environment, the reasons for choosing stainless steel (corrosion resistance, coefficient of expansion) become less important, and thus open up a wider variety of choices for pinning materials. Therefore, a set of tests was designed with the goal of determining the performance of a join using pins with reported moduli ranging from 0.5 to 197 GPa. These pins were set into Carrara marble cores using an epoxy resin adhesive and subjected to compressive-shear stress. Under these conditions, fiber-based rods such as fiberglass and carbon fiber out-performed both stainless steel and titanium in that they were of sufficient strength to withstand the maximum static forces of the sculpture being repaired and did not damage the stone core before pin failure. From these tests, the best-performing pinning materials were used in making full-scale stone mock-ups to evaluate the overall performance of a pinning/adhesive bond system.

1. INTRODUCTION

This paper is a summary of research carried to determine the best conservation practices for Tullio Lombardo’s Adam. The sculpture is one of the figures of the Vendramin tomb, which is now located in the church of Santi Giovani e Paulo in Venice. Dated 1490–1495, Adam is considered by scholars to be the most important monumental Renaissance sculpture in the Western Hemisphere (Remington 1937). It was acquired by the Metropolitan Museum of Art (MMA) in 1936.

In 2002, the sculpture fell when the pedestal beneath it collapsed. The sculpture, made of fine Carrara Marble, broke into several large pieces and many small fragments. The extremities of the figure, the arms, legs, as well as the decorative tree trunk, made up most of the fragments. The head and the torso were the least damaged and suffered minor losses.

The importance of the sculpture warranted a multidisciplinary collaboration to investigate new approaches to large-scale sculpture treatment. The Tullio team includes several conservators from the MMA’s Sherman Fairchild Center for Objects Conservation (Lawrence Becker, Michael Morris, Carolyn Riccardelli, Jack Soultanian, and Richard Stone), members from the Department of Scientific Research (Marco Leona, George Wheeler), Curators from the Department of European Sculpture and Decorative Arts (Ian Wardropper, James Draper), as well as the supervisor of the museum’s molding studio (Ronald Street).

In the time since the sculpture was damaged, the team has conducted extensive research in an effort to find the most suitable conservation treatment plan for this sculpture. Research has included CT scanning, 3-D laser scanning, and finite element analysis. Testing of conservation materials and methods has been systematically performed by teams of conservators, graduate students, and scientists.
2. BACKGROUND AND PREVIOUS RESEARCH

The high quality of Adam’s Carrara marble resulted in very clean breaks that fit together tightly. Thus, displacement of the fragments from added adhesive became a primary concern in choosing a treatment strategy. The characteristics of the breaks have guided the research approach throughout the project.

While many of the sculpture’s breaks are in compression, there are a few critical joins that are in a combination of compression and shear (fig. 1). Some of the most critical joins are at the ankles where the weight of the entire sculpture rests on the smallest surface area. These breaks occurred at an angle approximately 45° from the base. Another break in compression-shear is at the knee where there is a wedge-shaped fragment bridging the shin and the thigh of the left leg. Finite element analysis completed to date has shown that the load on any given join in the sculpture does not exceed 83 N/cm² (120 psi).

The tight joins found in the Tullio sculpture prompted the team to conduct adhesive testing with the goal of finding a strong reversible adhesive system with minimal glue-join thickness. Previous research has found that Paraloid B-72 alone or used as a barrier layer in combination with epoxy may be sufficiently strong under tension to be used as a structural adhesive (Podany et al. 2001).
2.1 INTERFACIAL FRACTURE TOUGHNESS SUMMARY

Since 2005, the Tullio team has carried out several materials research projects. The goal of the first project was to find an adhesive system strong enough to withstand the forces in the sculpture but not displace the joins. Columbia University Graduate Student Mersedeh Jorjani carried out an investigation into the interfacial fracture toughness— or strength—of several conservation adhesives (Jorjani 2007; Jorjani, Wheeler, et al. 2009; Rahbar, et al. 2010). Nine common conservation adhesive systems were tested on samples made of Carrara marble. The tested samples consisted of disks containing an elliptical hole in the center. Multiple samples were tested with the elliptical hole oriented at different angles with respect to an applied load. The resulting tensile load was increased until the sample broke into two or more pieces. The critical load at which the fracture occurred for each loading angle was recorded.

The best-performing adhesive system tested was a 3:1 blend of Paraloids B-72 and B-48N (see table 1), which displayed an energy trend that was close to that of Carrara marble alone. It is interesting to note that although the fracture energy of the B-72/B-48N blend tested to be slightly lower than that of marble alone, most fractures occurred within the marble itself, and not in the glue join. The same types of fractures were reported by Podany et al. in their 2001 JAIC article. When looking at the overall performance of the nine adhesive systems the thermoplastics were found to be nearly as strong as thermosetting adhesives. All of the tested systems were determined to have high enough strength for use on Carrara marble.

On the basis of these tests, the B-72/B-48N blend was selected for the treatment of Adam, because of its strength and ease of reversibility. This adhesive blend also performed well in a glue-join thickness investigation carried out in coordination with the fracture toughness study, as it resulted in a thin enough bond-width as to not cause significant displacement of Adam’s joins.

<table>
<thead>
<tr>
<th>Table 1. Recipe for thermoplastic adhesive blend</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-72/B-48N 3:1 Blend</td>
</tr>
<tr>
<td>40 g B-72</td>
</tr>
<tr>
<td>40 g B-48N</td>
</tr>
<tr>
<td>Above two mixtures combined 3:1 by volume</td>
</tr>
</tbody>
</table>

2.2 GLASS TRANSITION TEMPERATURE ($T_g$) TESTING

The goal behind combining the two thermoplastic adhesives was to adjust the $T_g$ of B-72. It was thought that B-48N would raise the $T_g$ of the blend and lead to better creep stability. Testing was carried out to determine the actual $T_g$ of the adhesive blend. $T_g$ testing was carried out at TA Instruments, facilitated by Dr. Gregory Smith of Indianapolis Museum of Art. The results were unexpected. The blend has a $T_g$ of 46° C, only slightly higher than the tested $T_g$ of B-72 alone (Smith 2010). It is interesting to note that in both cases the adhesives tested higher than the reported value, and in the case of B-48N substantially higher. The results of the $T_g$ testing are given in table 2.
2.3 CREEP TESTING SUMMARY

The Tullio team has also examined long-term stability of the tested adhesives, particularly in regards to creep. Columbia University Graduate Student, Andrea Buono, studied the creep behavior of adhesives for her Master’s thesis using a testing procedure developed at the Princeton Center for Complex Materials at Princeton University; the study was overseen by Dr. Nima Rahbar (Buono 2009). The creep testing samples were prepared the same way as those for Jorjani’s fracture toughness study. Two sample sets were prepared for each adhesive system, one with smooth join surfaces and one with fractured surfaces. A KG-B20 Krak-Gage was applied to each sample, which was then connected to a voltage meter. The sample was subjected to a load that was increased in incremental stages until some deformation was detected. All testing was done at room temperature.

The results of the load testing were subjected to mathematical calculations in order to extrapolate the short-term results into predictions of creep life over the long-term. The results are given in table 3.

Thermoplastics performed as well as thermosetting adhesives when the lifetime of a sculpture is taken into consideration. The graph indicates a very long-term gestation period for adhesive failure caused by creep. The adhesives tested can be classified as a Feller Class A2 material, lasting at least 100 years (Horie 1987). The B-72/B-48N blend performed very well for a thermoplastic adhesive and ranked a close second behind the B-72:Epotek 301-2 sandwich.

It is interesting to note that creep life predictions for smooth samples were higher by many of thousands of years compared to fractured samples made with the same adhesive. A possible explanation may be that an adhesive on smooth surfaces creates a more consistent bond, devoid of flaws. This result brings to the forefront the importance of how a conservator applies adhesive, and that a continuous, consistent film is critical to the strength of a joint.

Table 2. Results of $T_g$ testing

<table>
<thead>
<tr>
<th>Adhesive</th>
<th>Tested $T_g$ (°C (°F))</th>
<th>Reported $T_g$</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-72</td>
<td>$45\degree$ C (113° F)</td>
<td>$40\degree$ C (104° F)</td>
</tr>
<tr>
<td>B-48N</td>
<td>$69\degree$ C (156.2° F)</td>
<td>$50\degree$ C (122° F)</td>
</tr>
<tr>
<td>B72-B48N 3:1 Blend</td>
<td>$46\degree$ C (114.8° F)</td>
<td>n/a</td>
</tr>
</tbody>
</table>
3. PINNING RESEARCH

3.1 MODULUS TESTING

In a similar approach to the adhesive research, the Tullio team aimed to find a pinning material that would be strong enough to impart additional mechanical strength in the break, but not be so stiff as to cause damage in case the sculpture is ever subjected to future impacts. The early stages of the pinning testing were carried out by Columbia University graduate student Christina Muir who reported the results in her Master’s thesis (Muir 2008). The research was done in cooperation with the Tullio team as well as Wole Soboyejo and Nima Rahbar of the Princeton University Department of Mechanical Engineering.

The pinning research began with basic modulus testing. Modulus of Elasticity ($E$) is an indication of the stiffness of a material. The goal of the study was to determine if the stiffness of a pinning material effects how it behaves and performs in contact with marble. A variety of materials were chosen with a range mechanical properties, and elastic moduli. Pins were chosen based on their published modulus values, listed in table 4.

Because it was not always clear how the reported values were calculated, systematic testing of all materials was carried out with a single consistent technique. Samples of each material were tested using an Instron 4201, following the procedure for the ASTM Standard Testing Method for Ceramic Whiteware Materials (ASTM Standard C674-88), which is a 3-point bend test. Rods measuring 9.5 mm in diameter were cut into 100-mm lengths and placed on bearing edges spaced 76.5 mm apart. A load was applied at the midpoint between the two supports (fig. 2). Five specimens of each material were tested until either the material failed or they reached full extension.
The results are plotted in a graph of load vs. displacement. The graph describes two essential pieces of information about the pinning materials: the elastic modulus of a material—or its stiffness—and its mode of failure. The modulus of elasticity is determined along the initial slope of the graph as follows:

\[
E = \frac{4W^1L^3}{3d^4}
\]

where:
- \(W^1\) = load coordinate of the selected point (N)
- \(L\) = length of the span (mm)
- \(d\) = deformation coordinate of selected point; i.e. displacement (mm)
- \(d\) = diameter of specimen (mm) (ASTM Standard C674-88 2006, 4).

Figure 3 shows stress/strain curves for brittle failure (as with marble) and ductile failure (as with stainless steel). In ductile materials there is an elastic region (a) where the graph is nearly linear, and a ductile region (b), where there is significant strain before failure brittle materials (c) deform elastically until fracture occurs, they do not experience plastic deformation before failure. Such stress/strain curves correspond directly to the force/displacement curves illustrated in the remainder of this paper.
Stainless steel 316 is commonly used as a pinning material in marble sculpture, and has been chosen because of its strength and resistance to corrosion. The force/displacement graph produced from testing illustrates a typical ductile material with a linear elastic region and a long ductile region. It is in this ductile region that the material becomes permanently deformed as can be seen in the image of the tested samples (fig. 4, right). The calculated average modulus for stainless steel 316 was 55.58 GPa.

![Stainless Steel 316](image)

**Fig. 4.** (left) Force/displacement graph for stainless steel 316 rods (right) Stainless steel specimens showing ductile characteristics after testing (Photograph by C. Riccardelli)

On the other end of the modulus spectrum, are mold-cast Akemi Akepox 2000 rods. These rods were made to help answer what might happen if a pin hole were filled only with epoxy and no other material. While epoxy is generally thought of as an extremely hard material as an adhesive, in this form it is quite weak. The resulting force/displacement graph (fig. 5) shows that the epoxy rods produced an elastic region with low slope followed by a period of elastic deformation, and finally brittle failure. The modulus was calculated to be 3.26 GPa, which is similar to the elastic modulus of acrylic (Plexiglas) rods.

![Akepox 2000 Cast Rods](image)

**Fig. 5.** (left) Force/displacement graph for Akemi Akepox 2000 rods (right) Akemi Akepox 2000 specimens showing brittle failure after testing (Photograph by C. Riccardelli)
Carbon fiber reinforced plastic (CFRP) rods produced a graph with a steep elastic region, which is followed by a sudden failure, and then a wavy region. This type of failure, described as a kink, is typical of composite materials. It has neither a brittle or ductile fracture and the rod does not break in two (fig. 6, right). Rather, the vinylester plastic component fails but the fibers do not, thus producing a kink. The tested modulus of CFRP was 28.2 GPa.

![Force/displacement graph for CFRP rods](image)

**Fig. 6.** (left) Force/displacement graph for CFRP rods (right) CFRP specimens showing kinked failure after testing (Photograph by C. Riccardelli)

Structural fiberglass rods are also fiber based composites; in this case fiberglass fibers are embedded in a polyester resin. There is a kinking failure mode, as with carbon fiber rods, but with a lower slope (fig. 7). The tested modulus for structural fiberglass was 14.8 GPa.

![Force/displacement graph for structural fiberglass rods](image)

**Fig. 7.** (left) Force/displacement graph for structural fiberglass rods (right) Fiberglass specimens showing kinked failure after testing (Photograph by C. Riccardelli)

Finally, a set of 9mm diameter Carrara marble cores were drilled with a diamond core bit and subjected to 3-point bend testing (fig. 8). The tested modulus for Carrara marble was 6.7 GPa. This modulus is significantly lower than the reported modulus for Carrara because it describes the marble under compression. The three-point bend testing illustrates the weakness of marble in tension.
The results of the modulus testing are summarized in Table 5. The tested moduli differed quite a bit from the reported moduli, especially in the upper end of the range. Again, this exercise was done because the testing methods of the reported moduli were not given by their manufacturers, and a consistently obtained modulus for each material was desired.

<table>
<thead>
<tr>
<th>Material</th>
<th>Reported Modulus</th>
<th>Mean Tested Modulus (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teflon®</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Nylon</td>
<td>2.1</td>
<td>1.5</td>
</tr>
<tr>
<td>Acrylic</td>
<td>2.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Polycarbonate</td>
<td>3.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Kevlar®/Nylon</td>
<td>5.5</td>
<td>2.8</td>
</tr>
<tr>
<td>Fiberglass</td>
<td>35</td>
<td>14.8</td>
</tr>
<tr>
<td>Marble</td>
<td>55</td>
<td>6.7</td>
</tr>
<tr>
<td>Titanium</td>
<td>103</td>
<td>41.6</td>
</tr>
<tr>
<td>CFRP</td>
<td>Unrated</td>
<td>28.2</td>
</tr>
<tr>
<td>Stainless Steel</td>
<td>197</td>
<td>55.6</td>
</tr>
</tbody>
</table>

### 3.2 SMOOTH SURFACE MOCK-UPS

After modulus testing was completed, a set of full-scale models representative of the critical joints in the *Adam* sculpture were prepared. This first set of samples was designed to look specifically at the pin itself. The specimens were designed so that they would essentially isolate the behavior of the pin without interference by the join surface. The goal of this testing was to determine what happens to the marble when there is no adhesive on the joining surfaces, being dependent on the pin to hold the system together.
3.2.1 Sample Preparation

The samples were made with Carrara marble cores, measuring 10.2 cm in diameter and 20.3 cm long. Each core was cut at a 45° angle across the center of the cylinder using a Buehler Slab Saw. The angled surface was smoothed to minimize friction between the upper and lower halves and to focus force on the pin alone. Pin holes were drilled with a Lunzer diamond core bit on a drill press equipped with a water swivel. Akemi Akepox 2000 epoxy resin was used to secure the pins in place. Adhesive was not permitted to get on the smooth angled surface of the marble. For this set of samples the pins used were 10.2 cm long with a diameter of 1.4 cm. The pins were set into one half of the cylinder first, filling the adhesive up to the angled surface of the marble. The next day, that half was flipped over and inserted into the second half which had just enough epoxy inserted into it so it did no overflow onto the smoothed angled surface (fig. 9, left). Following a full cure time, testing was carried out at Princeton University in the Department of Mechanical Engineering Laboratory using an Instron 8501 Mechanical Testing Machine (Muir 2008).

All samples were subjected to gradually increasing compression loading at a rate of 0.01 mm/sec until there was failure of either the pin or the marble core. The combination of the downward compressive force of the Instron combined with the 45° angle results in an overall compression-shear force (fig. 9, right).

3.2.2 Stainless Steel 316 Testing Results

Stainless steel 316, with a calculated elastic modulus of 55.6 GPa is much stiffer than marble, which was tested to have a modulus of 6.7 GPa. When the specimen was pushed to failure, the pin remained intact, completely fracturing the core. A Y-shaped failure was typical for stainless steel as well as titanium (fig. 10). While the force required to reach failure (average
maximum load: 77 kN) in this test is higher than normal forces that exist in Tullio’s Adam—and likely most marble sculptures—it does give an indication of what might happen should a sudden impact occur.

3.2.3 Carbon Fiber Reinforced Plastic Testing Results
Testing showed that CFRP rods have an elastic modulus of about 28.2 GPa. In all three carbon fiber specimens tested, the marble core remained intact. The pin failed at an average maximum load of 62 kN. In one sample, the pin just displaced and did not completely separate, displaying the kinking behavior typical of fiber based composite materials.

3.2.4 Structural Fiberglass Testing Results
Not surprisingly, fiberglass behaved very similarly to CFRP, but failed at a lower maximum load. The modulus testing showed that fiberglass has an elastic modulus about two times that of marble. There was no damage to any of the marble cores with fiberglass pins, and
all pins broke cleanly through (fig. 12). The average maximum load to break the fiberglass rod embedded in the marble core was 59 kN—10 kN less than carbon fiber rods.

![Graph of force/displacement for structural fiberglass rods in smooth surface Carrara core](image1)

![Carrara core after testing, pin failure with no damage to core](image2)

3.2.5 Polycarbonate Testing Results

Polycarbonate rods are in the low end of the tested moduli. When tested, these plastic rods did not cause any damage to the marble cores. Significant plastic deformation occurred to the rod, as can be seen in fig. 13. The average maximum load for polycarbonate was substantially lower at 32 kN.

![Graph of force/displacement for polycarbonate rods in smooth surface Carrara core](image3)

![Carrara core after testing, pin with plastic deformation](image4)

3.2.6 Summary

The smooth surface testing set showed that the average maximum load corresponds well with the tested moduli of the pinning materials. Metal pins with their high elastic modulus proved too stiff, and caused the marble cores to break apart under an applied load. Fiber pins performed better and did not cause damage to the stone. Rather, the pin failed at a relatively high
applied load, indicating that these materials would be able to withstand the forces in a marble sculpture without causing damage to the stone in case of impact. Plastic pins with very low elastic moduli did not cause damage to the marble cores, but failed at an unacceptably low applied load.

3.3 FRACTURED SURFACE MOCK-UPS

Based on the results of the smooth surface tests, a selection of pinning materials were chosen for the fractured surface mockups. Titanium, CFRP, and structural fiberglass rods were chosen based on their promising performance in the smooth surface tests. This set of samples was designed as a mock-up of Adam’s ankle joins.

3.3.1 Sample Preparation

The fractured samples were prepared with the same 45° angle as the Carrara marble smooth surface set, but with a fractured join surface. The cores were smaller in scale—6.4 cm in diameter and about 15.2 cm tall. Because it was simpler to obtain and more affordable, the cores from this sample set were made of Vermont marble. Two pin-holes were drilled into each core with a Lunzer diamond core bit. The pin holes were then coated with a generous barrier layer of 10% B-72 w/w in acetone, and allowed to sit for several days.

![Fig. 14. (left) Diagram of fractured-surface mock-up (yellow area is epoxy, blue area is B-72/B48N blend) (right) Samples being prepared for joining (Diagram and photograph by C. Riccardelli)](image)

Pins 0.635 cm in diameter and 5.1 cm in length were set into the pinholes using Akemi Akepox 2000 epoxy in a similar manner as described for the smooth surface specimens. The fractured surfaces were joined with the B-72/B-48N blend (fig. 14). For the testing, all samples were subjected to gradually increasing compression loading at a rate of 0.05 mm/sec until there was failure of either the pin or the marble core.

3.3.2 Titanium (Grade 2) Testing Results

Titanium has commonly been used to repair marble sculpture and outdoor monuments because of its resistance to corrosion and its coefficient of expansion similar to marble. As with the smooth surface cores, titanium caused damage to the marble. All three samples were severely fractured while the titanium pin inside the sample was only slightly deformed by the applied load (fig. 15). The average maximum load for titanium was 59.41 kN.
3.3.3 Carbon Fiber Reinforced Plastic Testing Results

While testing did not show any damage to the smooth surface cores with CFRP rods, there was cracking in two out of the three fractured surface mock-ups CFRP rods (fig. 16). The elastic modulus of CFRP tested quite a bit higher than marble itself, so it is not a surprising result. The average maximum load in this sample set was 57.03 kN.

3.3.4 Structural Fiberglass Testing Results

Structural fiberglass rods performed the best in the fractured surface mockups causing no damage to the marble cores. In each sample, both the adhesive in the join and the fiberglass pins failed before there was any damage to the marble core, creating an ideal pinning system (fig. 17). The average maximum load for fiberglass pins was 41.51 kN.
3.3.5 No-Pin Testing Results

A set of cores fractured at 45° angle was adhered with no pin holes and no pins. This set was adhered only with the B-72/B-48N blend. After testing, there was no damage to any of the marble cores (fig. 18). The average maximum load was 50.65 kN, more than 9 kN higher than the fractured surface sample set made with structural fiberglass rods.

4. CONCLUSIONS

The use of pins or dowels in repairing stone has been common since ancient times. Conventional wisdom in art conservation suggests that repair materials such as pins or adhesives should have similar properties (such as strength and modulus) to the substrate. Stainless steel continues to be the most commonly used pinning material even though it has a much higher elastic modulus than that of marble.
When planning the repair of a sculpture that will remain in a controlled museum environment, the reasons for choosing stainless steel (corrosion resistance, coefficient of expansion) become less important, and thus open up a wider variety of choices for pinning materials. Fiber-based rods such as fiberglass and carbon fiber out-performed both stainless steel and titanium in that they were of sufficient strength to withstand the maximum static forces of the sculpture being repaired and did not damage the stone core before pin failure. It is significant that the set of fractured surface mock-ups prepared with adhesive only—and no pins—out-performed the sample set prepared with the best-performing fiberglass rods. All pins tested in the fractured surface mock-ups showed strength several orders of magnitude greater than the actual loads on the sculpture.

Will any of the joins on the Adam be pinned? It is the wish of the Tullio team to be as minimally invasive as possible, and to scale back the conventional approach to structural sculpture conservation. The jury is still out.

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NOTES

1. Finite Element Analysis (FEA) is accomplished by a computer model of a material that is analyzed for specific results. FEA is often used as a method of predicting failure by identifying problem areas and theoretical stresses within a material.

2. The Krak-Gage is a critical part of the fatigue-crack growth testing method. It is a thin, photo-etched, low-resistance metal foil, which functions as a DC transducer. The gages are bonded to the test specimen, and they yield a linear change in resistance vs. crack length. A propagating crack in a test specimen simultaneously propagates through the Krak-Gage. The change in voltage from the displacement of the Krak-Gage is translated to the attached Fractomat voltage meter and subsequently recorded by data acquisition software. The software then graphs crack length (a) vs. time (t). [http://www.krak-gage.com/krakgage.html](http://www.krak-gage.com/krakgage.html)

3. At the time of sample preparation, the Tullio team was considering using two small pins in the ankle in order to counteract the natural torque of the figure, as was determined by finite element analysis. Since that time, the team has decided to return to a single-pin scenario.
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SOURCES OF MATERIALS

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THE SCIENTIFIC EXAMINATION AND RE-TREATMENT OF
AN EGYPTIAN LIMESTONE RELIEF
FROM THE TOMB OF KA-APER¹

KATHLEEN M. GARLAND AND JOHN TWILLEY

ABSTRACT

Egyptian limestone sculpture in Western collections has often been subjected to repeated, well-intentioned treatments that are the result of an incomplete understanding of the issues surrounding the removal of sculpture from an archeological setting to a poorly controlled interior environment. Remedial treatments often follow without scientifically investigating the causes of deterioration. An important Old Kingdom painted limestone relief from the tomb of Ka-aper (fig. 1) at The Nelson-Atkins Museum of Art will illustrate past treatment failures and successes, and the need for consultation and scientific investigation in planning re-treatments.

Severe flaking of the surface required consolidation to withstand de-installation from a wall in 1992, resulting in major staining. In 2006 experts gathered to study the deterioration and staining with re-treatment of the stone in mind. A scientific study included mineralogical analyses, pore size measurements and soluble salt content studies. Analyses of areas with staining or apparent prior consolidation revealed applications of natural resins, a drying oil, polyvinyl acetate and cellulose nitrate.

These results and the experiences of the consultants formed the basis for the re-treatment. Backing removal and desalination posed greater risks than surface treatment, while environmental control was seen as the means for preventing future damage. Consolidation was undertaken with methylcellulose paste. The stains from previous consolidation attempts were reduced using benzyl alcohol in Laponite poultices.

Fig. 1. Relief of Ka-aper and his Wife, Fifth Dynasty, after conservation, 2008 (Photograph by K. Garland)

1. DESCRIPTION AND BACKGROUND

Fragments of a limestone relief from the early fifth Dynasty depict Ka-aper facing to the left, holding a staff in his left hand, embraced by his wife, who stands to his right. There is an inscription listing titles and names of Ka-aper and his wife running along the proper right side
and across the top. The low relief sculpture has traces of polychromy, mostly in the flesh and hair, and measures 28 x 59 in. (71.12 x 149.86 cm). Both Ka-aper and his wife’s eyes have gouge marks done with chisels. Under magnification these gouges have a patina that matches the patina and texture of the aged stone surface, suggesting that the damage dates to antiquity.²

The relief is part of the Abusir mastaba of the royal official, Ka-aper (Fischer 1959; Kanawati and Hassan 1996, 35; Barta 2001). Much smaller relief fragments from the same tomb can be found at the Metropolitan Museum of Art (08.201.2) and at the Detroit Institute of Art (57.38). The relief in Detroit is apparently in good condition and may never have been treated (Peck 2007). There are no treatment records at the Metropolitan Museum, but the limestone appears to have been heavily cleaned at some time. The relief was acquired from the Parisian dealer Paul Mallon in 1946.

2. CONDITION

Eleven fragmentary blocks of fine creamy limestone are held with modern plaster mortar and copper cramps to a grey limestone backing support. It is evident from tool marks along the edge of the relief that the blocks were cut from the wall of the tomb. Several of these blocks have been broken and repaired. A larger area of fill material from the proper right side of the relief, measuring 8 x 13 in. (20.32 x 33.02 cm), was found to be a piece from the late 5th–early 6th century C.E. Egyptian Arch (48-11), displayed nearby and purchased from Paul Mallon in 1948. The proper right corner has been filled with a similar material measuring 4 x 6 in. (10.2 x 15.3 cm). There is an old break with plaster fills running diagonally between Ka-aper and his wife. Large areas of shallow stone loss exist in the chest of both figures. Some of the losses in Ka-aper have been filled with white plaster and crudely overpainted, though generally the overpaint on the plaster fills is close in tone to the limestone. There is a triangular piece of carved limestone forming the nose and chin of the woman that has a very different yellow tone, and might be questioned as a modern replacement carving. However the blue and green paint of the necklace are clearly ancient. Three early undated negatives reveal the appearance of the relief prior to and during a restoration campaign.³, ⁴ One negative shows the fragments assembled without any fills. Handwritten in French on the negative is “Etat primitif du bas relief lors de l’achat,” and “mise en place des morceaux avant la mise en place du fragment” (fig. 2). A second negative shows the missing fragment with the chin and nose, with the note “partie du grand bas relief collée sur un papier d’emballage lors de son achat” (fig. 3). A third negative shows the chin and nose fragment in place on the relief fragments, which are resting on blocks of wood. The handwritten inscription says “deuxième état du bas relief après l’achat de la partie reproduite photo B” (fig. 4). Apparently the triangular piece of stone does belong to the relief, but was separated at some point, then was found, purchased and re-inserted in its original location, possibly by a restorer employed by Paul Mallon.⁵ The different appearance of this fragment is likely due to a slightly different restoration history. These three negatives also indicate that some carved areas, such as the wigs, are in much better condition than in the earliest Nelson-Atkins images, but loss had already occurred before the Museum purchased the relief.
Fig. 2. Enhanced digital image taken from an undated negative (Courtesy of The Nelson-Atkins Museum of Art)

Fig. 3. Enhanced digital image taken from an undated negative (Courtesy of The Nelson-Atkins Museum of Art)
3. CONSOLIDATION TREATMENT PRIOR TO 1992

Many areas of the relief were given consolidation treatments to re-adhere fragile paint and flaking stone, which saturated and stained the colors on the figures producing a darker, glossy surface. Analysis (see below) identified three different materials used for consolidation, possibly during a restoration done while in the hands of Paul Mallon. Consolidation seems to be the cause of the grey shadow or discoloration around the figures noted by Henry Fischer in his article on the tomb as “paint being applied too thickly, so that the aqueous medium has spread into the surrounding area” (Fischer 1959, 239). These stains around the heads of the two figures are obvious in the earliest known black and white negative (fig. 2), but have a different shape than the ones visible in the undated black and white image of the installed relief (fig. 5). The latter have produced a somewhat gray discoloration that appears very clearly as a shadow around the woman’s head, and may be related to a stain seen on images of the Ka-aper fragment in Detroit where a similar line of discoloration is present. More analysis needs to be done to distinguish the possible consolidation sequence, but visual observation suggests that the gray stain is different from a material applied to consolidate the stone flakes, which has a yellowish tone. This yellowish adhesive is mostly covered by a chalk wash or slurry, presumably applied to conceal the adhesive stains (figs. 6, 7). A third consolidation material found on the painted areas is a clear, shiny resin that has remained acetone-soluble. Many of the consolidated flakes are misaligned, or out-of-place, and particles of dirt have been incorporated into the consolidation.
The woman’s hair is a good example of this untidy consolidation; her wig is now saturated with consolidant and appears almost black, when it should probably have looked blue. Pigmented wax fills were added to Ka-aper’s face, probably all at the same time as the third consolidant, since the losses are un-restored in all the pre-installation photographs.

Fig. 5. Undated photograph of the relief in the Museum installation (Courtesy of The Nelson-Atkins Museum of Art)

4. SOLUBLE SALT DAMAGE AND THE 1946 MUSEUM INSTALLATION

The earliest, undated photograph of the relief in the Museum installation shows the relief restored, but with severe flaking around the two figures (fig. 5). This flaking is visible to some degree in the early negatives (fig. 2), but the lighting in the image makes it difficult to assess precisely how much deterioration occurred after installation. The original Nelson-Atkins installation had placed the relief in a niche closely adjacent to water pipes so hot that a hand could not touch them for more than an instant. Furthermore, hygrothermograph charts in the galleries indicated frequent periods of relative humidity above 80% as the heating and cooling systems (HVAC) only ran during operating hours until 1989, when the HVAC started to run 24 hours a day. The environmental fluctuations and hot, dry conditions behind the limestone could easily have contributed to the solubilization and re-crystallization of salts, leading to more loss on the carved surface.

A conservation examination report from 1992 describes the loss of surface, particularly in the hair, flesh and surrounding the figures (Conservation Department 1992). Much of this loss is visible in the undated negative described above (fig. 2), but it is likely that more occurred after the consolidation attempt discolored the stone, possibly while in the care of Paul Mallon. The surface exfoliation is particularly serious around the heads, with less activity in the inscription. Under the flakes of stone there is usually a pitted area or shallow loss about 1–3 mm. There is little visual evidence of soluble salt activity in the form of small salt crystals, except around some of the fresher plaster fills, but scientific studies (described below) later confirmed soluble salts have been involved in the flaking. A slurry of chalk and water, close in color to the Egyptian limestone, was brushed over the damaged areas, as well as over the stains around the two figures. This wash was not applied to the entire surface; the usual scraping and tool marks can be seen around the inscription and areas without the chalk wash are in distinctly better
condition. The slurry restoration is likely to have occurred before the relief came to Kansas City, perhaps to conceal stains caused by the initial consolidation. Another crude intrusion is thought to have taken place during installation at the Museum. The top edge of the relief was cut away, using a circular saw, by 2 cm and the proper left side by 1 cm, probably to make the relief fit better into the gallery wall.

Fig. 6. Cross section through the carved surface in the SEM. The red arrow indicates the slurry layer.

Fig. 7. UVC radiation showing fills. Arrows indicate areas with slurry. Slight orange fluorescence indicates consolidants applied at some time prior to 1991.
5. CONSERVATION INTERVENTION 1992

A gallery renovation in 1992 with a tight construction schedule necessitated the removal of the relief without pursuing detailed scientific studies. The relief had been firmly plastered into a niche since it was acquired by the Museum, and was covered with a sheet of clear acrylic at some point. An undated drawing in the files suggested that the stone fragments were mounted within plaster on a wire mesh set against a brick tile wall (Conservation Department 1992). Marble trim matching the walls of the gallery had been plastered and tied with wire twists to the brick tiles (fig. 8). The fragile flaking surface clearly required yet another consolidation treatment before the relief could be subjected to the vibration involved in chiseling off the surrounding plaster and marble (fig. 9). An ideal consolidant should be just strong enough for the job, reversible, stable over time, have low toxicity for the user, and be unlikely to aggravate soluble salt migration.

Since fine Egyptian limestone is easily stained and discolored by most consolidants typically used by conservators, a variety of reversible adhesives with a sound history of conservation use were discretely tested by the primary author. These tests were located along the flaking edge surface of the relief. The consolidant mixture was applied either with a hypodermic or by using drips from a fine brush. Methylcellulose 2 % w/v in water was found to be the consolidant that least affected the color of the stone, but it was also deemed too weak for the purpose, plus the addition of any water to a stone with probable soluble salt deterioration was not desirable. A 2 % isinglas (fish glue) solution was much stronger but also darkened the surface, and had the same concerns about introducing water into the limestone. Paraloid B-72 3 % w/v in acetone, toluene and 1:1 ethanol acetone mixtures were judged to stain the stone unacceptably, though of the two the ethanol acetone mixture had the best appearance. Of the synthetic adhesives, the one that best fit the criteria of strength, acceptable staining and reversibility was a
resin more frequently used in wood consolidation, Butvar B-98 in an ethanol/toluene mixture (Spirydowicz et al. 2001). There is evidence that the resin may crosslink under extreme circumstances such as high temperature, or excessive ultraviolet radiation, but these are unlikely in a museum environment (Spirydowicz et al. 2001, Horie 1987). Another slight risk is the dissolution and re-crystallization of soluble salts on a small scale because of water naturally present in ethanol. These risks were weighed by the conservator and the curator of Art of the Ancient World against the other desirable qualities of the Butvar B-98, and the risks were deemed acceptable. The consolidation of the flaking stone proceeded using a mixture of Butvar B-98 2%–3% w/v in 80:20 ethanol and toluene injected with a hypodermic after ethanol was used to pre-wet the surface. The consolidant wicked under the slurry and flaking stone and the usual darkening of the surface occurred as the mixture wet the stone surface. The relief was again tented with Saran wrap to slow the evaporation of the solvent mixture. This technique would theoretically minimize the adhesive from following the evaporating solvent to the surface of the object and cause saturation or darkening. However, when the surface was examined the next morning there was considerable darkening, more than had been suggested by the earlier testing along the edge. Attempts were made to move or remove what appeared to be excess consolidant using cotton swabs and/or sable brushes with solvents, as described above. Regrettably the staining only got worse, perhaps because older consolidants were re-dissolved by the fresh solvents (fig. 10).

At this point the curator and conservator decided to press forward with dismantling the relief from the wall, since the exfoliating surface did seem much stronger, and the staining could be further investigated after the relief was detached. The conservator chiseled the plaster out of the wall and found that the installation was close to that suggested by the undated diagram. When the relief was removed it was found to have been mounted using plaster of paris with small copper alloy clamps to a gray limestone backing 2 cm deep and shaped to conform to the relief (fig. 11). Once the relief was brought to the conservation laboratory, further attempts were made to reduce the staining by dissolving and drawing the consolidant out of the stone and into paper poultices. These did not help much with stain removal. After much discussion the relief of Ka-aper was put in storage until a proper scientific investigation into the causes of the flaking and staining would be possible.

6. CONSERVATION STUDY 2006–2008

In 2006 a group of specialists was assembled at the museum to study the relief and propose a treatment methodology. In order to plan for the treatment and future display of the relief of Ka-aper a series of meetings between consultants, the Nelson-Atkins Conservation staff and the museum’s Mellon Scientific Advisor were held to review the history of the relief and its present condition. All agreed that scientific investigation was critical before a treatment could be proposed. A series of follow-up meetings, examinations of the companion relief at the Detroit Art Institute, and examinations of the long-studied Abydos reliefs at the Metropolitan Museum of Art resulted in recommendations by the consultants regarding the need for testing of this artwork and proposals for treatment. A series of analytical investigations were undertaken in order to understand the root causes of the surface damage and discoloration phenomena and to answer questions posed by conservator in advance of treatment.
Fig. 9. Raking light detail of the surface flaking

Fig. 10. Location of some of the consolidation stains from the 1992 treatment
7. SUMMARY OF LABORATORY INVESTIGATIONS

Tests that could best be handled by standardized methods of analysis available in the commercial sector, or through agreement with colleagues, were conducted by outside laboratories on samples collected by the project scientist. The project scientist performed tests for which observational experience with antiquities was important for interpretation, or where flexibility was required in the methods to be applied to extremely limited material.

Quantitative X-ray diffraction analysis was performed on two samples of stone from below well-preserved and poorly-preserved surfaces. Particular attention was paid to the quantity and type of clays found in the stone and their potential for swelling. Petrographic analysis was conducted on the same samples as a means of identifying localized concentrations of clays and of assessing the cohesion or “lithification” of the limestone. No clay-rich strata were observed in the samples and the overall clay content was only between 1.4%–1.8%. Fortunately, montmorillonite clay was in the minority even in this total, suggesting that this example is not one highly susceptible to damage due to clay swelling. Petrographic analysis indicated that the
Calcareous sediments have been extensively recrystallized, and that this contributes to the cohesion of the resulting stone.

Nannofossil analysis, which holds the potential to place boundaries on the geological period in which the limestone originated, was made difficult by the scarcity of intact examples in the recrystallized stone. Based on a very limited population of examples, the stone was determined to be a marine limestone broadly dated to the Middle Jurassic to Late Cretaceous period of 170–165 million years before present (Quinn 2007). It was found to be relatively free of the deleterious properties associated with the most unstable Egyptian limestone sculptures: layered strata containing expansive clays, high salt content, and poor intergranular bonding of sediments (Talbot 2007). Trace levels of iron pyrites found in the stone were not undergoing or showed no evidence of active oxidation or damage, but seemed to be the geological basis for small amounts of iron that contribute to the yellow cast of the stone. Natural redistribution of iron traces may have been a confusing factor in prior restorations during attempts to match local colors.

The plaster used in the relief’s prior mounting was found to be a simple plaster of paris without evidence of any role in exacerbating damage to the relief. The overall salt content of the limestone was found to be around one half of one percent, a relatively low value compared to many salt-damaged stones (West Coast Analytical 2007). Importantly, the only salt associated with surface damage was sodium chloride and the next largest components were nitrates in the interior of the stone. Numerous sodium chloride crystals were observed through scanning electron microscopy under the flakes of stone. Sulfates, with their higher potential for damage, were found at lower levels and not associated with the surface losses.

Samples collected from the surface demonstrated that some of the damage resulted from applications of a chalk slurry applied in prior restorations, probably to conceal surface losses in the limestone. Analyses of the organic components of areas exhibiting staining, surface sheen, or apparent prior consolidation revealed a history of applications involving natural resin, a drying oil, and cellulose nitrate. Polyvinyl acetate was found locally, but was not confirmed to have been intentionally applied to the relief. The mechanism and materials associated with the discoloration around Ka-aper’s head, mentioned in Fischer’s article, and also visible on the Detroit relief, could not be positively identified.

Pigments that could be identified represented simple components of the Egyptian palette drawn from natural mineral sources with the exception of carbon black and the man-made furnace product Egyptian blue. A final determination on whether the female originally was painted with an iron oxide yellow could not be made, since only slightly elevated levels of iron were found in the stone surface. The situation was complicated by the fact that calcium oxalate alteration products were found in a few locations on the relief surface, including some of the ones which presented a yellowed appearance.

8. SOLUBLE SALT CONTENTS

The existence of efflorescent or sub-fluorescent salts at the surface is an indicator of the presence of potentially damaging salts. However, the species that can be identified in surface deposits are dependent upon the environmental history of the stone and do not necessarily represent the type or proportions of salts found deeper in the stone. Information on these is needed because salts play an important role in maintaining the equilibrium moisture content of the stone at any given relative humidity imposed by the environment. This information must be considered in order to
anticipate the potential benefits or detriments of a shift in environmental conditions. While the equilibrium relative humidity of saturated solutions of common salts is well-established, the behavior of mixed salt solutions is considerably more complex. There have been organized attempts to develop systems for predicting the behavior of mixed salts (Price 2000). However; there have also been well-controlled practical experiments that document deviations from the behavior predicted by such models. In at least one case, important deviations have been noted in salt-damaged Egyptian limestone with continued salt crystallization under conditions predicted to halt crystal growth (Nunberg et al. 1996). It has been noted that systems involving nitrate ions are less-adequately modeled than others at present and that non-uniform distribution of salts in stone imposes a limitation on the ability of such methods to predict behavior (Price et al. 1994). In the present case, and in many prior investigations involving exterior stone and masonry, nitrates were readily detected in interior samples but were not present in surface samples.

The information gained about the soluble salt contents of the limestone was later incorporated into the case design. The primary environmental threat is sodium chloride dissolution, at around 75% relative humidity (Brigham Young University), and the subsequent damaging re-crystallization of the salt in the stone pores. Since the relative humidity at the Museum is maintained at a very even 50% ± 5%, we anticipate that a well-designed display case with silica gel added to the interior chamber will be sufficient to protect against major spikes of humidity due to possible HVAC malfunctions.


Once the scientific report was complete, a treatment approach was developed. All past interventions have caused some damage to a very fragile surface (figs. 9, 12). The history of treatment of salt-damaged Egyptian limestone has shown that scientific study is critical for understanding the true physical condition of the stone and its inherent vulnerabilities, and thus to prevent future damage. As noted above, the analysis indicated that the modern plaster backing is not contributing significant quantities of salt to the deterioration of the surface, so that a risky plaster and backing removal is not necessary. Furthermore, the clay-rich strata that often are responsible for a high degree of swelling susceptibility in Egyptian lime stones are not present. The only soluble salt of major concern is sodium chloride, which can be controlled environmentally. The risks inherent in poulticing to remove the salts did not seem justified in light of their type and distribution. The disfiguring modern materials, the shiny adhesive and white slurry covering the surface of the relief were found to be 20th century additions, to be removed if possible. Treatment could be limited to consolidation with weak adhesives; stain removal, and if possible should be followed with judicious cosmetic re-integration. While the extreme deterioration suffered from poor restoration in the past cannot be reversed, the visual results can be reduced.

The choice of consolidant was limited to methylcellulose (mc) 1.5%–2% in water, since it did not stain the stone. Methylcellulose is not a very “strong” consolidant, but the other synthetic polymers tested in 1992 are likely to result in more stains. Other possible plant or animal-based consolidants such as gelatin, fish glue and funori10 require more water than methylcellulose, darken the stone more, or cause light tide lines. The small quantities of water in the methylcellulose are also unlikely to activate any soluble salts. The methylcellulose has good aging qualities and remains re-treatable (Feller et al. 1990; Kühn 1986; Hatchfield 1988). Gentle pressure with a sable brush on some of the consolidated flakes suggested that the methylcellulose...
was a stronger adhesive than might be expected. Any areas requiring a structural adhesive were adhered using Paraloid B-72 50% w/v in acetone.

Flaking and stained areas several inches wide were selected for cleaning and consolidation tests. All cleaning and consolidation was done under a binocular microscope. Ethanol was applied with a small bush to pre-wet the areas needing consolidation. The ethanol quickly soaked under the top of the stone surface, confirming the project scientist’s observation that most of the carved surface has a porous sub-surface caused by the soluble salt activity. The methylcellulose was then injected to fragile areas and allowed to dry. Laponite RD poultries were made using benzyl alcohol. The solvent was added to the powder to make an appropriately thick slurry. The slurry was applied using small spatulas where the stone was strong enough, or using a hypodermic without a needle in weaker areas. The hypodermic required a more dilute poultice mixture.

The poultries were allowed to dry for two or three days, until cracks developed in the poultice. At this point the Laponite was dry enough to be lifted with a scalpel off the surface in small flakes, and dusted up using a vacuum cleaner on low suction. If the Laponite was removed before it was dry, the stone below was too spongy to clean safely. The poultice was very effective at removing stains, even those caused by the methylcellulose, but the solvent gelled the methylcellulose making it harder to clean the dried poultice in places where there is excess consolidant. It was often necessary to reconsolidate areas, and then apply another poultice to remove the mc stains. Any small fragments of stone that were dislodged were either re-adhered, if they could be relocated, or bagged and saved. A number of small stone fragments (millimeters in diameter) were completely pulverized, especially during the early phases, before the technique was more developed. The removal of discolored, increasingly intractable, old consolidants seemed to justify the very small stone losses. The biggest visual changes occurred in the wigs and faces, where the shiny, saturated resin was very effectively removed. A further benefit was the removal of the adhesive stains behind Ka-aper’s head, revealing a discoloration similar to that seen in the Detroit relief. Surprisingly, the remaining particles of paint in the jewelry were well attached, so cleaning was quite effective even in these areas.
After poulticing, the stone often had a hazy white appearance. Several samples of materials used in the cleaning of the stone were examined to determine whether any salt was being transferred from the relief into the mixture, and whether residues of the Laponite remained on the limestone. SEM examination showed that it was removed fully, even in areas of high surface roughness. Chlorides were not detected in the dried Laponite, suggesting that the stain removal had been achieved without remobilizing salts near the surface. Nevertheless, particles of Laponite have unavoidably been left in and under many of the flaking areas. These were excavated as completely as possible using #11 scalpel blades, but the Laponite cannot be removed entirely without further damage to the stone.

Unfortunately it was not possible to remove the white slurry without damaging the original limestone beneath; however the slurry is close in color to the stone and is not too visually disturbing. The exfoliating stone surface does remain visible since there is no way to lay the flakes of stone flat. However the methylcellulose consolidant is preventing further loss and can be re-applied should it be necessary. Reducing the stained and shiny adhesives from the previous consolidation efforts has considerably improved the appearance of the relief, and was well worth the effort.

Filling and inpainting was undertaken after consulting with Dr. Diana Craig Patch, Metropolitan Museum of Art, and with Dr. Robert Cohon, Curator of Art of the Ancient World at the Nelson-Atkins. The filling material consisted of 7% Klucel G (hydroxyl propyl methyl cellulose) in ethanol with 1:1 glass microballoons (3M Scotchlite) and cellulose powder mixed with dry pigments. This matched the texture of the stone quite well, was thixotropic and may be easily reversed with solvents or by mechanical means. Inpainting was done with dry pigments mixed with methylcellulose. The inpainting was restricted to old and new fills only; no paint was applied to stone. Thus there are fill areas which remain visually obvious, but it was deemed preferable to reduce further treatment of the already damaged stone. Only the fill on Ka-aper’s cloak and nipple area were modeled to match adjacent carving, since Patch felt that these two areas would not interfere with art historical dating, and would make the piece more legible. Filling the wife’s right arm and Ka-aper’s mouth was discussed, but this was considered too extreme for an important archeological piece.

10. CONCLUSION

The limestone relief of Ka-a-per and his Wife has suffered greatly from past interventions, and regrettably the damage will always be visible. Sometime during the 1940s disfiguring surface flaking caused by soluble salt re-crystallization required consolidation. The restorers used materials current at the time, such as natural resins, drying oils, and cellulose nitrate, probably without considering appearance changes as these resins aged and shifted color. Stains from the initial consolidation were concealed by a chalk and water slurry, close in color to the stone. It is probable that the wet slurry aggravated the soluble salt activity that originally caused the surface exfoliation. The plaster of paris used by the restorers for assembly must have introduced considerable water to the stone as well. The 1992 consolidation by this conservator was well intentioned, but done under the pressure of a deadline, and without the benefit of a scientific investigation. When this study did take place it guided the treatment by identifying the salts responsible for the surface damage. The quantity of plaster of paris used in the early restoration made it likely that gypsum might be a source of the damaging salts and that these might be sulfates, but the scientific study indicated that sodium chloride was the salt involved in the
surface damage. Thus a risky plaster removal and backing was avoided, and the sodium chloride can be controlled with a stable museum environment of 50% relative humidity. Regrettably the flaking of the stone surface cannot be reversed.

A collaborative approach to the scientific study and treatment methodology should be considered part of any intervention on artifacts that are in poor condition and have suffered from past restorations. Viewing the relief in person with the consultants, comparing associated stones from the same tomb and discussing similar treatments with experts was important to establish the treatment methodology, and allowed for a rich exchange between the responsible art historian, conservator and conservation scientist. Together we were able discuss our concerns and expectations, make informed decisions, and do the best possible treatment for the relief of Ka-aper and his Wife.

ACKNOWLEDGEMENTS

The authors wish to thank the Andrew W. Mellon Foundation for funding the scientific research. From The Nelson-Atkins Museum we thank Dr. Robert Cohon, Curator of Ancient Art; and Elisabeth Batchelor, Director of Conservation and Collections Management.

APPENDIX

<table>
<thead>
<tr>
<th>Consolidant tests, 1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methylcellulose and Klucel G</td>
</tr>
<tr>
<td>Isinglas (fish glue) and Jade 303</td>
</tr>
<tr>
<td>Acryloid B-72 3% in toluene</td>
</tr>
<tr>
<td>Acryloid B-72 3% in acetone</td>
</tr>
<tr>
<td>Acryloid B-72 3% in acetone/ethanol 1:1</td>
</tr>
<tr>
<td>Butvar B-98 2% in ethanol and toluene</td>
</tr>
</tbody>
</table>
### Pigments Identified using SEM, 2007

<table>
<thead>
<tr>
<th>Description</th>
<th>Pigment Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black pigment from woman’s wig over ear</td>
<td>Carbon black</td>
</tr>
<tr>
<td>Black of Ka-aper’s wig</td>
<td>Carbon black</td>
</tr>
<tr>
<td>Blue-green pigment over white ground on woman’s neck</td>
<td>Egyptian Blue (calcium copper silicate) and malachite</td>
</tr>
<tr>
<td>Dark green pigment under brown coating from Ka-aper’s necklace (alters with contrasting green)</td>
<td>Copper chlorides. It is likely that larger samples would have contained other copper species responsible for the greater saturation and bluish cast of this layer.</td>
</tr>
<tr>
<td>Light green pigment on hieroglyph</td>
<td>Copper chloride. It should be remembered that in the presence of sodium chloride, many ancient Egyptian pigments containing copper have been found to have altered to copper chlorides, so that the original mineral may have been another copper species</td>
</tr>
</tbody>
</table>

### Stain Removal Tests, 2007

<table>
<thead>
<tr>
<th>Method</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toluene and acetone on swabs</td>
<td>Moved stain around, not much is removed</td>
</tr>
<tr>
<td>Toluene and acetone, cotton poultices</td>
<td>Moved stain around, large tide lines</td>
</tr>
<tr>
<td>Benzyl alcohol on swabs</td>
<td>Moved stain around, tide lines</td>
</tr>
<tr>
<td>Benzyl alcohol, cotton poultice</td>
<td>Not much effect, stain moves, removes shiny resin on faces</td>
</tr>
<tr>
<td>Benzyl alcohol, Laponite RD</td>
<td>Excellent stain removal, not too much tide line. Must wait till full dryness of poultice. Minimal residues, except where preconsolidated with methyl cellulose.</td>
</tr>
<tr>
<td>Benzyl alcohol, acetone Laponite RD</td>
<td>Same as above</td>
</tr>
<tr>
<td>Cyclododecane in benzine applied to strengthen lifting stone flakes, benzyl alcohol Laponite poultice applied.</td>
<td>Heavy tide line even after CDD sublimates</td>
</tr>
<tr>
<td>Benzyl alcohol, Sigmacell 50 cellulose powder</td>
<td>Decent stain removal, but the cellulose power is very difficult to remove</td>
</tr>
<tr>
<td>Methanol on swabs</td>
<td>Not much effect, moves stain around</td>
</tr>
<tr>
<td>Methylene chloride on swabs</td>
<td>Even less effect</td>
</tr>
<tr>
<td>Benzyl alcohol, Laponite RD, Japanese paper interleaf</td>
<td>Decent removal, but very thick tide line around the edge of the paper</td>
</tr>
<tr>
<td>Benzyl alcohol, Sigmacell 50 cellulose powder with a Japanese paper interleaf</td>
<td>Poor removal, tide lines.</td>
</tr>
</tbody>
</table>
NOTES

1. A version of this paper will appear in The Journal of the American Research Center in Egypt (JARCE 45).

2. A similar gouge mark is visible in the smaller fragment of Ka-aper from the same tomb, now in the Detroit Museum of Art.

3. The negatives are located in Imaging Services, The Nelson-Atkins Museum of Art, accession number 46–33.

4. Fischer obtained prints of negatives he had seen in the Saqqara office of the Egyptian Department of antiquities in 1956. He apparently used images of two blocks of hieroglyphs above the Nelson-Atkins image to assist in determining a possible location of the relief in the mastaba.

5. There are no records before the 1990s noting any restoration. Until the objects conservation lab was established in 1989, sculpture purchased by the museum was usually restored prior to its arrival in Kansas City. The notations in French on the negatives and the discovery of a fragment of the Arch purchased in 1948, used in the restoration of the relief, purchased in 1946, both from Paul Mallon, suggest that the restoration may have taken place under his direction. It is not uncommon for mason/restorers to reuse old fragments that are lying around in their shops.

6. When salts naturally present in the stone, or ones that wick into the stone from adjacent sources go through cycles of wetting and drying, they can migrate through stone pores when wet and recrystallize when dry. This re-crystallization can exert physical pressure on the stone pores, often causing physical decay in the stone. Typical soluble salts of concern are sodium chloride (table salt), as well as various compounds of nitrates and nitrites, sulfates and carbonates.

7. Polyvinyl butyral, a polyvinyl acetal resin formed by the reaction between aldehydes and alcohols.

8. The team included Dr. Robert Cohon, Curator, Art of the Ancient World; Elisabeth Batchelor, Director of Conservation and Collections Management; Kathleen Garland, Conservator; and Joe Rogers, Conservation Associate, all from the Nelson-Atkins Museum. Consultants included Jerry Podany, Head of Antiquities conservation, The J. P. Getty Museum; John Twilley, Project Scientist, Hawthorne, NY; and George Wheeler, Research Scientist, Metropolitan Museum of Art, NY.


10. Funori is a mild consolidant and adhesive used by Japanese scroll conservators, and is made from seaweed.
REFERENCES


Quinn, P. 2007. Research Officer, Archaeological Ceramic Analysis, Department of Archaeology, the University of Sheffield, UK. June 2007 report.


**SOURCES OF MATERIALS**

Sigmacell cellulose fiber, type 50
   Sigma Chemical Co.
   St. Louis, MO

Cyclododecane
   Kremer Pigment, Inc.
   228 Elizabeth St.
   New York, NY 10012

Glass microballoons
   3M Scotchlite
   St. Paul, MN 55144-1000
   612-736-1691
   available from:
   Conservation Support Systems
   P.O. Box 91746
   Santa Barbara, CA 93190-1746
   800-482-6299

Isinglas: fish glue
   L. Cornelissen & Son
   105 Great Russell St.
   London WC1B 3RY, England

Butvar B-98
   Klucel G: non-ionic adhesive (hydroxypropylcellulose) soluble in water and alcohol
   Methylcellulose
   Talas
   568 Broadway
   New York, NY 10012
   212-219-0770
Laponite RD: synthetic inorganic colloid gel-forming powder  
Conservation Resources International, Inc.  
8000-H Forbes Place  
Springfield, VA 22151

Paraloid B-72: ethyl methacrylate/methyl acrylate copolymer  
Rohm & Haas Co.  
Philadelphia, PA  
Supplied by:  
Conservation Support Systems  
P.O. Box 91746  
Santa Barbara, CA 93190-1746  
800-482-6299

KATHLEEN M. GARLAND received her BA in Art History from Brown University, and her MA in Art Conservation from the State University of New York, Cooperstown. She completed her internship in the Sculpture Conservation Department at the Victoria and Albert Museum in London. From 1986–1989 she held the position of senior sculpture conservator for the National Trust for Great Britain. In 1989 she established the objects conservation lab at the Nelson-Atkins Museum of Art where she is senior conservator. Address: The Nelson-Atkins Museum of Art, 4525 Oak Street, Kansas City, MO 64111. E-mail: kgarland@nelson-atkins.org

JOHN TWILLEY began conducting research into the materials of Indian painting as an undergraduate in analytical chemistry in 1973. Thereafter he served as conservation scientist of the J. Paul Getty Museum followed by a period in industrial microanalysis overlapping with an appointment from 1979–2000 in which he taught an introduction to art conservation for the Graduate Program in Historic Resources Management of the University of California, Riverside. As senior research scientist of the Los Angeles County Museum of Art from 1985–1998 he supervised conservation research. In 1998 Twilley left LACMA to establish an independent practice in art conservation science in New York where he now works for a spectrum of public and private institutions on problems of conservation treatment, attribution and artists’ techniques. Address: P.O. Box 215, Hawthorne, NY 10532. E-mail: jtwilley@sprynet.com
THE FIELD MUSEUM ARCHAEOLOGICAL METALS PROJECT:
DISTRIBUTED, IN SITU MICRO-ENVIRONMENTS FOR THE
PRESERVATION OF UNSTABLE ARCHAEOLOGICAL METALS
USING ESCAL BARRIER FILM

J.P. BROWN

ABSTRACT

Low-humidity microenvironments using polyethylene (PE) and, latterly, polypropylene (PP) boxes with ca. 80 kg/m³ of desiccated silica gel are widely used in preventive conservation for the storage of unstable archaeological metals from terrestrial contexts (Cronyn 1990, Logan and Selwyn 2007, Scott and Eggert 2009). One notable disadvantage of this method is that, because PE and PP are poor moisture barriers, the silica gel must be regenerated or replaced annually. The Field Museum was found to have 4,500 unstable archaeological metal objects distributed through its stored collections, requiring an estimated 400 kg of silica gel if PE or PP boxes were used. Instead, we opted to use enclosures made of Escal, a transparent plastic laminate primarily used for anoxic storage because of its low oxygen transmission rate, but which also is also suitable for low-humidity applications by virtue of its extremely low water vapor transmission rate (comparable to aluminized plastic barrier films). Using Escal has allowed us to reduce the amount of silica gel used to 5 kg/m³ with a predicted regeneration interval of at least ten years for iron objects and at least forty years for copper alloy objects. In other words, the use of Escal reduces the quantity of desiccant by a factor of sixteen and extends the interval between regenerations by a factor of ten. In this paper we discuss the theoretical considerations that led to our choice of Escal as a barrier film, the practical details of implementation, and report on the progress of the program after the first six years.

1. INTRODUCTION

A series of broad condition surveys performed at the Field Museum in the late 1990s noted that there were a significant number of archaeological metal objects which were actively corroding in the Anthropology Department’s storage vaults. In 2002 funding became available specifically for metals conservation and we were able to address the problem.

We first performed an object-by-object condition survey broadly following Keene (1996) and entering data directing into a FileMaker database on a laptop. Objects with corrosion products that appeared to be unstable chloride-related compounds (copper trihydroxychlorides, β-ferric oxyhydroxide) were sampled and the corrosion product tested for chlorides using acidified silver nitrate on a blue spot-plate after Odegaard et al. (2000). Object condition was rated on a 1-4 scale with 1 representing good stability, and 4 representing active corrosion and/or delamination. Objects testing negative for chlorides were rated in categories 1 and 2. Additional information was collected to describe the number of objects and fragments associated with each catalog number, as well as the non-metallic components of composite objects (fig. 1).

By the end of the survey we had found 6,832 catalog numbers representing 10,237 archaeological objects made wholly or partially of metal with 9,838 associated fragments. 863 pieces (about 4% of the total) were classified as class 4 objects showing active corrosion; these objects were mostly archaeological iron but also included some copper alloys. A further 3,173 pieces (about 15% of the total), mostly copper alloy showing evidence of bronze disease, were categorized as class 3 objects and judged likely to be unstable at high humidity. Several of the class 3 and 4 objects had associated, non-mineralized organic remains.
Treatment was not possible for this number of objects within the constraints of the available funding, so we looked for an environmental control method to prevent further deterioration.

2. ENVIRONMENTAL CONTROL OF CORROSION

Corrosion of iron and copper alloy objects can be controlled environmentally either by removing oxygen from the atmosphere surrounding the objects, or by controlling the relative humidity to low levels.

Anthropology collections at the Field Museum are stored by continent, country and culture group rather than by period or material type; storage space, although not critically limited, is at a premium. Relative humidity in the archaeological storage rooms varies from a summer high of 66 %RH to a winter low of 20 %RH and median values are in the mid 40’s – even the winter levels are moist enough for unstable iron to corrode (Watkinson and Lewis 2005) and the median and summer levels are sufficient for bronze disease to progress (Scott 1990). Curatorial policy required that we maintain storage organized by culture group rather than material sensitivity (i.e., that we keep any unstable objects at or very near their original shelf locations). This requirement immediately ruled out a dedicated low-humidity room and meant that the selected control method(s) should not measurably increase the storage footprint of the objects.
We considered classical storage in polythene boxes with desiccated silica gel (Watkinson 1987:21), but the range of object sizes that we needed to accommodate would have made this very difficult to accomplish. In addition, polythene is not a particularly good moisture barrier and so 80 kg/m² of desiccated silica gel are recommended and the gel needs to be regenerated every year, sometimes biannually, to keep humidity below the corrosion point for unstable archaeological iron. From the survey we estimated that we required at least 5 or 6 m³ of space for the corroding and at-risk collections giving a total of around half a metric tonne dry weight of silica gel to regenerate every year. The question then became whether there was a more effective material that we could substitute for polythene.

3. BARRIER FILMS AS AN ALTERNATIVE TO POLYTHENE BOXES

Metalized plastic films such as Marvelseal 360 have orders of magnitude lower oxygen and water vapor transmission rates than polyethylene (Burke 1992), the film material can be conformed close enough to object surfaces to allow the packaged object to be returned to its original shelf location, and enclosures for large objects can be pieced together from sections of the film.

We chose Escal as our barrier in preference to Marvelseal 360. Escal is a three layer composite film: polypropylene on the outside, tiny ceramic platelets in a polyvinyl alcohol binder at the center providing a tortuous path to control gas exchange, and polyethylene on the inside to allow heat-sealing (Keepsafe Microclimate Systems, nd). Escal’s oxygen and water vapor transmission rates are very low – comparable to Marvelseal – and, whereas Marvelseal is opaque, Escal is transparent and thus allows inspection and inventory of the objects in the enclosures.

Escal is available as rolls of sheet stock or as lay-flat tubing in three exterior widths: 16, 24, and 48 cm. We used the lay-flat tubing because the material can be cut to length and only requires two heat-seals (one at each cut end) to form a sealed enclosure. Each of the two long sides of the lay-flat tubing has a 1 cm seam and so the interior dimensions of the tubes are 2 cm less than those given above. The bulk Escal film has a water vapor transmission rate of 0.01 g/m²·day at 60 %RH and 25 °C (Mitsubishi Gas Chemical Company, nd). The polythene-to-polyethylene heat-sealed seam travels right around the edges of a finished enclosure and, given that the water vapor transmission rate of polythene is much higher than an equivalent thickness of Escal, the thickness of this seam is the limiting factor in the oxygen and water vapor transmission rates of the enclosure. If the polythene-to-polythene heat-seal seam is 10 mm wide, the seam’s resistance to the passage of water vapor is only a little less than the resistance of bulk Escal. A white data stripe is printed on one side of the tubing which allows labeling of the enclosures with permanent marker to help with subsequent inventory and survey.

For control of corrosion we generally used desiccated silica gel to reduce the relative humidity in the Escal enclosure below the threshold for corrosion. However, where unmineralized organics were attached to an unstable metal object we chose an oxygen scavenging as the primary corrosion control mechanism with buffered silica gel to maintain mid-range humidity conditions inside the enclosure and prevent damage to the organic components.
3.1 CONSTRUCTION OF BARRIER FILM ENCLOSURES

To make an enclosure we cut an appropriate length of tube, and sealed one end. A unique identifier was assigned to each enclosure and written on the data stripe. We added an appropriate amount of environmental control agent and an environmental performance indicator so that we could tell when the action of the control agent was exhausted. Early experimentation showed that it was better to bundle the control agent and the performance indicator together to stop all the components sliding around independently inside the enclosure. The bundling material needs to be fairly transparent to water vapor and oxygen (and light so that the performance indicator can be read) and so we used 2 mil polythene bags with press-to-close seal at the top for bundling the control agent.

For objects we cut a shaped support for the object so that it did not slide around in the Escal enclosure. 1.5 cm thick, Plastazote LD45 (medium density, nitrogen-blown, closed cell polyethylene foam) was used as the support material. The Plastazote sheets were cut down to strips of standard width to fit the three standard Escal tubing sizes.

Objects were placed on the Plastazote strip and their outlines scored into the foam with a wooden modeling tool (fig. 2). The objects were then removed and a cavity to receive the object was carved in the foam using the hot knife with a flat sled attachment (fig. 3). The flat sled attachment on the hot knife ensured that, when multiple cuts were required to form the cavity, all cuts were at a consistent depth (fig. 4). The catalog number for each object was then written next to the corresponding cavity on the Plastazote with a black permanent marker. The objects placed in the support, the appropriate environmental control agent and indicator were added to the enclosure, and the enclosure sealed (fig. 5).

Plastazote is available in a range of colors; we used the white-colored product in this project to make catalog numbers clearly visible. In retrospect, a higher density (more rigid) grade of foam would have been a better choice—the LD45 is too flexible to provide adequate support for larger enclosures and we have subsequently had to place the larger enclosures in acid-free cardboard boxes to provide adequate support.

Generally we had more than one unstable object from a particular shelf or drawer. Where objects were small we put several objects in one enclosure as far as the geometry of the storage location and the objects’ properties permitted. For multiple small fragments we first bundled the fragments together in one or more 2 mil press-to-close polythene bags and then enclosed them in Escal with a separate 2-mil polythene bag containing the appropriate environmental control agent and indicator.

The cut ends of the Escal tubing proved more difficult to heat-seal than we had expected: in particular, if the sealing iron is a little too hot, then the PVOH interlayer bubbles, compromising the tortuous path; if the sealing iron is too cold then the inner polythene layers do not weld together to form a seal. The product literature for Escal suggests using an impulse sealer which heats both the top and bottom jaws, has at least a 10mm seal width, and has a timer cycle; we have found that such a unit gives satisfactory results. The model we used (AIE AIE610FDA) can be remotely operated by a foot switch, leaving the operator free to pull the mouth of the enclosure taut prior to sealing. Even with this unit, we sometimes had to make two overlapping seals to get a satisfactory seal.
Fig. 2. Tracing shape of objects onto Plastazote foam with wooden modeling tool (Courtesy of JP Brown)

Fig. 3. Carving cavities to receive objects with a hot knife and sled (Courtesy of JP Brown)
Fig. 4. The hot knife and sled, showing how the sled attachment gives a consistent depth for repeated cuts in the Plastazote foam (Courtesy of JP Brown)

Fig. 5. Heat sealing the open end of an Escal enclosure (Courtesy of JP Brown)
3.1.1 Low-Humidity Enclosures

We determined during the design phase for the project that 5 kg/m³ dry silica gel would provide adequate desiccating capacity for a well-sealed Escal enclosure, the volume being calculated on the basis that the tube is formed as a cylinder of circular cross-section. Design parameters were that the interior of the enclosures would not reach 10 %RH (just below the threshold for iron corrosion) until after ten years and not reach 40 %RH until after 40 years. Calculations were conservative and assumed the presence of pin-holing, minor imperfections in the heat seal, and a constant exterior humidity of 60 %RH.

It would have been possible to weigh out the dry silica gel for each enclosure, but the weighing of gel into enclosures would have been time-consuming and messy. We purchased dry WR Grace ProTek Sorb silica gel, prepackaged in 0.5, 1 and 2 "unit" nonwoven polyolefin sachets. A "unit" of silica gel is a performance-based measurement defined in US Military Specification MIL-D-3464E (1987) as the amount of desiccant required to absorb 2.85 grams of water vapor at 20 %RH and 5.7 grams of water at 40 %RH. The dry weight of a unit of this silica gel is 23.5 grams.

We developed a nomogram for the number of units of dry gel required for a particular length of the different widths of Escal tubing (fig. 6). Clearly, the internal volume per unit length of a given width of tubing will vary depending on the contents and the degree of inflation (the profile of the cross-section of the enclosure). However, the surface area of a given width of tubing is proportional to its length, and since control of the internal humidity of a diffusion-controlled enclosure is dependent primarily on its surface area and the absorption abilities of the control agent, the mass and efficiency of the control agent (expressed here in MIL-D-3464E units) and the length of the tubing are the appropriate measures.

The silica gel sachets together with a humidity-indicating card reading 10-40 %RH were enclosed in a 2 mil polythene bag with press-to-close seal. We cut away the excess card at top and bottom of the indicator strip to make it easier to pack.

Fig. 6. Nomogram showing the number of “units” of silica gel required for different lengths of the three widths of Escal lay flat tube (Courtesy of JP Brown)
3.1.2. Low-Oxygen Enclosures

Where there were unstable metals and associated organic materials which could be separated (e.g., wood stand for Chinese mirror) we enclosed the metal separately and then boxed the metal and organic components together (fig. 7).

Where there were non-mineralized organics which could not be removed from corroding metals (e.g., bone handle on unstable iron blade) we used humidified low-oxygen enclosures to control corrosion without desiccating the organics (fig. 8).

We added 5 kg/m³ of silica gel conditioned to 40 %RH to stabilize relative humidity in the enclosure (primarily as a precaution against humidity changes caused by abrupt temperature fluctuations) and RP-K oxygen scavenger to maintain low oxygen levels. Some oxygen scavengers are activated by atmospheric moisture and consume the water vapor in the enclosure (thus reducing the relative humidity in a sealed environment close to 0 %RH). RP-K, however, is moisture-neutral (i.e., does not consume water vapor), and was ideal for our low-oxygen, mid-range humidity application. For each enclosure, three Ageless eye oxygen indicating tablets were bundled together with the RP-K sachets and a silica gel sachet in a 2 mil press-to-close polythene bag. The Ageless eye tablets are blue in color at >0.5 % oxygen, but change to pink at ca. 0.1 % oxygen and below. Manufacturer-recommended quantities of RP-K were multiplied by three to allow for imperfections in enclosure sealing, pin-holing, and extended life. After the objects, support, and environmental control and indicator bundle had been placed in the Escal enclosure, the open end of the enclosure was partially sealed leaving enough space for a gas tube to be introduced. The enclosure was then flushed with dry nitrogen prior to final sealing to maximize the life of the scavenger and prevent the enclosure contracting.

Fig. 7. Unstable Chinese mirror placed in low humidity enclosure and boxed together with associated wooden stand (Courtesy of JP Brown)
3.1.3 Enclosures for Large Objects

Although Escal is too stiff to drape easily, the film can conform fairly closely to the surface of the objects. Where the Escal tubing was not large enough for objects, we opened up the 48 cm size tubes to make 92 cm wide sheets and supplemented the missing areas with Marvelseal 360 (fig. 9). A layer of Plastazote was cut and shaped to prevent direct contact between the bottom of the object and the Escal film. We found that Escal seals much more easily to Marvelseal (and to aluminized polythene films in general) than to itself. We speculate that this is because one can safely use a higher temperature to get a good weld since the aluminum foil in Marvelseal dissipates some of the excess heat.

3.2 PROCEDURE FOR OPENING ENCLOSURES

A significant feature of gas barrier enclosures for long-term storage of objects is that, compared to storage in polythene boxes, the opening and resealing of the enclosures is a relatively complex process. In early experiments we had tried leaving excess length of the enclosure to allow for cutting and resealing, folding the extra length under the enclosure, and securing it with pressure-sensitive tape. Folding the extra length proved difficult to implement for the more three-dimensional objects, and was abandoned in favor of re-sealing with gas-tight removable clips after enclosures are opened.

It is important that as much is done as possible to preserve the proper functioning of the environmental control agent while the objects it contains are being examined. The end of the enclosure should be cut open as close to the original heat-seal as possible and the objects withdrawn on their support. The environmental control agent and the performance indicator are left inside the enclosure and a reusable gas-tight clip (supplied by Mitsubishi Gas Chemical Corp, the manufacturer of Escal and RP-K), is applied to the open end. When examination is complete, the clip is removed, the objects are slid back into the enclosure on their support, and then the enclosure is resealed with the clip (fig. 10). The enclosure is then left overnight and the environmental control agent is checked for correct performance (as shown by the environmental indicator in the enclosure) before returning the enclosure to storage. This procedure works well for silica gel controlled enclosures, but the low-oxygen enclosures require re-flushing with nitrogen prior to re-sealing. The clips are available in lengths corresponding to the three different widths of Escal lay flat tubing and are relatively expensive. We bought only the size
corresponding to the 24 cm width and cut them down as necessary for the narrower enclosures. The clips tend to splinter when cut by hand with box-cutter-type knives, but a ratchet-action cutter designed for cutting 2" PVC tubing works well.

Fig. 9. Large enclosure made by opening up 48 cm Escal tube supplemented with Marvelseal (Courtesy of JP Brown)

Fig. 10. An opened enclosure re-sealed with Mitsubishi gas-tight clip (Courtesy of JP Brown)
4. PERFORMANCE OF ESCAL ENCLOSURES AFTER SIX YEARS

We surveyed all the enclosures at the end of the housing phase of the project in Dec 2004. Only two out of 848 enclosures showed a change in indicated environmental properties: these were both medium-sized humidity-controlled enclosures and the failures were due to visible defects in the heat seals.

In March 2010 we completed a new survey of all the enclosures, six years after all enclosures were completed (Table 1). The majority of the 836 humidity-controlled enclosures are maintaining internal relative humidity at or below 10 %RH, but 39 of them (about 5% of the total) are now at 20 %RH or above. The ends of ten of 39 “failing” enclosures were cut open and, for unknown reasons, left open and not resealed. Another ten that have been opened and resealed with clips are above 20 %RH -- the high humidity may be the result of procedural error (failure to keep the bag clipped shut after the objects were withdrawn). However, the final 19 enclosures (about 2% of the total) are still heat-sealed and their internal environments are nonetheless above 20 %RH. The heat-seals on these enclosures do not appear defective to the naked eye. It is possible that these enclosures were opened, left unsealed, and then resealed. It has also been suggested (Shiner 2010) that if the two surfaces of the cut end of the Escal tubing are slightly twisted during sealing, then a small, unsealed aperture can form along the edge of the tubing seam – more work is needed to confirm whether this is the cause of the problem.

Of the 22 anoxic enclosures, six have been opened and then clipped, and, based on the color of the Ageless Eye oxygen indicating tablets, three of these were showing oxygen levels above 0.5%. It is not clear whether this is due to the clip seal, procedural factors, or some other cause. Procedural factors seem likely. However, it is now six or seven years since these bags were sealed and it is possible that the active life of RP-K oxygen scavenger is reaching its endpoint.

Table 1. Performance of environmental enclosures as surveyed March 2010, six years after initial survey

<table>
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<th>RH controlled bags: 836</th>
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<td>Indicated %RH</td>
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<td>total</td>
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<th>Oxygen controlled bags: 22</th>
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<td>16</td>
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<td>&gt; 0.5</td>
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5. CONCLUSION

Escal barrier film enclosures with 10mm wide heat-seals and appropriate control agents can be used to create humidity-controlled micro-environments for storage where active control of environment is unavailable or inappropriate. The use of 5 kg/m³ of silica gel in these enclosures will generally maintain internal humidity below 10 %RH for at least six years, probably ten years. A small percentage of enclosures can be expected to perform more poorly than anticipated for reasons which are presently unclear but may relate to imperfections in the heat-seals that are small enough to become significant only after several years. Close control of procedures for opening and resealing the enclosures is required during access to objects if the environmental control agent is not to be exhausted by the enclosure being left open. In view of the small number of enclosures that failed to maintain expected humidity and oxygen parameters it is apparent that a regular program of inspection of enclosures (once every two or three years) is required to spot faulty enclosures. One cautionary note is that the long-term stability of Escal in this application is not known. We have not observed any deterioration of its properties, but the long-term success of this storage method may well be determined by this factor.

ACKNOWLEDGMENTS

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Keepsafe Microclimate Systems. Escal Oxygen Barrier Film.


Shiner, J. 2010. Personal communication. Keepsafe Microclimate Systems. 9 Oneida Avenue, Toronto, ON CANADA M5V 1M3


SOURCES OF SUPPLIES

AIE610FDA Dual 24” Impulse Heat Sealer, 10mm seal width
American International Electric
2835 Pellissier Place
Whittier, CA 90601

Escal lay-flat tubing, RP-K oxygen absorber, Ageless Eye oxygen indicator tablets
Keepsafe Microclimate Systems
9 Oneida Avenue
Toronto, ON CANADA M5V 1M3

SMD-Humector HM-04 humidity indicator cards
AGM Container Controls Inc.
3526 East Fort Lowell Road
Tucson, AZ 85716

ProTek Sorb Prepackaged Silica Gel
WR Grace
7500 Grace Drive
Columbia, MD 21044

Plastazote LD45 Foam, 1x2m sheet, 1.5 cm thickness
UFP Technologies
1235 National Avenue
Addison, IL 60101
Quick Cut hot knife, sled attachment, and blades
University Products
P.O. Box 101, 517 Main St.
Holyoke, MA. 01041

Press-to-seal polythene bags, ratchet-action tube cutter for 2” PVC pipe
McMaster-Carr
600 N County Line Rd.
Elmhurst, IL 60126-2081

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EXAMINING PAST TREATMENTS OF CEDAR AND SPRUCE WATERLOGGED BASKETRY FROM THE NORTHWEST COAST
DANA K. SENGE AND ELLEN CARRLEE

ABSTRACT

Basketry artifacts fabricated from limb wood, spruce and cedar root, and the inner bark of yellow and western red cedar have been found in water-saturated archaeological sites in the Pacific Northwest since the mid-20th century. These artifacts range in age from a few centuries to more than five thousand years old. While these materials retain their overall physical structure due to burial in an anoxic environment they are degraded on the cellular level. Experiments and treatments performed by archaeologists and conservators over the past 40 years have attempted to stabilize these degraded structures to minimize splitting, crumbling, and distortion of the woven structures as they dried. Early treatments were guided by research done for preserving waterlogged ship timbers from the Vasa warship in Sweden and boats from Lake George, New York. Recent research has shown that the size of typical basketry elements limits the use of the PEGcon computer program developed at the Canadian Conservation Institute to determine the level of cellular degradation and that the cellular structure of some basketry material, such as inner bark, differs enough from trunk wood to require a variation in treatment. Recommendations for the best conservation methods for these materials is still under examination as conservators in Alaska, British Columbia, the Pacific Northwest, and scientists at the Canadian Conservation Institute continue to study the woody elements of these artifacts and the effects of treatment products. This paper summarizes and compares past treatments and the current condition of basketry from multiple wet sites on the Northwest Coast and discusses some of the current avenues under research.

1. INTRODUCTION

Water saturated archaeological sites, or wet sites, became part of the archaeological excavations in the Pacific Northwest in the late 1950s when the Biderbost Site in Washington State was excavated by the Washington Archaeology Society (Nordquist 1976) and Dr. David Rice (Phillips and Deep 2008). Artifacts fabricated from wood and plant based materials ranging from 200-5000 years old have been recovered from wet sites around the northwest coast region of the United States and Canada and have provided a window into the culture, tools, techniques and life of the Native/Aboriginal communities in the region. Materials recovered from these sites range from baskets and mats, clothing, house planks, spindle whorls and looms, tools, carvings, and detritus from carving and processing materials.

These organic artifacts, fabricated from wood, limb, inner bark and root, are preserved in an anoxic environment created by the continuous presence of water. In this environment deterioration of the wood structure is slowed but not stopped. The water-soluble molecules, such as cellulose, are slowly removed from the structure either through slow bacterial removal or slow hydrolysis and are replaced with water molecules. When recovered from the burial environment the organic material of the object may look whole, but quickly proves delicate when handled. Individual segments of root or inner bark may be so deteriorated they can easily be mushed apart by fingertips or split into thinner components. Woven or twined artifact and segments are stronger despite the degraded nature of the individual elements, the three dimensional macro structure itself acting to hold or restrain the materials from complete deterioration.

If allowed to air dry, these wood based materials will split, check, curl and distort as observed in materials both thick and thin in controlled slow air-drying tests (Erling 1990; Senge 2009) as well as air drying in an uncontrolled environment.
For at least fifty years conservators and archaeologists in the Northwest Coast region have been testing and implementing techniques to reduce the shrinkage and physical distortion of basketry. While similar to larger wood artifacts the fine elements of basketry materials have proven to require additional considerations in treatment solutions. Much has been researched and published about the preservation of wood from underwater or water-saturated burial environments, therefore the remainder of this publication will focus on history of treatment of basketry materials, an area that has not been discussed to as great an extent. For the purposes of this article, basketry materials in the Pacific Northwest are defined as artifacts fabricated from twined or woven elements and take the form of a variety of artifacts including: hats, baskets, mats, nets, cordage, and clothing. The materials themselves range from splints of limb, withe (narrow diameter ‘twig’), root and inner bark (phloem). The width of these materials used in basketry ranges regardless of material type. Inner bark materials range from 1” wide strands used in matting to 1/4” wide or narrower used many types of baskets. Limb, twig and root also range from approximately 1/4” wide splints, most often used as warp material in open weave baskets, to 1/16” inch or narrower strands, most commonly used as weft material in twined basketry.

2. BACKGROUND

In 1976 the proceedings of two conferences focusing on the preservation of waterlogged artifacts were published: *The Excavation of Water Saturated Archaeological Sites (Wet Sites) on the Northwest Coast of North America* (Croes 1976) and *Pacific Northwest Wet Site Wood Conservation Conference* (Grosso 1976b). While the papers published in these proceedings covered a range of organic materials, many discuss the treatments tested, immediate results and conclusions regarding the treatments of basketry material. These papers provide some of the only published treatment documentation for waterlogged basketry collections on the Northwest Coast. In general they describe the transition of treating waterlogged materials with diluted vinyl copolymer adhesives to working with polyethylene glycol as an impregnant (Borden 1976; Croes 1976; Daughtery 1976; Gleeson and Grosso 1976; Grosso1976b; Hobler 1976; Munsell 1976; Norquist 1976; Onat 1976; Simonsen 1976; Sprague 1976). This transition was inspired by publications in Europe and North America on waterlogged timbers from the Vasa and dugout canoes in Lake George, NY (Barkman 1962; Seborg and Inverity 1962).

Throughout the research represented in the papers published in 1976 one reads the dissatisfaction archaeologists and conservators had with treatment methods. This continues into the 1980s and 90s as people continued to research the use of the most popular impregnant, polyethylene glycol. Jo Ann Erling, a contract conservator working in Victoria, British Columbia, tested a wide range of concentrations of polyethylene glycol and impregnation time when considering the treatments of materials from Water Hazard (DgRs30). While this testing remains unpublished, her research and images remain with the collection housed at the Laboratory of Archaeology at the University of British Columbia.

In the early 1990s, Vincent and Deborah Cooke worked with conservators from the Canadian Conservation Institute (CCI) to examine re-treatment options of basketry materials from Ozette currently housed at the Makah Cultural and Research Center in Neah Bay, Washington. They selected three basketry fragments to include in their testing, removed the impregnate, freeze dried the fragments and tested consolidation with Polyox and Parylene. They felt the consolidants improved visibility of woven design and the artifacts maintained stability after re-treatment (Cooke and Cooke 1994). When examined in 2009 the samples show some
sheen from the consolidant materials but appeared stable for handling, exhibit and research after fifteen years in their relatively stable storage environment at the Makah Cultural and Research Center.

In 1996 and 1998 conservators and scientists from the CCI presented and published their work with polyethylene glycol (PEG) treatments of waterlogged basketry materials and a study into the penetration of PEG into the inner bark of western red cedar (Grant 1996; Bilz 1998). In the treatments described in the 1996 article, ‘Conservation of Waterlogged Cedar Basketry and Cordage’, the basketry material and cordage treated with PEG 400 was stabilized but somewhat brittle. Some of the pieces required additional consolidation with Parylene to be stable for travel and exhibition. The research described in the 1998 article, ‘Treating Waterlogged Basketry: A Study of Polyethylene Glycol Penetration Into the Inner Bark of Western Red Cedar’, shows that the cellular structure of cedar inner bark is different enough from the wood that treating baskets with the same concentration and molecular weight of PEG as waterlogged cedar wood may not be the best course of action for stabilizing these materials. The research was performed on processed fresh inner bark. The results of these examinations were used to extrapolate how polyethylene glycol would enter the degraded materials from an archaeological wet site.

The testing performed in the 1970s, 80s and 90s has been very helpful in understanding the movement of different molecular weights of polyethylene glycol into the cellular structure and the challenges of working with basketry materials. In 2006, the authors began to summarize the historic background of past testing and treatments in an effort to make informed choices for the treatment of waterlogged basketry materials, and build on the experimentation published in the 1998 article from Bilz, Grant and Gregory. The following sections summarize these past treatments of basketry materials and how they have aged through visual and physical characteristics.

3. HISTORIC TREATMENTS

Many of the historic and current treatments of basketry face the challenge of removing water from water-saturated cells without also losing the structural support the water provides in the degraded material. The treatment must also counteract the strong forces caused by capillary action and the high surface tension of water when it evaporates. Treatments have revolved around variations of slowly drying the materials or impregnating the structure prior to drying to replace lost molecules, bulk the voids, and control shrinkage or deformation of the elements of the artifacts. Additional treatment methods have included consolidation of loose, dry, brittle material after the drying or impregnation/drying treatments.

Early treatment materials and techniques included coating the surface with vinyl copolymer adhesives such as Elmer’s or Plyamul diluted in water, slow drying with Firewater and Houston #3 drying between two layers of glass and impregnation with polyethylene glycol at various molecular weights in various concentrations and for various lengths of time. More recent published consolidation tests have focused on the use of Parylene and Polyox recognizing that stability had not been fully achieved in the earlier treatments. The physical characteristics of the treated artifacts ranges from tan-colored, lightweight, brittle and dry on one extreme to dark brown, heavy, waxy, flexible, and slightly moist to the touch on the other extreme.

The treatments described in this paper were gathered from existing treatment records from 27 of 37 recognized water saturated terrestrial sites in Oregon, Washington State, British Columbia and Alaska that contained basketry materials. While anecdotal information about
possible treatment techniques used have been relayed to the authors, distant memories can be mistaken therefore following summaries depend solely on the written record from both published sources and collection treatment records.

3.1 AIR OR SOLVENT DRYING TREATMENTS

In general the air and solvent dried materials are light, brittle, shrunken or misshapen (unless dried between two plates of glass), regardless of age and level of deterioration (fig. 1). The basket recovered from the Castle Hill site in Alaska is an exception to this finding (fig. 2). The records for this piece describe it as not fully waterlogged when found. The basket was placed on a sheet of Plexiglas in a refrigerator. After several years of debating treatment options, the piece was re-examined and discovered to be dry with basketry elements remaining flexible and was considered stable when handled. This result was attributed to the basket being only slightly damp and not water saturated when excavated. The condition of the basket at excavation was only minimally deteriorated. Sufficient air drying likely occurred within the first year.

Fig. 1. Air-dried fragment from Spruce Root Basket, Baranov Museum (Photograph by Dana Senge)
3.2 COATING WITH ADHESIVE TREATMENTS

Several authors have published anecdotal information regarding treatment with a white glue, either vinyl acetate copolymer (VAC) or poly vinyl acetate adhesive (PVA). These include the archaeological sites of Ozette (Daugherty 1976), Hoko River (Croes 1976) and Biderbost (Nordquist 1976). Of these three collections only artifacts from Biderbost collection were found to exhibit this type of treatment. A few artifacts from Ozette and Hoko River were treated with a PVA adhesive before treatment solutions shifted to the use of polyethylene glycol (Daugherty 1976; Croes 1976). However no evidence of basketry with the characteristic sheen of white glue treatment or treatment records citing artifact numbers have been found by the authors in either the Ozette or Hoko Complex collections.

All of the materials from the Biderbost site were treated with 25% Plyamul adhesive #9153 in Firewater, a heavy detergent manufactured by the Firewater Company of Los Altos. These were examined in 2009 and found to be rigid and firm with excess adhesive dried on the surfaces. The treatment was considered successful at the time since it minimized shrinkage and splitting of the material, however a contemporary assessment is that the treatment is somewhat crude with pools of adhesive on the basketry elements confusing the visual understanding of the material. In addition, the Plyamul adhesive has proved slightly soluble in ethanol and not very reversible. The conservation material contaminates any samples taken from the treated artifacts, impacting potential instrumental analysis in research. The rigidity of the basketry materials observed might be due in part to the conservation materials and in part to the physical characteristics of original elements, which were thick sections of bark and root. Cross sections cut from the inner bark samples of Biderbost basketry were brittle and crumbled during slicing; the root material was hard but maintained its structure during sectioning with a razor. Examination of a transverse section of the root material viewed under ultraviolet irradiation shows the adhesive along the edge and filling the lumina near the surface (fig. 4).
Fig. 3. Basketry fragment from Biderbost collection, 45SN100-335
(Courtesy of the Thomas Burke Memorial Washington State Museum)

Fig. 4. Transverse view from sample of root from Biderbost collection (45SN100-330a) at the Thomas Burke Memorial Washington State Museum, viewed with Olympus BX-51 using ultraviolet irradiation to view fluorescence of adhesive along top edge. Lignin in cellular structure in exhibiting natural fluorescence. Bar is 10m.
(Photograph by Dana Senge)
3.3 POLYETHYLENE GLYCOL TREATMENTS

During the initial seasons at Ozette in 1966 and 1967 the archaeologists realized that the white glue adhesive treatment was not an ideal solution. The effects of the adhesive were described as producing a stiff whitish looking basket (Daugherty and Croes 1976). This spurred the research of Gerald Grosso into the possibilities of working with polyethylene glycol to impregnate the structure and replace water molecules that would leave during the drying process. Over the next several years he and Richard Daugherty looked at treatments developed in U.S. and Europe for waterlogged wood artifacts including the Vasa treatments published by Lars Barkman (Barkman 1962) and the treatments of waterlogged boats from Lake George, NY published by Seborg and Inverarity (Seborg and Inverarity 1962). From this research they tested a range molecular weights and concentrations to develop a method of volume processing these materials in the remote worksite of Cape Alva in order to safely move the artifacts from the site to a workspace (Grosso 1976a).

Around the same period other archaeologists in the region were inspired by the publications of Barkman and Seborg and also developed methods of working with polyethylene glycol. As a result during the 1970s many basketry artifacts in the northwest coast region were treated with a range of treatments using polyethylene glycol (PEG) as a consolidant or impregnant. Treatments developed during this time period varied by impregnation bath time, molecular weight of polyethylene glycol and concentration of the PEG in water. These variables in treatment, along with variables of material types and level of degradation, resulted in a wide range of final results from tan-colored/lightweight/dry/brittle at one extreme to dark-colored/heavy/waxy/flexible materials at the other.

The most significant variable found in past basketry treatments in this region is duration of impregnation. Artifacts with short treatment times (1/2 day – 2 weeks) in medium to high molecular weight (1000-4000) polyethylene glycol (PEG) are generally dry in appearance and delicate to handle. The PEG appears to have aided in slow drying the artifacts and minimizing shrinkage and distortion, but did not truly penetrate the inner bark and root cellular structure leaving the artifacts delicate to handle for exhibit and research. This is observed when examining a transverse section of material from the Conway wet site (fig. 5).

These objects were treated by soaking in ethyl alcohol for 2 days and then placing in an impregnation baths of 33% PEG 1000 in water for 2-4 days, upon removal from the bath these artifacts were allowed to dry from 1-2 weeks. The section sample was stained with cobalt thiocyanate (Bilz 1998) and examined at 400x magnification with an Olympus BX-51 microscope under ultraviolet irradiation. The stain bonds to any PEG in the structure and quenches the natural fluorescence of the lignin in the structure. Figure 5 shows that there was little to no PEG present in the structure for the stain to bond with and the auto fluorescence of the lignin is clearly observed.

The main treatment method developed for the materials from Ozette was a four week impregnation period with 50% PEG 1500. PEG 1500 was renamed in the mid 1970s to PEG 540 Blend, which is believed to be the same 540 blend that exists today: 41% PEG 300 and 59% PEG 1450. These materials are often dark brown/black, sometimes waxy in appearance and are slightly moist to the touch. Transverse sections cut from a sample western red cedar inner bark from the Ozette material were pliable and PEG oozed from the structure when placed in a warm, humid environment. The inner bark material from Ozette disintegrated during the cobalt thiocyanate staining process, the material was too delicate to examine the level of impregnation of PEG into the cellular structure.
In the mid-90s Tara Grant and Malcom Bilz at CCI began testing treatment solutions and found a mix of lower concentration (20%) and lower molecular weight (400) and long immersions that provided a step towards a more desirable treatment outcome for many materials from the Scowlitz site (DHR1-16W). Several pieces were treated with these concentrations and time periods, frozen and freeze-dried, then consolidated with Parylene. These pieces are light in
color and appear fairly stable overall, the basketry elements were flexible and the surface spongy to the touch. However, the need to consolidate with Parylene (itself an experimental, last-resort treatment that does not allow easy re-treatability) suggests the PEG protocol alone was not enough for these materials.

The South Baranof Island Basket #1 from the Alaska State Museum was treated in 1994 with 20% PEG 400 and 5% PEG 4000 over the course of 6 months, upon the recommendations of Tara Grant at CCI. Upon examination in 2009 the basketry fragments have a very natural-looking, pleasing appearance with no observable shrinkage or distortion, and the individual elements appear to have maintained some of their flexibility. However, the material is also very spongy to the touch, sheds fibers, and is too delicate for travel or exhibition.

A variation of this technique developed at CCI is currently in use at South Puget Sound Community College. The lab within the archaeology department has been treating materials for an active site at Mud Bay (Qwu? Gwes³) in Washington State for several years, as well as basketry material found at Sunken Village in Oregon in 2006 and 2007. The general treatment process in practice in the lab is to place basketry materials in a bath of 50% PEG 400 for 4 months. The authors have not had an opportunity to observe or examine these materials treated through this specific variation of the polyethylene glycol impregnation treatment.

3.4 OTHER TREATMENT METHODS

Wet storage in a cold environment may have been considered for a while by conservation departments in museums in southern British Columbia (Alten 2010). While no records exist regarding actual use of this method at the Royal British Columbia Museum Conservation Lab or the University of British Columbia Museum of Anthropology Conservation Lab (Clavir 2010; Brewer 2010; Mackie 2010), Alten recollects a possible shift in preservation thinking towards preservation in the wet state. The main considerations may have been that a fair amount of change to the materials occurred during the impregnation and drying processes and that the materials would be more useful as archaeological record in their wet state as biological specimens are stored in a natural history museum. The basic wet storage technique is thought to have been placing the artifacts in shallow trays with deionized water and biocide or alcohol and storing the trays in a cold storage environment such as a refrigerator. Not only does this preservation solution require regular maintenance, there is a major drawback to this as a long-term storage solution: the oxygen in the water will continue to degrade the basketry materials. At this point it is unclear to the authors if this was put into practice for longer than just a few years of temporary storage prior to treatment of the materials.

4. CURRENT RESEARCH

The authors examined the historic treatments of waterlogged basketry with an eye to what avenues to consider for future treatment tests. What became clear through this examination was while treatments with polyethylene glycol have become standard for basketry, determining the proper procedure and analyzing the results is challenging due to two sets of variables. The first focuses on artifact variables:

- Hardwood vs. softwood and the species of wood
- Component of tree or plant (i.e. root, inner bark, trunk, branch etc)
- Degree of deterioration, particularly whether or not the secondary cell wall is present for bonding with lower PEGs of lower molecular mass.
The second set of variables focuses on treatment design:

- Which molecular weight PEG is chosen
- Concentration of PEG
- Duration of impregnation
- Heated or unheated during impregnation
- Drying method: air drying, non-vacuum freezer drying, or freeze drying

Considering these variables the authors endeavored to find methods for determining level of deterioration of waterlogged basketry, as this variable seems key to designing successful PEG impregnation treatments. Many PEG treatments for wood rely on comparing the density of the artifact to density expected for sound wood. The assumption is that more deteriorated wood will be much less dense than sound wood because of the missing constituents. The challenge of measuring density for tiny, geometrically complex basketry fragments is compounded by the lack of appropriate comparative standards for the materials used (root, bark etc). Therefore, measuring degree of deterioration in basketry is much more difficult than measuring degree of deterioration for artifacts made of sizeable pieces of trunk wood, especially if there is a lot of material available for destructive testing, as typically afforded by timbers from shipwrecks. Visual characteristics of flexibility and hardness can provide some information. On the macro level visual and physical characteristics provide some information but can only really be valuable with personal experience comparing waterlogged basketry materials from different sites. In general root, limb, and withe materials are harder and can be more rigid than inner bark. Some of this has to do with cellular structure and some with how finely the material is split during preparation for weaving. Degraded waterlogged root can vary from hard to easily penetrated with a pin or even mushed apart between two fingers. Degraded inner bark is regularly soft, penetrable with a pin and mushed into nothing between fingers. In addition degree of deterioration can be deceptive in basketry that has woven physical forces helping to hold it together.

If there is sufficient material available to allow destructive testing, observing shrinkage and distortion with slow, controlled air-drying alone can be helpful. A well-controlled photographic set-up to allow before and after photographs on graph paper can be a useful tool in this analysis, as can measuring all dimensions possible with a precision calipers. Greater dimensional change and distortion suggests a higher level of deterioration, possibly suggesting loss of secondary cell wall for low molecular weight PEG to bond with, and may merit a PEG treatment designed to incorporate higher percentages of high molecular weight PEG.

4.1 MICROSCOPY

The next step in examination is to look at samples of the material with a microscope to begin understanding degradation on the cellular level. Transverse sections were cut from samples of fresh material as well as treated and untreated archaeological materials and examined with a Nikon Eclipse 600 polarizing light microscope and an Olympus BX-51 polarizing light microscope. The transverse view was selected for examination and comparison because this view appears to show the most evidence of degradation (Florian 1990; Hoffmann and Jones 1990).

At 600x magnification degraded spruce root has some clues of level of degradation. A 2000 year old sample (fig. 9) looks similar to a fresh sample of spruce root (fig. 7) and the ~200 year old sample (fig. 8) shows some tearing of the tracheid cell walls. The variation in condition can be attributed to variations in the burial environments. Physically the cellular structure of the ~200 year old sample of spruce root is so degraded that a sample of material can be mushed apart
between two fingers. The 2000-year-old spruce root sample is physically strong, maintains rigidity with pressure, and while a pin can penetrate the surface it cannot be easily pushed through the core. Neither cross section of these samples shows separation of the secondary cell way as an indicator of deterioration. This may become clearer at a higher level of magnification or with environmental scanning electron microscopy. Several samples of archaeological western red cedar inner bark were examined on the cellular level (figs. 10-12). These showed a surprising level of change in comparison to fresh western red cedar inner bark. Depending on the level of degradation the network of thin cell walls (parenchyma) and middle lamella holding the structure together was lost leaving the thick walled cells (phloem fibers) without a structure to hold them together.

Fig. 7. Transverse section, fresh spruce root, viewed in normal illumination. Bar is 10m.
(Photograph by Dana Senge)

Fig. 8. Transverse section, ~200 year old archaeological spruce root from the Baranov Museum viewed in normal illumination. Bar is 10m. (Photograph by Dana Senge)
Fig. 9. Transverse section of a sample from Liyonmxetel basket, DgRm-1, 210. 2000-year-old archaeological spruce root, viewed in normal illumination. Bar is 10m. (Photograph by Dana Senge)

Fig. 10. Transverse section. Fresh Western Red Cedar Inner Bark viewed in UV irradiation. Bar is 10m. (Photograph by Dana Senge)
4.2 SUMMARY OF RECENT TREATMENT TESTS

While long impregnation baths with low molecular weight PEG appear to have fairly good results in reducing shrinkage and distortion there is still concern regarding long term storage of these materials with fluctuating RH and stability of materials for handling and travel. There is concern about ongoing mobility of excess liquid lower molecular weight PEG within the basketry structure.

Over the past several years Ellen Carrlee has been studying impregnation of ~4,500 year old spruce root with high molecular weight PEG and the use of heat to increase penetration. Her latest results show samples of root treated with heated 55% PEG 3350 for 3 months followed by freeze drying in a non vacuum freeze drier created a stable robust material that has withstood the fluctuations of high RH. In addition she has been testing a wide range of consolidants for friable pieces already treated with PEG and has found promising results with Butvar B98 (Carrlee and...
Dana Senge has been testing low and high molecular weight PEG treatments in various concentrations and times on archaeological spruce root samples ~200 and ~2000 years old followed by slow air drying. The physical characteristics of the materials tested indicate that the most flexible samples without splits or distortion were samples treated with 4 weeks of 20% PEG 200 and 4 weeks of 40% PEG 200. Samples treated with 4 weeks of 20% PEG 400 and 4 weeks of 40% PEG 400 are more brittle, likely due to the higher molecular mass taking longer to penetrate the cellular structure of the material, therefore less impregnant is present. A longer impregnation time with PEG 400 may improve the flexibility of the material for handling. While these lower molecular weights are known to penetrate the cell wall and reduce cellular collapse, if excess is introduced to the system the molecules will remain in the lumina of the cellular structure and move around the structure with fluctuations of relative humidity, possibly leading to the weeping of PEG from the structure.

The ~2000 year old spruce root samples tested with 55% PEG 3350 for 10 weeks were rigid and snapped into two pieces when flexed, similar to the physical characteristics of historic basketry materials composed of the similar material. The ~200 year old material treated with 55% PEG 3350 was so hard after treatment it was almost brittle. The rigidity of this material may be a desirable outcome, but the level of hardness from the PEG 3500 may also be a flaw when handling the basketry (Senge 2010). The impregnations times used for these test samples may not translate to treating larger artifacts and as with all treatments using polyethylene glycol, density measurements of the bath water should be used to determine how the impregnant has moved into the structure and when treatment may be complete.

Variation in results between Carrlee’s and Senge’s tests can be attributed to treatment variables such as heated impregnation and drying in the freezer by Carrlee and room temperature impregnation and slow air drying by Senge as well as variables in the condition of the spruce root material. The ages of the archaeological material do not specifically indicate level of deterioration. For example: the youngest material at ~ 200 years appeared much more deteriorated that the ~2000 year old material as seen in figures 8 and 9.

4.3 FUTURE RESEARCH

This initial research into the historic treatments used on these waterlogged basketry artifacts has only scratched the surface of information these materials may hold. Further understanding of the individual burial environments and age may help predict level of degradation without specialized instrumentation. Burial environment is a major influence on condition of artifacts and thus the appropriate treatment design. Throughout the research summarizing past treatments of basketry materials the artifacts were examined independently of burial environment information. This is partially due to burial information being inconsistent. One article or note may list the pH of the burial environment and the next may only describe the soil in terms such as “sandy” or “clayey”. Understanding soil chemistry and collaborating with a plant pathologist or deterioration biologist is needed to fully round out this body of work and understand burial degradation observed in the materials.

Use of microscopy to create a reference set of images may be the key to identifying their level degradation. Presence or absence of secondary cell wall seems to be crucial for the application of the proper molecular mass of PEG, but its observation is exceedingly difficult for conservators who are familiar with general polarized light microscopy but do not have specialized plant anatomy training. Most of the major reference articles and texts describing
The deterioration of cellular structures involve the expertise of wood anatomists with considerable specialized training and experience. Perhaps collaboration with these professionals and refining the understanding of the structures with supplementary environmental scanning electron microscope images could create a reference set of cedar and spruce images that may help interpret what is seen through more accessible polarized light microscopy.

This study focuses on some of the major materials used in basketry in the region: western red cedar inner bark and spruce root. However, other materials were used such as tule reed, cherry bark, and sweet grass. The treatments used on these materials and their results should be examined as well.

Future research into treatment solutions may include examining treatment methods using PEG 2000. Initial testing with higher molecular mass PEG in spruce root is promising. Perhaps PEG 2000 may afford the advantages of the large molecule without excessive hardness.

This examination into treatments has shown that some success is found with a two stage consolidative approach. Perhaps it is time to consider the treatment of waterlogged basketry as impregnation with a low molecular weight PEG followed by consolidation with Butvar 98 or Ethulose.

Another treatment option that may be important to examine the impregnation of the materials with alkoxysilanes or silicone oil. This treatment technique has been considered controversial for many years but it is important to understand the advantages and disadvantages of the technique as more people turn to it for the conservation of waterlogged materials. There is only one attempt to treat waterlogged basketry using silicone oil known to the authors. Unfortunately the basketry material didn’t survive the treatment process and could not be be assessed by the authors. While the poor results of this treatment may have been operator error, it underscores a major challenge of working with this method: when it works well it works beautifully, when it doesn’t work well it can be disastrous. Is this an acceptable risk? The other treatment methods used for basketry may not be perfect, but the treatments can be adjusted, even partially reversed and re-done if mistakes are made in the treatment process.

While the silicone treatment process may be successful for wood, root and limb based materials it may not be appropriate for degraded inner bark. As described in an earlier section, archaeological inner bark samples viewed by the authors has very little structure left, leaving very little to for the silicone oil to bond to and support in the treatment. Current understanding of the silicone oil treatment process is that the consolidant bonds covalently to the interior surfaces of the lumina and enters much of it enters the middle lamella. Very little of this remains with the archaeological inner bark, additional research should be performed in understand the deterioration of the inner bark and how silicone oil would enter and support this system.

There is a great deal of science behind the decisions and treatments of waterlogged basketry, however the actual treatment of the materials is still an art for each method selected, and published results on the archaeological material are sparse.

5. SUMMARY

The authors learned a great deal about the tremendous amount of research performed by others in the field of conservation of waterlogged basketry materials. The past preservation treatment techniques for waterlogged basketry have been effective in preserving these materials for later generations. However, many of these artifacts are difficult to handle, study, and exhibit due to issues of stability or excessive conservation materials present.
The conservation of waterlogged basketry materials is still a complex challenge and conservators in several labs in the Northwest are considering new variations of treatment solutions in order to improve overall physical characteristics of the treated artifacts. Refining the palette of treatment is ongoing through continuing research with low molecular weight PEG and more in depth research with high molecular weight PEG.

While the more recent treatments of longer impregnation times with PEG 400 and PEG 3350 have made some major strides towards basketry materials that appear stable and can be gently handled a deeper understanding of level of deterioration and desired outcome is required to refine these techniques. Fairly degraded material appears to require additional consolidation when impregnated with a low molecular weight. The recent test of PEG 3350 on spruce root should be expanded to a wider range of levels of degradation to understand where this tool is most useful.

The structure of the archaeological western red cedar observed in figures 11 and 12 may indicate that the basic strategy of using an impregnate to bulk up cell walls and possibly fill the lumina isn’t truly effective with this material. No doubt the polyethylene glycol is aiding in preservation, possibly as a waxy consolidant holding the phloem fibers in the recognizable shape of inner bark than actually contributing the cellular structure that truly no longer exists.

Many important archaeological sites along the Northwest coast are wet. In an ideal world, excavation of these sites would be well planned with ample resources for treatment. The reality often involves remote sites done on a salvage basis with little funding. The methods to analyze and treat basketry from these sites needs to be accessible to conservators and archaeologists working without the benefit of wood anatomy specialists and scanning electron microscopy, and even to collaborating with archaeologists who may need to treat this material remotely under the guidance of a conservator.

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NOTES

1. Plymul adhesive is a polyvinyl acetate emulsion produced by Reichold Chemical in the 1960s.

2. Firewater and Houston #3 are referenced in the treatment information described in Nordquist 1976 and Bernick 1991. To date, the authors have been unsuccessful in finding product information associated with these brand names.

3. Qwu? Gwes is the name given to the Squaxin Island tribal heritage wet site at Mud Bay in the south Puget Sound area of Washington State. This name, given by the Squaxin Tribe holds the meaning ‘coming together, sharing’ (Croes et al. 2005).
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FURTHER READING


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