Rebecca Summerour

Buffalo State College

The Examination and Conservation of a Snake Skin Suit Jacket

ABSTRACT

A snake skin suit jacket was analyzed and conserved at the Buffalo State College Art Conservation Department in preparation for display at the Rochester Museum and Science Center (RMSC), the institution that owns the jacket. Steps toward the primary goal of preparing the jacket for display included surface cleaning, humidification and reshaping, repairing structural damage, filling lost leather, and sculpting a support mount for display and storage. The historical context, materials, construction, and previous treatment were also investigated. Analytical techniques included computed X-radiography, microchemical spot testing, shrinkage temperature testing, polarized light microscopy (PLM), X-ray fluorescence spectroscopy (XRF), Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS), and pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS).

KEYWORDS: XRF, FTIR, PLM, PY-GC-MS, Snake skin, Leather repair, BEVA, Peter Gruber, Rattlesnake Pete

1. INTRODUCTION

The snake skin leather jacket described in this report was originally owned and worn by Peter Gruber, a Rochester, NY celebrity (fig.1) who was, and remains, best known by his nickname, Rattlesnake Pete (Stilson et al. 2007). It is now owned by the Rochester Museum and Science Center (RMSC). The jacket (acc. no. 50.372.4) is one item in an ensemble that also contains a hat, a pair of pants, a vest, a pair of shoes, and a belt, that are primarily made from rattlesnake skins (figs. 2-6). All of these items belong to the RMSC. In October 2010, the RMSC staff brought the suit jacket, vest, pants, and hat to the Buffalo State College Art Conservation Department for treatment because the items were not exhibitable owing to their poor condition. The pieces were soiled, brittle, and distorted with varying amounts of insect damage. The jacket, hat, and pants were accepted as

From the Albert R. Stone Negative Collection
Rochester Museum & Science Center, Rochester, N.Y.

Figure 1: Peter Gruber standing next to his automobile, wearing a jacket, vest, and hat that look very similar to items in the RMSC collection. Taken ~1914. From the Collections of the Rochester Museum & Science Center, Rochester, NY. Acc. No. 40.332.8652.

Figures 2, 3, 4, 5, and 6: Peter Gruber's snake skin jacket, hat, pants, shoes, and vest.

student projects. The vest was not due to its extremely poor condition. The jacket was treated first because it is considered to be the centerpiece of the ensemble. The pants and hat were treated as separate projects by conservation students Fran Ritchie and Christine Puza, respectively. Now that a protocol has been devised for these projects, the vest might be accepted as a future student project.

2. BACKGROUND

2.1 Peter Gruber's Background

Peter Gruber (1857-1932) was the proprietor of a restaurant and oddities museum at 8 Mill Street, Rochester, NY from 1894 to 1932. Gruber and his establishment were famed locally and abroad for Gruber's knowledge of snakes and the curious items in his museum. Gruber earned the nickname "Rattlesnake Pete" because of his knowledge of and expertise in catching, handling, and maintaining rattlesnakes in captivity, as well as his ability to procure medicinal treatments from snakes of all sorts. He was unusually comfortable with venomous snakes, but his love for serpents was broad and he often had both venomous and non-venomous snakes in captivity at his museum. One story from his biography

describes how he once saved a boa constrictor from abandonment in an American Express Company Office (Stilson et al. 2007, 79-80). He collected snake venom and oil, retained the skins of dead snakes for use in poultice treatments, successfully treated poisonous snake bites, and was famed for treating goiters by wrapping non-venomous snakes around his patients' necks (fig. 7) (Stilson et al. 2007). He was proud to have learned most of these medicinal treatments from the "Cornplanter's Indians"[1] who he knew while growing up in Oil City, Pennsylvania (*Rochester Democrat and Chronicle*, 11 October 1932; 15,18).

Figure 7: Gruber administering a goiter treatment to one of his clients. From the Collections of the Rochester Public Library Local History Division, Image. No. rpf00477.

Contrary to his intimidating nickname, Gruber was known for his congenial temperament and kindness toward his customers and clients. He became a restaurant owner because his father wished him to take over the family business. The profession did not appeal to the younger Gruber, so he enlivened the environment with captured serpents and an array of curiosities. His museum started with an operating miniature oil well and gold mine that Gruber built as a young man, with the help of a good friend. By the end of his forty-year career, his museum showcased numerous sensational objects, including New York state's first electric chair, John Wilkes

Figure 8: A Rattlesnake Pete advertisement that depicts Gruber and lists some of the curiosities in his museum.

---

[1] Members of Chief Cornplanter's Tribe were part of the Seneca Nation (Meyers 2011)

Booth's meerschaum pipe, firearms of all sorts, World War I memorabilia, an axe that belonged to a wife murderer, the skull of General Phil Sheridan's horse, an Egyptian mummy, and a battle flag and war club used in Custer's last stand. The collection also included taxidermy specimens of an alligator, a Percheron horse, a two-headed calf, a cougar, and at least one python (Stilson et al. 2007; *Rochester Democrat and Chronicle*, 26 November 1932, 10 and 9 July 1933, 10). Many of Gruber's curios are listed on his postcard advertisements (fig. 8). Based on Gruber's biography and the many newspaper articles written about him, it is clear that Peter Gruber left a lasting impression as a colorful character in Rochester's history (Merrill 1946, 77-79; Stilson et al. 2007; *Rochester Democrat and Chronicle*, October 11, 1932; 15, 18).

2.2 History of the Jacket

Much about the history of the RMSC jacket remains uncertain. Stilson et al. mention that Gruber owned three snake skin jackets (2007, 94). It seems likely that the RMSC jacket is the same one that Gruber is wearing in figure 1, taken around 1914. Both jackets have a shawl collar, a single button closure, and the skin arrangement and patterns appear to be identical. Although the button in the photo appears smaller and lighter in color that the button on the RMSC jacket, the button might have been replaced. It seems possible that Gruber is wearing his other two jackets in additional photographs (figs. 9 & 10) that are undated. The jacket in figure 9 is clearly different because it has a notched lapel. While the basic

Figures 9 & 10: Peter Gruber in two of his snake skin jackets. Photographs undated.

structure of the jacket in figure 10 is the same as that of the RMSC jacket, the museum's jacket does not show signs of snake head buttons having been previously stitched along the jacket closure. The jackets in figures 9 and 10 both match Gruber's description of his first jacket, which had "buttons [that] are made of the heads of snakes" (*Rochester Democrat and Chronicle*, December 14, 1952).

William L. Clay, Peter Gruber's former attorney, gave the RMSC jacket and accompanying ensemble to the museum in 1950. These items are likely to have been part of an assortment of objects that Clay purchased at an auction of Gruber's personal and professional belongings after his death in 1932. Clay took many objects into his home and stored large and unwanted items in a barn in Rochester (*Rochester Democrat and Chronicle*, July 9, 1933; 10). It is unknown if the jacket and ensemble were stored in the barn. Based on the before treatment condition of these items, it is clear that they had been neglected.

Figure 11: Jacket Front and Back, Before Treatment, Normal Illumination.

3. DESCRIPTION AND MATERIALS

3.1 Jacket Description

This single-breasted leather suit jacket (Buffalo State CNS# 106713, fig. 11) is made from a variety of snake skins, most of which are rattlesnake skins. It is assumed that the skins were tanned, as tanning would prevent putrefaction and increase flexibility and durability. The analyses performed indicate that the leather was probably mineral tanned; however, the exact tanning agents remain undetermined. The jacket has a single button closure, a shawl collar, banded cuffs, and three double besom pockets (Calasibetta 1988; 133, 441). One pocket is at the proper left (PL) breast

Figure 12: Cigar with tobacco leaf fragments, Normal Illumination.

and the other two are at the waist. A cigar was discovered in the breast pocket during examination (fig. 12). The pockets are lined with a white cotton twill fabric and have two-inch snake skin pocket facings just below the pocket openings. The skins are machine stitched together in vertical rows with lapped seams, onto a black plain woven wool interlining fabric. This lining appears dark green in some areas. The top stitching over the lapped seams limits access to the reverse of the skins. The overall lining in the jacket body is a light brown cotton twill fabric. A blue and white striped cotton fabric lines the sleeves. All fibers were identified by polarized light microscopy (PLM).

Figure 13: Detail of Button.

The single button is securely hand stitched with cotton thread, just below the shawl collar. The button has four piercings and the front is textured with a fine grid relief pattern (fig. 13). The button material was initially suspected to be an early polymer, such as ebonite, but was later identified as vegetable ivory by Fourier transform infrared spectroscopy (FTIR). The buttonhole was hand stitched, but most of the thread is now lost due to abrasion. The keratinous surface layer of scales that is typically removed during reptile skin tanning (Graemer et al. 2006, 171) was not removed in this case, but the majority of this layer had fallen off. The extant keratinous layer remains primarily along the seams

where the skins are stitched together and on smaller skins. These scales and the collagenous scales below them are pigmented with similar patterns, making the matching of displaced keratinous scales somewhat easier. Approximately 40 keratinous scales were discovered in the waist pockets during treatment. As the original locations for these scales were completely unknown, they were placed in a labeled bag that is stored with the object, rather than being reattached.

The jacket displays a number of features that are characteristic of custom tailored jackets, such as straight seams, loose lining fabrics, a "neck" below the button, and a hand stitched buttonhole (Poulin 1952, 15-16). Due to the complex structure of the jacket and Gruber's reputation for hunting and maintaining snakes in captivity, it is suspected that the jacket and its accompanying ensemble were custom made for Gruber making use of skins that he collected.

3.2 Skin Identification

The skins with readily distinguishable pigmentation were identified by visual examination (fig. 14), in consultation with Bob Myers, Director of the American International Rattlesnake Museum in Albuquerque, New Mexico and in comparison to published photographs. The jacket is primarily comprised of rattlesnake skins, but a few bullsnake skins were also used. Skin types include eastern diamondback (*Crotalus adamanteus)* (fig. 15), western diamondback (*C. atrox*), and Mojave rattlesnakes (*C. scutulatus)* as well as bullsnakes (*Pituophis catenifer sayi*) (fig. 16) (Hubbs and O'Connor 2009; 36-37, 42-43, 58-59). The snakes identified are native to the southeastern and western United States, as well as northern Mexico (Hubbs and O'Connor 2009, Mattison 2007). This is consistent with the reports that Gruber traveled around the United States on hunting expeditions and hired other people to ship him snakes when he was not able to go hunting. According to his biography, most of Gruber's snakes were from the USA, but he occasionally obtained snakes from abroad (Stilson et al. 2007, 83-91).

Figure 14: Images of jacket, front and back, with skins colored by species.

Green – Eastern Diamondback
Pink – Western Diamondback
Orange – Bullsnake
Blue – Mojave Rattlesnake

3.3 The Snakes

Rattlesnakes are venomous pit vipers that belong to the *Crotalidae* subfamily of the *Viperidae* family. *Crotalidae* is further broken down into the *Crotalus* and *Sistrurus* rattlesnake genera. Twenty-nine species belong to the former genus and three to the latter. All are indigenous to the Americas, with the majority living in northern Mexico and the western United States. Rattlesnakes' distinguishing features are the set of articulated keratinous rattles at their tails and the heat-sensing pits between their eyes and nostrils on each side of their face. Each species has characteristic pigmentation and many are distinguished by diamond shapes on their backs, including the eastern diamondback, western diamondback, and Mojave rattlesnake skins in this jacket. Rattlesnakes are venomous rather than poisonous, meaning that they secrete poisonous venom through their fangs, while the rest of the snake is non-poisonous (Hubbs and O'Connor 2009; Mattison 2007; Klauber 1972).

Bullsnakes belong to the *Colubridae* family and subfamily. They are large, strong snakes that are known for defensive behavior when approached by humans. Although they are often mistaken for rattlesnakes, they are non-venomous. Their habitat stretches across southern Canada, the central and western USA, and northern Mexico (Mattison 2007, 228, 247-248).

3.4 Additional Materials

The wool, cotton, and vegetable ivory that comprise the lining fabrics, threads, and button are all materials that were readily available to tailors at the beginning of the 20th century, around the time that this jacket was made. The fibers in the wool fabric, cotton fabric, and cotton threads appear to have been machine spun and woven, based on their tight and regular structure. A lock-stitch sewing machine was used to complete most of the stitching in the garment; only finishing stitches, such as the stitching around the buttonhole, were completed by hand. These materials and construction techniques are consistent with textile manufacture at the beginning of the 20th century (Greeley 1872; 47-56, 914-919, 964-970, 1126-1137).

Vegetable ivory nuts, also known as tagua nuts or corozos, are the hardened endosperm of certain trees belonging to the *Phytelephas* or *Metroxylon* genera. The former genus is native to Central and South America and the latter is from the Pacific Islands. *Phytelephas macrocarpa*, *Metroxylon amicarum* and *M. salomonense* are three species found in the literature that are the most commonly used for making buttons, jewelry, tourists' souvenirs, and other small items by turning and carving. *Phytelephas macrocarpa* appears to be the species that was most commonly used for button manufacture beginning in the 19th century. As the name suggests, vegetable ivory nuts have dense cream-colored endosperm that, when polished, can look very similar to animal ivory. The nuts are approximately two inches in diameter and their primary component is cellulose, which can be dyed to look like the button on this jacket (Elevitch et al. 2006, 508-509; Fletcher 2008; Hornbeck *Ivory*; Janick and Paull 2008, 151-153; Holtzapffel, Charles 1993, 112; Hunger, Fred J. 1991).

3.5 Condition

Prior to conservation, the jacket was physically distorted and extremely soiled. The leather was brittle with significant tears and losses, caused by a combination of moth damage and breakage from handling. The most serious tears were a 13" H x 2 ½" W tear on the PL sleeve and a 1 ¼" H x 5 ½" W complex tear on the back, just below the collar (fig. 15). A large crumpled leather fragment, 3 ¼" x 1 ½" x ½", was found in the storage box containing the whole suit ensemble (pictured in figs. 11, 21, & 22). Initially, it was unclear if this belonged to the jacket, but during treatment it became clear that the fragment was part of the leather loss in the PL sleeve.

The wool and cotton lining fabrics are structurally stable overall with some losses. The wool losses are due to moth damage and the cotton losses are due to embrittlement and weakening from stains. Aside from the stained cotton, neither the leather nor fabric is friable. Overall soiling consisted primarily of grey particulates, frass, and white crystalline accretions. The grey soiling has accumulated more heavily in crevices. Larva casings on the light brown lining fabric and frass nestled in the scale crevices (primarily in tight areas like the armpits) are evidence of moth damage. The white crystalline accretions had built up on the exterior and interior of the leather and were most prominent on the jacket back; these were identified as a mixture of sodium chloride, fatty acids, and protein by FTIR, SEM-EDS, and Py-GC-MS. Two red-brown stains on the jacket back were noticeably less fluorescent than the surrounding area in UV-A radiation (fig. 18). Similar red stains were present in the lining fabric on the interior of the jacket, near the large damage below the jacket collar. These stains span across the interior of the shoulders, as if having come into contact with a corroded clothes hanger. The lining fabric was stiff and more degraded in this area. The jacket had a strong musty smell. The tips of most scales have delaminated from the leather and many are bent. Most of the keratinous scales have fallen off and the largest extant keratinous scales are about to fall off. Loss of these scales appears to be an inherent vice, as the extant scales are very loosely attached to the leather below, around the edge of each scale.

Figure 15: Complex tear below jacket collar, back.

3.6 Previous Treatments

There is at least one snake skin patch, 8" H x 1 ½" W, on the side of the PL sleeve that is closest to the jacket body. This patch covers a series of small holes (presumably from insect damage) and appears to have been applied before the skins were stitched together. The leather of the patch is darker, thinner, and more degraded than the leather underneath it. Most of this patch is now lost. At least two areas, approximately 2" x 1", were previously repaired with a brown silk thread. One of these areas, on the front of the PR sleeve, had a long ~10" tail of thread hanging from it. At the start of the treatment, only the tail could be seen. As the jacket was humidified and reshaped, it became clear that this thread was used to stabilize a tear with stitching (fig. 16). According to the RMSC staff, the vest in the ensemble was treated with para-dichlorobenzene, an ingredient present in some mothballs. Although there is no record for treating the jacket, the absence of para-dichlorobenzene was confirmed with Py-GC-MS.

Figure 16. Detail of stitched repair on the proper right arm.

4. IMAGING TECHNIQUES

4.1 Photographic Documentation

The jacket was documented using visible light, which is the portion of the electromagnetic spectrum (fig. 20) that the human eye can detect (400 – 800 nm λ), and long wave ultraviolet (UV-A) radiation, which is the adjacent region of the spectrum with higher energy and shorter wavelengths (300 – 400 nm λ). Visible light documentation included normal illumination (fig. 11) to capture the general appearance of the jacket and raking light (fig. 17) to emphasize the texture of the scales and distorted shape of the leather. UV-A radiation is invisible to human eyes, but it has the ability to excite some molecules to emit visible radiation that is called fluorescence (Stuart 2007, 75). The UV-A induced fluorescence in the jacket (fig. 18) helps to distinguish the areas with keratinous scales, which appear light blue, from areas in the leather where the scales are now lost, which appear more orange. This image also distinguishes areas that do not fluoresce, such as the light brown lining fabric, the button, and the red-brown stains on the back of the jacket.

Figure 17: Jacket Front and Back, Before Treatment, Raking Illumination

Figure 18: Jacket Front and Back, Before Treatment, UV-A Induced Visible Fluorescence

4.2 Computed X-radiography

The jacket was X-radiographed as part of the structural examination and documentation (figs. 19 & 20). X-rays are a type of high energy radiation in the electromagnetic spectrum (0.1-10 nm λ) that are used to identify the density and thickness of materials by irradiating an object at a specific energy, and then collecting the radiation that is transmitted and scattered by the object on an x-ray sensitive detector (Stuart 2007, 78). The images produced are based on the relative atomic weights and thicknesses of the materials in the object. Thicker and denser areas scatter radiation and appear white in the radiograph, while thinner and lower density areas transmit more radiation and appear dark.

Computed X-radiographs were captured using a Philips MCN 101 X-ray tube with a 1.5 mm focal array and 40° emergent beam angle. The jacket was radiographed in quadrants that were stitched together in digital format. The radiographs were made using a Kodak Industrex HR Flex 2174 imaging plate without filtration and scanned on a Kodak/Carestream Health ACR 2000 scanner. The exposure for the radiograph was 25 kV, 25 mAS (50 seconds, 10mA), 55"FFD, with an 8-ply mat board for tube filtration. The radiographs revealed a dense cylindrical object in the breast pocket, which was identified as a cigar (fig. 12), and small, high density spots throughout appear to be the white crystalline accretions. The multilayered fabric structure is also visible in the radiograph.

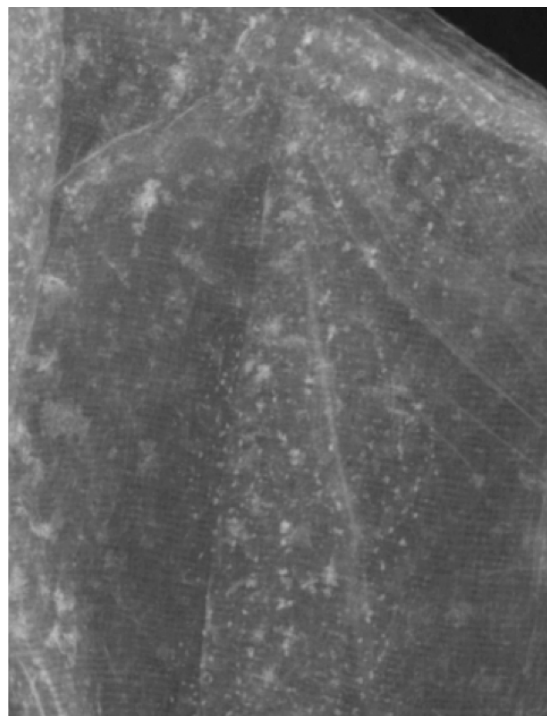Figure 19: X-radiograph (25 kV, 25 mAS (50 seconds, 10mA), 55"FFD, with an 8-ply mat board for filtration)

Figure 20: Detail of X-radiograph, from proper left shoulder showing white specks of dense material (probably white accretions), layered fabrics, and woven lining fabric structure.

5. MATERIAL ANALYSIS

5.1 Objectives

Analysis was completed in order to identify materials present and help characterize the condition of the leather. Specific goals were to identify pesticide residues, tanning agents, shrinkage temperature of the leather, the button material, and fibers. The red stains and white accretions were also characterized with the aim of identifying their origins. The red stains, in particular, were tested for the presence of blood, because the RMSC staff suspected that some red stains on other items in the ensemble might have originated with blood. These findings informed treatment decisions and provided information that contributes to the historical knowledge of the jacket.

5.2 Tanning Agent, Pesticide, and Stain Characterization with Microchemical Tests

Microchemical tests were performed to help characterize tanning agents in the leather, inorganic pesticides, and the red stains on the jacket (Table 1). Each test was run with the material in question, along with other materials that provided known positive and negative results.

The absence of lead in the white accretions and powdery soil was confirmed using Plumbtesmo® paper. Accretions on the inner cuff of the right sleeve were moistened with deionized water, applied on a cotton swab, and Plumbtesmo® paper was laid on the damp area. The pink or purple color change on the paper that would indicate the presence of lead was not observed.[2]

The absence of vegetable tannins was established in three leather samples taken from different areas on the jacket using a 1% ferric chloride solution (Thompson 2006, 59). The unknown samples were tested alongside known chrome and oak tanned leather fragments. The procedure included wetting the samples in deionized water, adding a drop of 1% w/v ferric chloride solution, and looking for a deep blue/black color to develop.

The test for aluminum tanning agents (Thomson 2006, 59) was negative. The snake skin samples were tested alongside alum tawed goat skin and chrome tanned leather. Each sample was moistened with a drop of 2M ammonium hydroxide followed by a drop of 0.1% sodium alizarin sulphonate solution in a 9:1 mix of ethanol and deionized water. After five minutes, excess reagent was removed with filter paper, and 3-4 drops of 1M acetic acid were added. The snake skin and chrome tanned leathers turned slightly yellow, while the alum tawed skin remained red.

The presence of iron was established in samples taken from the red stains on the back of the jacket and the lining at the shoulders. Burnt umber and rose madder pigments were used as known positive and negative materials, respectively. A drop of concentrated hydrochloric acid was applied directly to each sample on a white testing plate as it was being observed under a stereomicroscope. Development of a yellow color indicated a positive result (Odegaard et al. 2000, 64-65).

Table 1: Summary of microchemical test results.		
Material tested	*Material in Question*	*Result*
white accretions	lead (Pb)	−
leather	vegetable tannins	−
leather	aluminum tanning agents	−
red stained-accretion	iron (Fe)	+
red stained-accretion and stained lining fabric	blood	−

---

[2] A microchemical test for arsenic would also have been carried out if its presence has been identified by XRF analysis, which was completed before the microchemical analysis.

The absence of blood in the red stains on the back of the jacket and on the interior of the shoulders was indicated using a solution of benzidine dihydrochloride in acetic acid and hydrogen peroxide (Odegaard *et al*. 2000, 140-141). Fresh animal blood and burnt umber pigment were used for the known positive and negative materials, respectively. Each sample was placed on a piece of white filter paper before a drop of benzidine solution was placed on each sample. Development of a dark blue/blue green color indicated a positive result. The animal blood turned a bright green color, providing a strong positive result, while the stained accretion did not change color. Although aged and unaged blood may respond differently to the test, the lack of a distinct color change in the unknown sample was interpreted as a negative result.

5.3 Polarized Light Microscopy

The yarns in the linings, interlinings, and sewing threads were identified by polarized light microscopy (PLM) using a Zeiss Axio Imager MAT Reflected-Light Microscope with brightfield transmitted light. The observed images were recorded using AxioVision Microscope Software. The characteristic scale pattern on the warp and weft of the black interlining fabric indicates that it is wool. The characteristic twisted fiber morphology, which results from the collapsed lumen in cotton fibers, indicates that the original sewing threads and the warp and weft of the brown lining and white interlining fabrics are all cotton. The brown repair thread from the stitched repair on the proper right (PR) arm was identified as silk by the smooth, uniform diameter with slight irregularities (Hall 1982; 17, 19-20: Textile Institute 1985; 143, 160, 163). The identification of the silk was supported by FTIR analysis, which indicated that the thread is proteinaceous. Representative samples for each fiber type are pictured in figure 21.
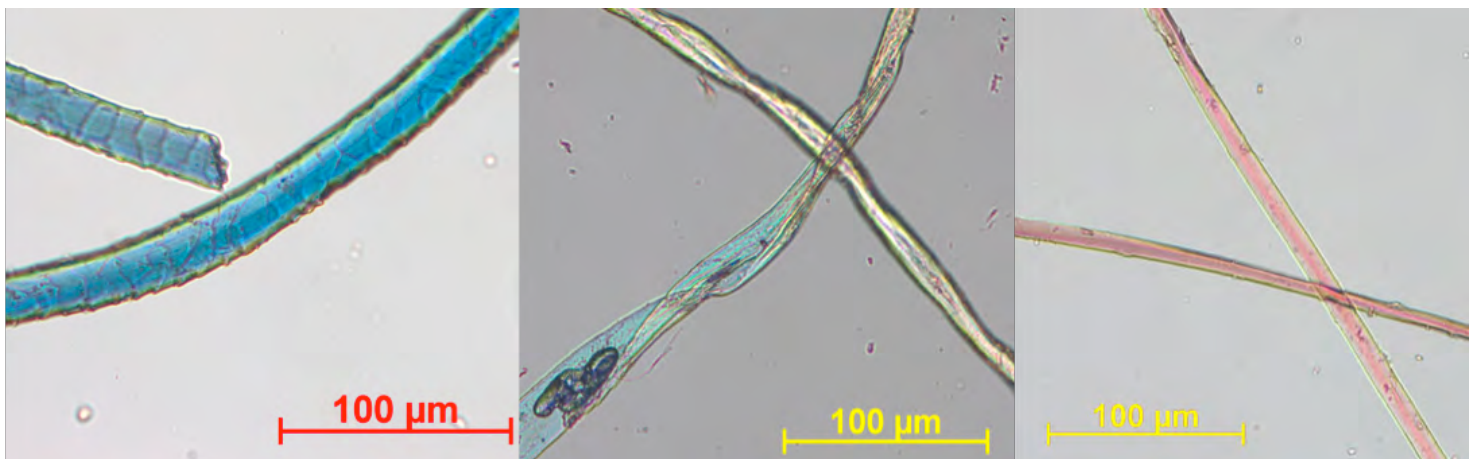

Figure 21: Wool fibers from the black interlining fabric (left), cotton fibers from the white interlining fabric (center), and silk fibers from the brown repair thread in proper right arm (right).

5.4 Hydrothermal Stability Assessment

The hydrothermal stability, or shrinkage temperature (T_s), values for three samples of snake skin were identified as 40-45°C. Hydrothermal stability is the temperature at which protein chains in leather are denatured (Florian 2007, 104; Haines 1987, 3). Shrinkage temperature identification provides the conservator with a sense of the stability of the leather in relation to other leathers. Species, tanning agents, deterioration, pH, and salts can all impact shrinkage temperature (Haines 1987, 1). Tanning agents increase T_s, while deterioration decreases T_s (Thornton 2009). As standardized test procedures are necessary to attain comparable results, methods described by Young (1990) were followed. Small leather fragments were degreased in acetone, hydrated in deionized water (neutralized to pH 7), heated in a water bath at a controlled rate (4°/minute) on a Micro Hot Stage (fig. 22), and observed under magnification with reflected illumination. The temperatures at which the samples began and ceased shrinking were recorded (fig. 23).
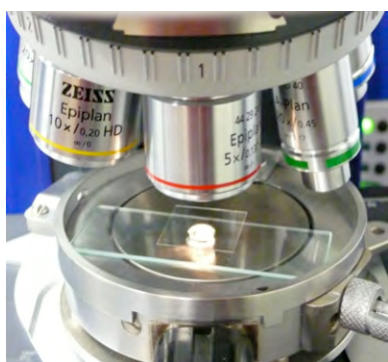

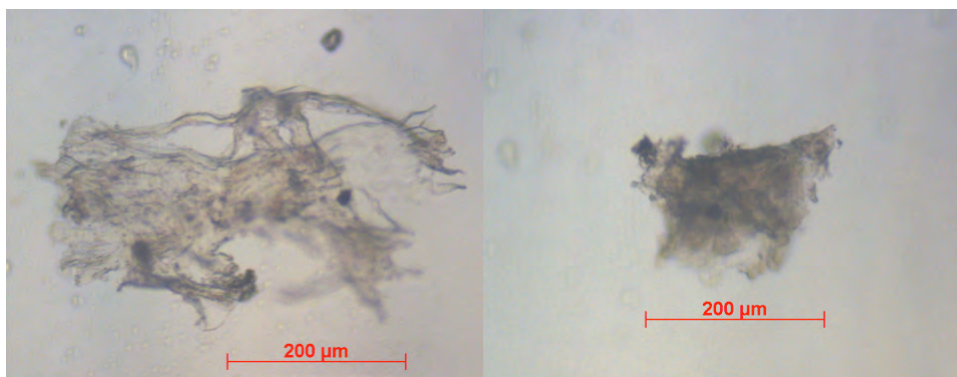Figure 22: Shrinkage test set-up on the hot stage.

Figure 23: Corium fibers before and after shrinkage between 40-45°C.

5.5 X-ray Fluorescence Spectroscopy

X-Ray Fluorescence (XRF) spectroscopy was used to identify potential tanning agents, dye mordants, soiling components, and pesticides. XRF is a qualitative, non-destructive method of analysis that involves exciting a material with high energy photons (X-rays) and studying the emission of characteristic fluorescent X-rays to determine the elemental composition (Stuart 2007, 234). Spectra are often taken at higher and lower energy settings at the same location, because atoms are more or less sensitive in different energy ranges depending on their atomic weight. Sometimes peaks in XRF spectra overlap, causing difficulties in interpretation. This is the case with the peak at 4.5keV in all of the spectra from the jacket, which may be due to either barium or titanium. The assignment of such peaks can be aided by looking for different characteristic peaks for one of the two elements in question. A higher scan setting would have been necessary to confirm the presence of barium by one of its higher characteristic peaks; however, this was not done as identification of barium and/or titanium was not

critical to this study. XRF has been used to successfully identify a variety of art materials, including dye mordants and pesticides, in other studies (Green and Daniels 1990; Derrick et al. 1999, 18; Katayama et al. 2008; Odegaard and Sadongei 2005; Podsiki 2007; Sirois et al. 2007, Janssens et al. 2000). It is assumed that XRF analysis will also be useful for identification of elements in mineral tanned leathers, such as chromium, sulfur, and aluminum. The results are summarized in table 2, followed by two selected spectra (fig. 28).

Table 2: Summary of XRF data														
Sample Area (kV)	**Al**	**Si**	**S**	**Cl**	**K**	**Ca**	**Ti**	**Cr**	**Fe**	**Cu**	**Zn**	**Pb**	**Br**	**Ba**
Wool Interlining PR arm (30kV)	-	-	m	M	m	m	m?	M	M	m	M	m	-	m?
Wool Interlining PR arm (15kV)	-	-	M	M	m	m	m?	M	M	m	M	-	-	m?
Leather, Interior Collar (40kV)	-	-	t	m	m	m	t?	t	M	M	M	m	m	t?
Leather, Interior Collar (15kV)	t	t	m	M	m	m	t?	t	M	M	M	m	m	t?
Button (40kV)	-	-	-	t	t	m	t?	M	m	m	m	m	m	t?
Leather PR Breast Pocket (30kV)	-	m	m	M	m	M	t?	m	M	m	M	t	t	t?
Leather PR Breast Pocket (15kV)	t	m	M	M	m	M	t?	m	M	m	M	-	-	t?
Soiling, removed with deionized water (30kV)	-	-	-	m	m	m	m?	m	M	M	M	-	-	m?
M = major component m = minor component t = trace component														

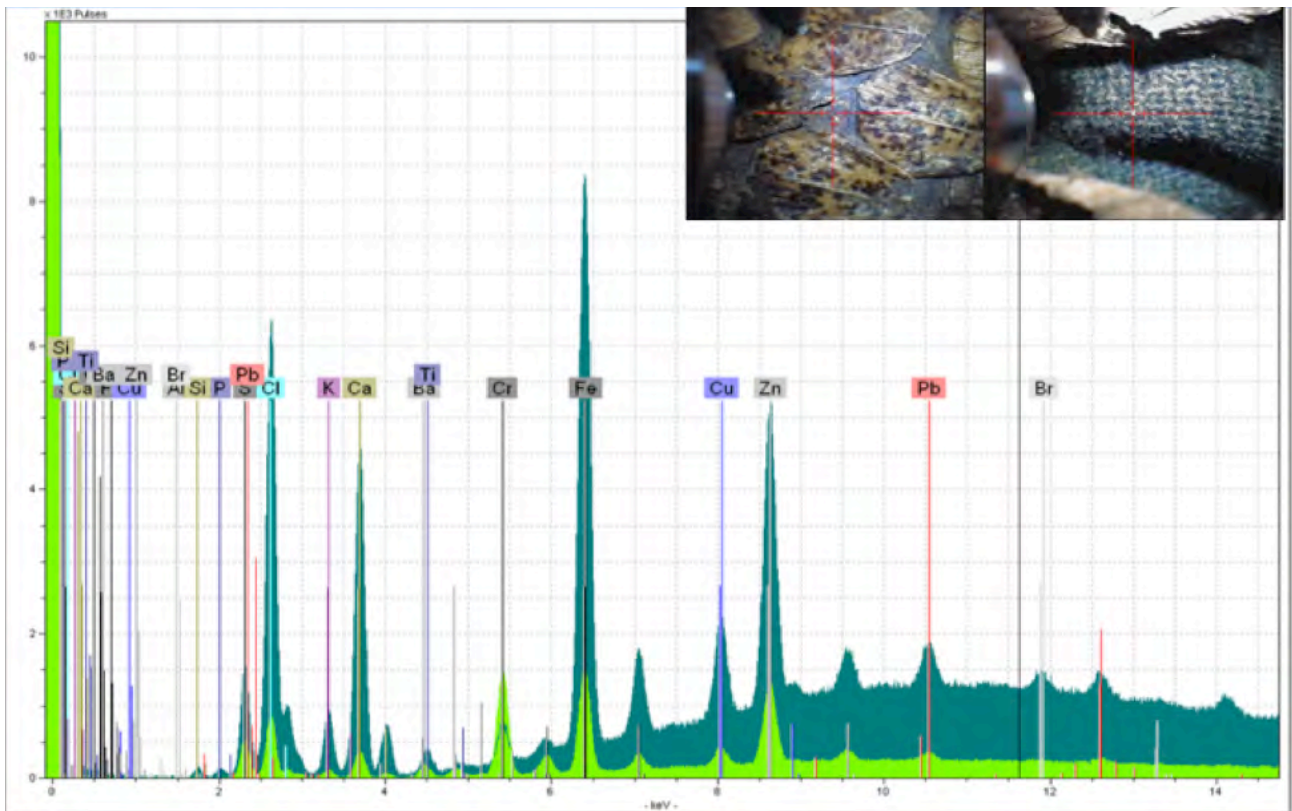Figure 24: XRF spectra taken on adjacent areas on the green interlining fabric (bright green) and leather (darker green). [15kV, 1500 µA, vacuum, 90 seconds, no filter]

5.6 Fourier Transform Infrared Spectroscopy

Fourier transform infrared spectroscopy (FTIR) was used to characterize the button material, silk repair thread, and components in the white crystalline accretions (fig. 25) found on leather surfaces throughout the jacket and accretions sampled from the red stains on the back of the jacket. FTIR is a qualitative technique that measures the absorbance of infrared radiation by a sample to determine its molecular makeup. The absorption peaks identify the types of chemical bonds or functional groups present in the sample and can serve as a molecular fingerprint. This type of analysis is best suited for organic materials and substances that absorb in the range of 4000-1000 cm^{-1}. FTIR has been used successfully to identify organic materials in artworks (Stuart 2007, 110-136).
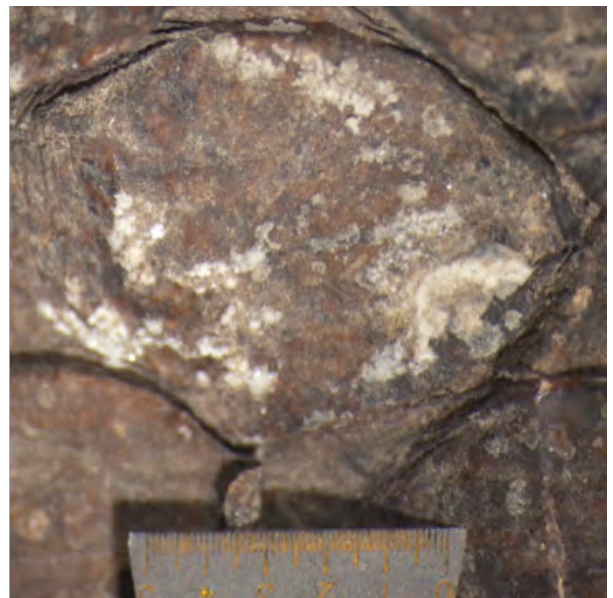

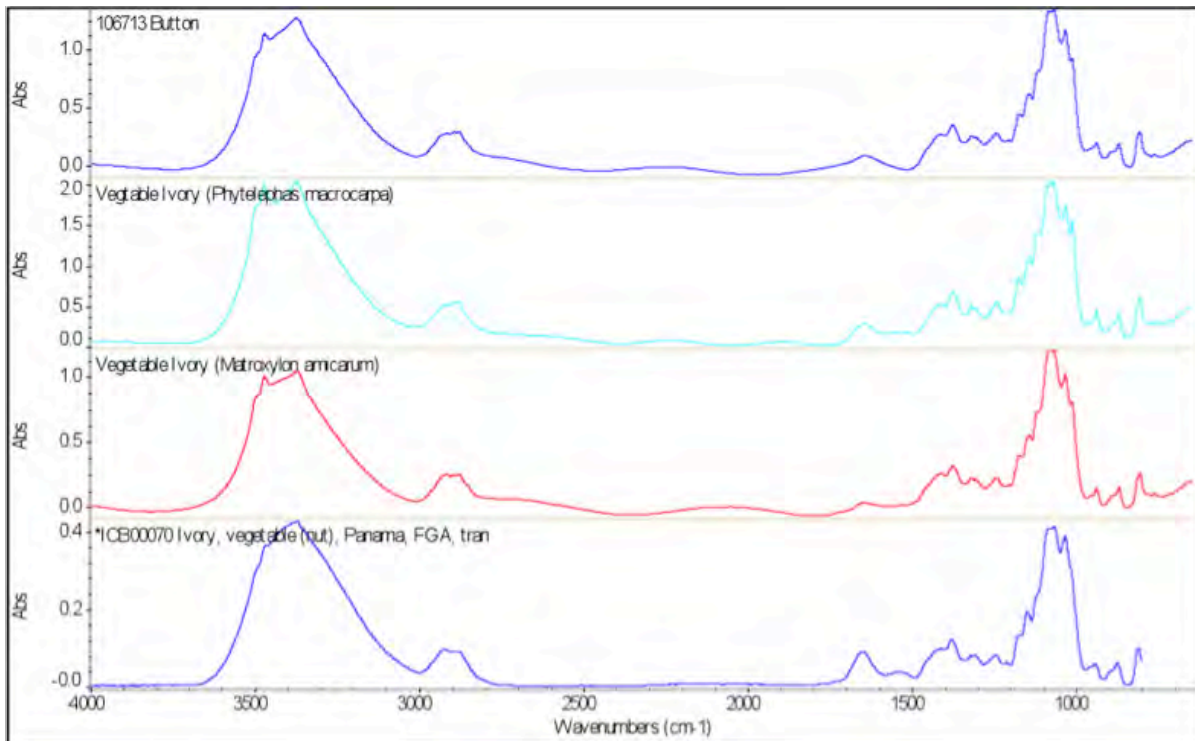Figure 25: White accretions on leather, back proper right shoulder.

Figure 26: Infrared Spectra for (top to bottom) the button material, two vegetable ivory species from the study collection at Buffalo State College, and an unknown species in the FGA library.
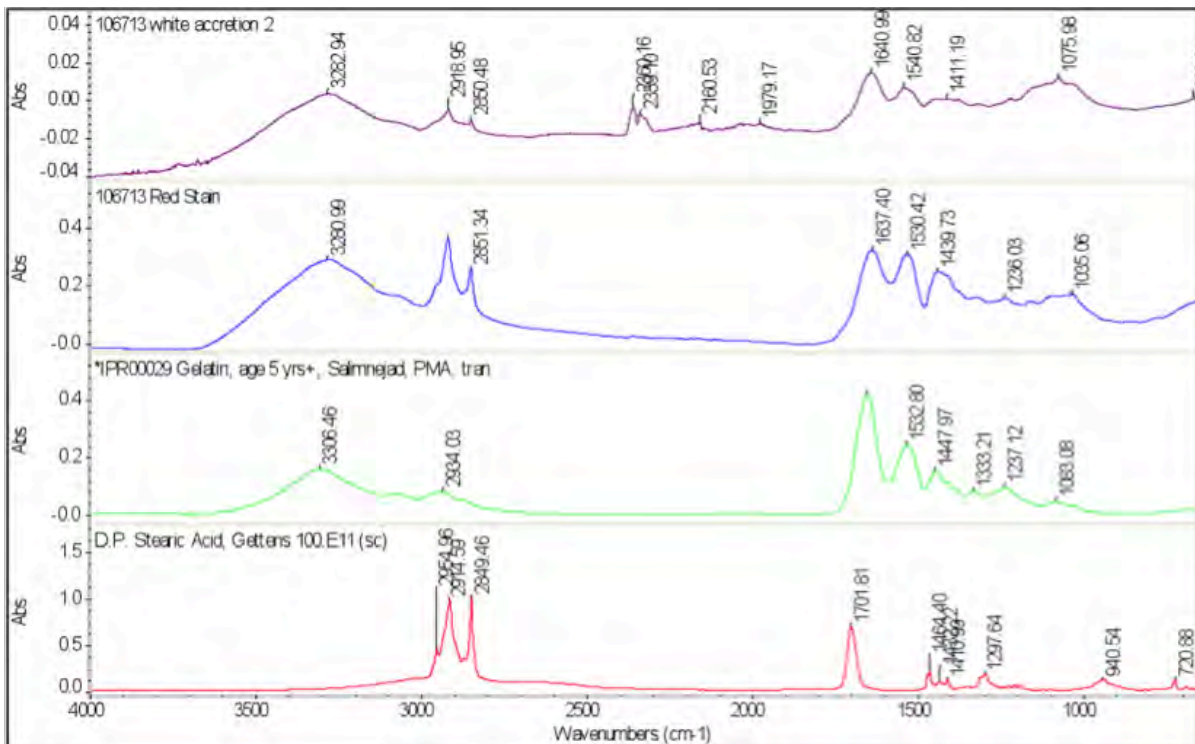

Figure 27: Infrared spectra for (top to bottom) the white accretion, red stain, gelatin, and stearic acid.

The button material spectrum is nearly identical to three vegetable ivory spectra (fig. 26). The spectra for *Phytelephas macrocarpa* (light blue) and *Metroxylon amicarum* (red) were collected from specimens in the study collection at Buffalo State College, following the same protocol that was used for the button. Although the species and collection method for the vegetable ivory spectrum from the artists' materials database are unknown, this spectrum (dark blue) is also very similar to that of the button.

The spectra for the white and red stained accretions (fig. 27) are similar and both closely match the spectra for proteins, such as gelatin. The sharpness of the peaks around 2850cm^{-1} and 2915cm^{-1} suggests that fatty acids, such as stearic acid, are present. These peaks are due to CH_2 and CH_3 groups that are part of both proteins and fatty acids, and both of these materials are potentially present in the accretions. The presence of fatty acids was confirmed by Py-GC-MS. The crystalline form of the white accretions and the weak signal intensity of these spectra indicate that they also contain infrared-transparent material, which was later identified as sodium chloride by SEM-EDS.

The spectrum for the long repair thread was very similar to the spectra for silk (fig. 51, APPENDIX B). This, in combination with the morphology observed by PLM, indicates that the repair thread is silk.

5.7 Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy

Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDS) was used to further characterize the white accretions on the jacket, specifically by identifying the inorganic crystalline component. SEM analysis involves scanning a sample with a beam of excited electrons and detecting secondary and back-scattered electrons to produce detailed images that show topography of the sample surface and differences in atomic composition, respectively. The EDS portion of the analysis involves detecting characteristic X-ray fluorescence of the atoms in the sample, also produced by the excited electron beam, for elemental analysis. Non-conductive samples are coated with a conductive material, such as gold or carbon. The procedure is carried out in a vacuum, and the technique is more sensitive to lower density atoms than the XRF. High magnification levels allow for greater precision in identifying elements at specific locations on a sample. SEM-EDS has been used to identify the composition of organic and inorganic art materials (Stuart 2007, 91-100). The SEM spectra indicate that the inorganic component is predominately sodium chloride. Calcium, potassium, sulfur, phosphorus, silicon, and aluminum are present in smaller quantities (fig. 28).
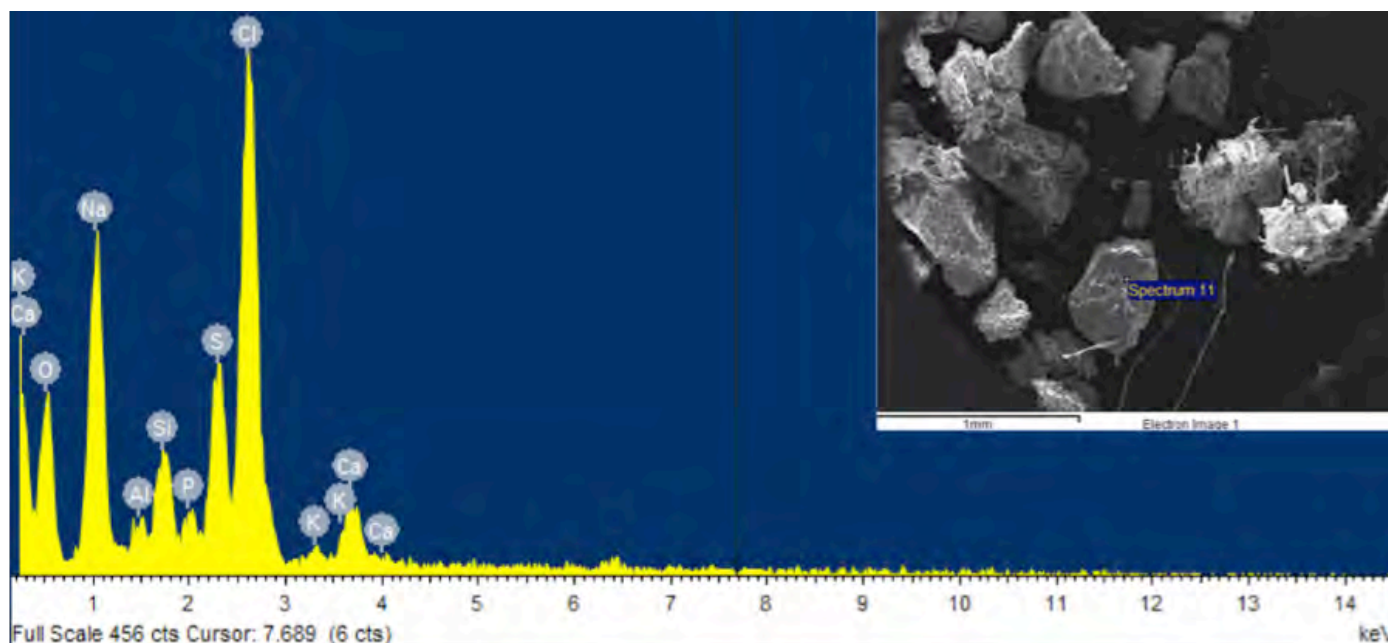
Figure 28: EDS spectrum and secondary electron image of white accretion.

5.8 Pyrolysis-Gas Chromatograph-Mass Spectrometry – The Schilling Method

Pyrolysis-gas chromatography-mass spectrometry (Py-GC-MS) was used to analyze a sample of white accretion, a cotton lining fragment with red-brown stain, and a *Magic Chemisorber L[3]* that had been exposed to the jacket during humidification. The *Magic Chemisorber L* contains a polymeric material that absorbs volatile organic molecules, such as organic pesticides, that can then be analyzed by Py-GC-MS. Py-GC-MS is a type of qualitative or quantitative analysis for organic materials in which the macromolecule bonds in a sample are cleaved by pyrolysis, enabling the molecule fragments to travel through a gas chromatography capillary column. The fragments have varying affinities for the material in the column and those of different sizes and polarities exit at different times; the time of exit is the retention time for each fragment. Upon exiting the column, the molecule fragments enter a mass spectrometer (MS), where they are ionized and guided by a magnetic field toward a detector to record their atomic weights. The atomic weights correlate to the peaks on the chromatogram and specific components of a sample. This technique has been used to identify a variety of organic materials, including fatty acid in oil paints (Stuart 2007, 269-272, 300-315). Sample collection using the *Magic Chemisorber L* is similar to the solid phase microextraction (SPME) method that Heald et al. used for organic pesticide identification with GC-MS (2005).

The presence of fatty acids in the white accretions on the leather was confirmed (fig. 29). The smaller peaks in the spectrum may be due to proteins in the accretions that fragmented into many small

---

[3] A Solid Phase Extraction Element (SPEE), Frontier Laboratories Ltd., Fukushima, Japan, www.frontier-lab.com.

molecules during extraction or pyrolysis. These peaks are numerous and the associated molecule fragments are not readily discernible as amino acids, or fragments of amino acids. No porphyrins were identified in analysis of the fabric sample, indicating that the stain is not blood. The *Magic Chemisorber L* that had been exposed to the jacket during humidification did not contain residues of organic pesticides such as para-dichlorobenzene, dichlorovos, naphthalene, or ethylene oxide.
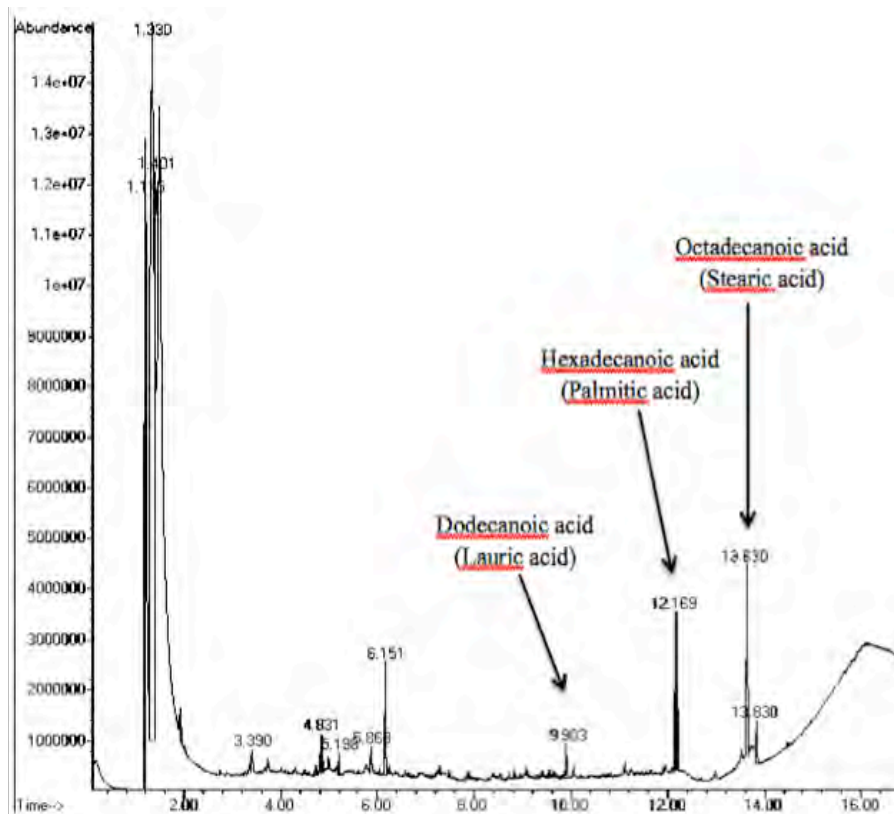

Figure 29: Total ion chromatogram showing fatty acid peaks.

5.9 Discussion of Findings from Scientific Analysis

The analyses performed helped characterize the materials and condition of different parts of the jacket. Identification of specific materials in the jacket was successful with microchemical tests, PLM, FTIR, SEM, and Py-GC-MS. Hydrothermal stability assessment helped characterize the condition of the leather. The XRF analysis identified at least 13 elements, many of which might have been present for one or more reasons. The interpretation of the results is discussed below, as it applies to different parts of the jacket.

Potential Pesticides

The jacket may have been treated with one or more pesticides. Zinc, silicon, bromine, chlorine, and sulfur, identified by XRF, are all elements that could have been applied in pesticide or fungicide treatments. The trace amount of phosphorus, identified in the white accretions by SEM-EDS, may also be due to one or more potential pesticides. Fortunately, arsenic and mercury were not found, indicating that poisonous arsenical and mercuric pesticides are not present. Although lead and copper were identified by XRF, the absence of arsenic indicates that copper acetoarsenite and lead arsenate are not present and these elements are probably from other sources. The prominent zinc and smaller silicon peaks suggest that zinc hexafluorosilicate[4] may have been used. This mothproofer came into use around 1950, the year that the jacket was accessioned at the RMSC, and it was commercially available until 1987. Zinc phosphide[5] is a rodenticide that was in use around the same time. Zinc dithiocarbamate, a fungicide, is another potential source for zinc as well as sulfur. Sodium fluorosilicate,[6] ammonium fluosilicate, and silica gel[7] are all potential silica sources. Ethylene dibromide and methyl bromide[8] are two toxic pesticides that could be related to the bromine content. A variety of organic pesticides, many of which contain chlorine, may have been applied to the jacket. Analysis by Py-GC-MS found that the most common organic pesticides, dichlorobenzene, dichlorovos, napthalene, and ethylene oxide are absent. This analysis, in combination with the identification of the white accretions as sodium chloride, suggests that the chloride content is largely due to the accretions throughout the jacket rather than chlorine in an organic pesticide. In addition to zinc dithiocarbamate, potential sulfur sources are propargite,[9] sulfuryl fluoride,[10] and sulfur dioxide. Sodium fluoride[11] and sodium fluoroacetate,[12] are

---

[4]Trade name: Arko Moth Proof.
[5] Trade names: Arrex or Ridall-Z
[6] Trade name: Larvex.
[7] Dri-Dri was the trade name for a mixture of silica gel and ammonium fluorsilicate.
[8] Trade name: Bromogas and Methyl Fume.
[9] Trade name: Comite.

potential pesticides well, although the fluorine components were not detectable by the analyses performed on the leather. Future analysis of the leather with SEM-EDS could help identify the presence, or absence, of fluorine as well as confirm the presence of phosphorus in the leather (Odegaard and Sadongei 2005, 15-30; Goldberg 1996).

Fabrics and Threads

All original fibers in the jacket are cotton or wool, which are natural fibers that were commercially available as threads when the jacket was made. Identification of the silk thread in the stitched repair does not help date the restoration, as silk threads were also available when the jacket was made. Chrome, copper, aluminum, sulfur, iron, and titanium, identified by XRF, are all elements in dye mordants that could have been used to dye the black wool lining, brown interlining, and/or vegetable ivory button. The relatively high chrome content of the button and fabric might be indicative of chrome mordants (Matthews 1920, 645). Iron might be present in the black wool interlining fabric, as tannin-rich dyes with iron mordants are traditionally used for black dyes. This seems somewhat unlikely, because these dyes are prone to degrading fabric substrates (Barker 2002) and the black interlining fabric is in relatively good condition where it is not moth damaged. Copper sulphate, aluminum sulphate, chrome-alum, and tannin-titanium-oxelate are all materials used for dying fabrics around the turn of the last century that could potentially have been used to dye the fabrics in the jacket (Society of Dyers and Colourists 1899).

Table 3: Shrinkage Temperature (T_s) for Un-tanned Leathers (°C)	
Cold-water fish	33-44
Warm-water fish	52-58
Sheep	58-62
Rabbit	60-62
Goat	64-66
Cattle	65-67
(Thornton 2009, class notes)	

Soiling and Stains

The red-stained accretions from the back of the jacket and the red-stained fabric from the shoulders were both found to contain iron and be free of blood. It seems likely that these stains were caused by contact with a ferric alloy. The stains on the interior of the shoulders, in particular, appear to have been caused by a corroded clothes hangar.

The white and red-stained accretions were identified as a mixture of protein, fatty acids, and sodium chloride. The protein and fatty acids are potentially due to components in the leather migrating

---

[10] Trade name: Vikane
[11] Trade name: Florocid.
[12] Trade name: Compound 1080.

to the surface. Both substances occur naturally in the leather. An oil-based treatment may also have been applied as a dressing at some point (Kite et al. 2006, 128). The exact origin of the sodium chloride is unknown. If it was introduced to the jacket while solubilized, the organic components in the material may have been drawn to the surface of the leather as the soluble salts dried and precipitated on the surface. Some of the chloride might remain from a sodium chloride curing process used to preserve the skins before tanning. Chlorine may also be due to perspiration, rainwater, or another unknown contaminant (Florian 2007, 87). Interestingly, the presence of sodium chloride in the leather may increase the T_s of the jacket (Florian 2007, 105; Haines 1987, 4). Iron, sulfur, and lead, identified by XRF, may be partially explained as common soils and pollutants. The presence of calcium remains unexplained.

Leather

The absence of vegetable tannins, identified by microchemical testing, and the presence of chromium, copper, aluminum, iron, and titanium, identified with XRF, indicate that the leather was probably mineral tanned. The exact tanning method remains unknown. The microchemical test for aluminum was negative, although it is possible that the test was not sensitive enough to detect the small quantity present. Chrome seems like a likely tanning agent, as chrome peaks are present in all XRF spectra. As previously mentioned, chrome may also have been used as a dye mordant. Sulfur, chloride, and potassium may also remain from a mineral tanning procedure, as metal salts are typically used in tanning (Covington 2006; American Leather Chemists Association 1907, 144-145; Flemming 1916; Florian 2007, 87; Rogers and Flemming 1922).

The T_s values for three samples of snake skin were identified as 40-45°C, indicating that the leather has a relatively low shrinkage temperature in comparison to the published T_s values for other untanned leathers, which range from 33-67°C. While the tanning agents in the snake skin would have increased the T_s when the skins were freshly tanned (Florian 2007, 104; Thornton 2009), the untanned values are referenced because of the degraded state of the leather. These values also represent a variety of animals (most published values of tanned leather are for cattle hides). Published T_s values for reptilian skins would be useful in analyzing this data; however, one were found in the cited sources. The T_s values of 40-45°C indicate that heat should be used cautiously in the conservation treatment.

6. CONSERVATION TREATMENT

6.1 Treatment Goals

Treatment goals were to surface clean the leather overall, humidify and restore the shape of the garment, repair tears in the leather, fill major losses, and prepare the jacket for display and storage on a three-dimensional mount. The relatively low shrinkage temperature of the leather indicated that caution should be used when applying moisture and heat. Prior to treatment, additional testing with humidity and heat was completed on the large leather fragment that was associated with the jacket and in discrete areas of the jacket. Aqueous cleaning and a heat set adhesive were chosen for the treatment; heat and moisture, however, were never applied to the leather simultaneously. The old stitched repairs were left in place, as they are adequately stabilizing damage and their removal is likely to worsen damage.

Table 4: Soil Solubility Testing	
Solvent	Solubility
Deionized water	Grey soiling – very soluble White accretions – very soluble
Saliva	Grey soiling – very soluble White accretions – very soluble
1% solution of Triammonium Citrate	Grey soiling – very soluble White accretions – very soluble
Ethanol	Grey soiling –partially soluble White accretions – partially soluble
10:20:30 mix of Xylenes:Ethanol:Water	Grey soiling –partially soluble White accretions – minimally soluble
Odorless Mineral Spirits	Grey soiling – minimally soluble White accretions – insoluble

6.2 Cleaning

Careful vacuuming, inside and out, was completed using a soft brush and a HEPA vacuum with variable speed control. The vacuum nozzle was not covered with nylon net, due to the quantities of moth casings and insect frass that were vacuumed away. Instead, the smallest vacuum attachment was used and care was taken to avoid losing keratinous scales. When a loose or detached keratinous scale was found, it was surface cleaned and consolidated with BEVA film, as described below *(6.4 Consolidation)*. Vulcanized rubber soot sponges were used to further reduce soiling on the accessible areas of the blue striped and brown lining fabrics. A significant quantity of soil was removed, but the fabrics did not appear noticeably lighter or cleaner.

Surface soiling on the leather was tested for solubility in a variety of solvents (Table 4). Deionized water, triammonium citrate, and saliva were most effective. Saliva was ruled out based on sanitary concerns and the large quantity of solvent that would be required to clean the large, heavily

soiled jacket. Triammonium citrate might have been a good chelating agent for the iron-rich soil, but it was ruled out as well, due to concern about clearing residues on the intricate leather surface. Deionized water applied on cotton swabs was ultimately chosen, as it was readily available, did not leave residue, and was efficient in reducing both the grey soil and white accretions. Wet swabs were rolled on blotter paper before application, which reduced the potential of causing discoloration, hardening, tidelines, and/or movement of salts or tannins by over wetting (Kite et al. 2006). Significant quantities of the grey soiling (fig. 30) and white accretions (fig. 31) were removed. In some areas, local humidification was brought about by the surface cleaning treatment. When this occured, these areas were clamped flat between blotters and corrugated acid-free blue board, using rare earth magnets (fig. 32).

6.3 Humidification and Reshaping

Figure 30: During cleaning. The proper left side of the collar is surface cleaned.

Figure 31: Photomacrographs of before and after cleaning white accretions.

Figure 32: Local clamping with rare earth magnets.

Reshaping began with local humidification of the deepest creases using humidified tissue (Doyal and Kite 2006, 188). Acid-free tissue papers were humidified with deionized water, shaped appropriately, and then stuffed into tight creases. The areas were loosely covered with a Mylar barrier. Although a tight seal was not achieved due to the uneven overall shape of the leather jacket, these areas were more pliable after approximately one hour. Relaxed leather was reshaped and clamped with a combination of rare earth magnets, as described above, and stuffing with pillows. The pillows were made for this project in varying sizes out of a plain woven, low friction polyester fabric with thermally bonded polyester

Figure 33: The largest fragment before (left) and after (right) humidification and flattening. Once flattened, it became clear that this fragment belonged in the largest loss on the back of the PL arm.

stuffing. Square pillows, ~ 8" x 8", were prepared with a small opening that allowed stuffing to be inserted or removed as necessary. Tube-shaped pillows were prepared for the sleeves, which were open at the top and bottom so that stuffing could be inserted at the shoulder or cuff.

Prior to overall humidification, the detached leather fragment and two ivory nut samples from the study collection were humidified to 80% RH in separate chambers with saturated ammonium sulphate solutions. These tests were completed to gain a better sense of how the leather and vegetable ivory button would respond to humidity. After five hours in the chamber, the leather fragment was sufficiently pliable as to be opened up and flattened. It was dried under weights while pressed between two blotter papers. Once flattened (fig. 33), it became clear that this fragment belonged in the largest loss on the back of the PL arm. Measurements of the vegetable ivory samples were taken in multiple locations before, during, and after the humidity rise using a micrometer. No dimensional changes were observed, even at 80% RH.

Figure 34: Overall humidification under acrylic dome.

Overall humidification was completed inside a humidity chamber that was comprised of an acrylic dome on top of a large suction table (fig. 34). Water vapor was produced with an ultrasonic humidifier. The jacket was arranged on top of a sheet of blotter paper with a blue board tray underneath. The jacket was humidified at 80-85% RH for six hours. It was periodically removed from the chamber, on the tray, during this period for repositioning as the leather relaxed. After the six hour period, the jacket was more supple overall and the general shape was positioned using stuffing materials as described above, with the addition of a torso-shaped Ethafoam® support. The support was covered with polyester batting and surgical cotton stockinette tubing. The most severe distortions along the jacket closure were still very stiff.

Figure 35: Application of local humidification using the ultrasonic nebulizer wand. Although not pictured, a blotter paper was wrapped around the tip of the wand to prevent dripping.

The final humidification step involved local humidification along the stiff jacket closure using the ultrasonic humidifier wand (fig. 35). Once supple, the area was clamped between blotter paper and blue board with rare earth magnets and allowed to return to ambient humidity. This step was completed three times, first directly after the overall humidification. It was allowed to return to ambient humidity over a 15 hour period after the first application and then a 24 hour period after the second application.

The humidification and repositioning treatment was successful overall. The jacket is much closer to its original shape. Despite repeated humidification and clamping steps, some undulations remain in the leather.

Figure 36: A scale before (left) and after (right) reattachment of the keratinous scale with BEVA film. The color of the area with the missing scale on the left is lighter.

6.4 Consolidation and Tear Repair

Consolidation of Keratinous Scales

Loose keratinous scales were heat-set in place using BEVA film. This adhesive was chosen because the film could easily be custom cut for each loose scale, inserted between the corium and keratinous scales, and heat-set in place using a wood burning tool (set to 160- 165°F), under a silicon release Mylar barrier (fig. 36). These repairs are easily reversible with heat or solvents. Scales that became detached during treatment and others that were clearly about to fall off were consolidated. Consolidation of all of the remaining keratinous scales was not possible because they are so numerous, and many would have had to be disrupted before they could be consolidated. Therefore, many of the extant keratinous scales remain loosely bound to the leather and are vulnerable to future loss. Minimal and careful handling is imperative for the preservation of these scales.

Tear Repair of Leather

Tears in the leather were repaired using heat-set adhesive patches. The intent was for these patches to provide support without overpowering the structural integrity of adjacent areas, and to be as reversible as possible. BEVA film was chosen because of its high strength, high glass transition temperature, uniform thickness, and reversibility with both heat and solvents that will not damage the leather. Heat setting was the preferred attachment method because it is fast and controllable. It also minimizes saturation of the leather with solvents and misalignment of repairs. Heat application was tested on leather fragments before treatment and no negative effects were observed. *Hon mino*, a medium weight *kozo* Japanese paper, was chosen for the support material because it is strong, lightweight, and easy to tint. This proved too flimsy for areas larger than a square inch, so larger patches were made from two sheets of *hon mino* that were

Figure 37: Repaired area on front of PR arm, before (top) and after (bottom).

laminated with BEVA film. The papers were pre-toned with acrylic paints, applied by pneumatic gun.
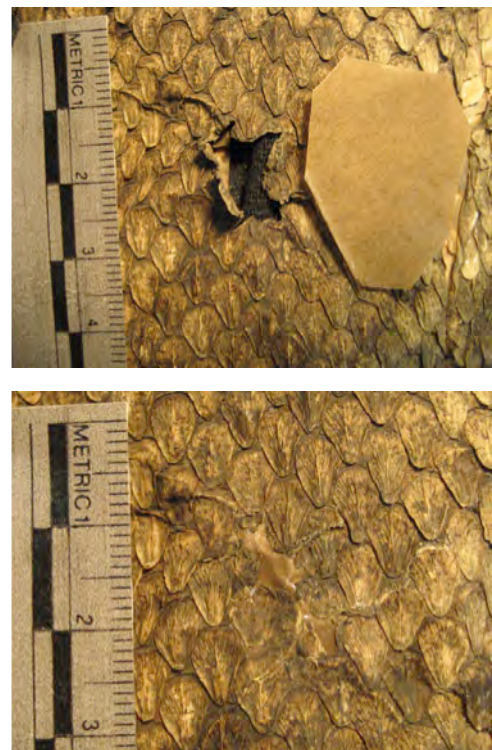
The backside of the leather around each tear was cleaned using deionized water before inserting the patch. The patches were custom cut approximately 3/8" wider than the damaged areas (fig. 37, top), inserted through the tears (as the backs were not accessible), and set in place using a heated spatula at 160ºF (71ºC) with a silicon release Mylar barrier. In most cases, the leather was supported on the backside with finger pressure, but a wooden
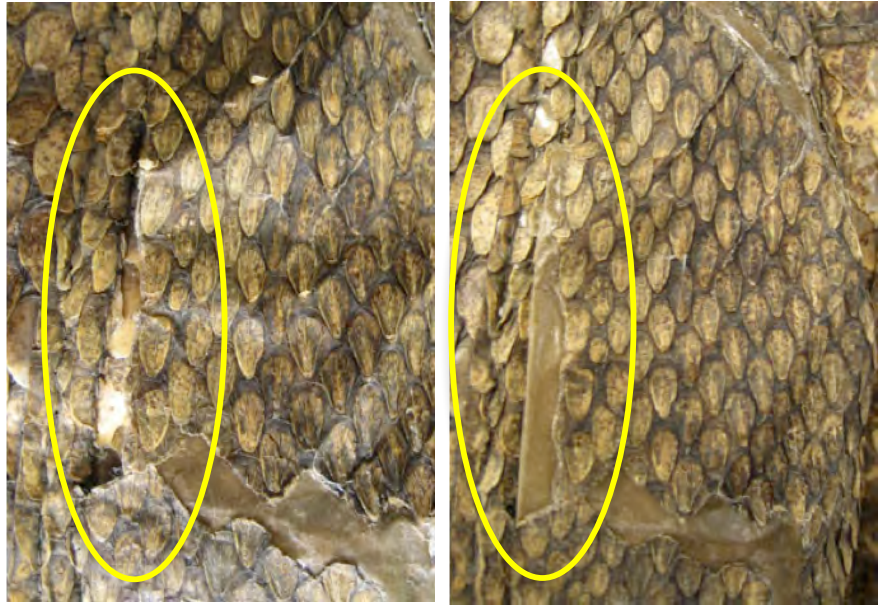

Figure 38: Repair on front PR arm near the shoulder. Before (left) and after (right) patch was inserted along torn skin-to-skin seam. The patch within the oval on the right was adhered directly to the lighter colored scales visible within the oval on the left.

block or flat stick was used for support in areas that could not be reached easily, particularly in the arms.

In most cases the BEVA film was adhered only to the back of the damaged area. There were, however, two patches along skin-to-skin seams where the only stable leather available for anchoring the patches was an area of the adjacent skin that was under the lapped seam. These two instances were in the loss at the front of the PR arm (fig. 38) and in the large loss on the back of the PL sleeve. In these cases, a piece of BEVA film was placed between the back of the patch and heat-set to the leather below.

The tears below the back of the collar and on the PL sleeve were more complex than those in other areas. The loss below the collar was patched with multiple patches, adhered to each other, and that conformed to the hump-like shape of the leather. These patches are not anchored along the top edge because there is no leather on which to anchor the patch. Repairing the loss on the PL sleeve began by consolidating small damages along the sides with small BEVA-infused Japanese paper patches, applied to the back (fig. 40A). The large leather fragment (fig. 33) was then adhered to a large Japanese paper repair patch that was aligned and adhered in the largest loss on the jacket (fig. 40B).

Filling and Inpainting

Filling and inpainting were completed to cover the shiny exposed surfaces of the BEVA-infused patches. Inpainting was completed with acrylic paints in small areas, ~1" in either direction (fig. 39). The areas were toned to a flat or mottled color. The detailed snake skin pattern was not replicated with inpainting. Larger losses were filled with printed Japanese paper that was adhered to the exposed BEVA film on the underlay patches. The paper was applied to the exposed BEVA with a warm tacking iron. The largest of these were the areas below the collar and on the PL arm. The fills were created by obtaining digital snake skin images, manipulating the images in Adobe® Photoshop®, and printing them out on Japanese paper with Epson UltraChrome K3™ pigment inks on an Epson Stylus Photo R2880 Ink Jet Printer.

Figure 39: Area with small losses that are toned with acrylic paints.

The digital images were obtained in two ways: the large fragment was scanned while detached, and an area of the central skin on the back of the jacket was digitally cut from the before treatment documentation photo. These two digital images were manipulated to be an appropriate size, shape, and color, so that they would match the losses at the back of the neck and on the PL sleeve when printed out on Japanese paper. The colors on the computer screen and the printed colors were quite dissimilar, so a sample area was printed out on a small piece of Japanese paper after each color manipulation. For each printout, the Japanese papers were cut to an appropriate size and taped to computer paper with clear pressure-sensitive office tape.

The fills at the back of the neck and top of the PL sleeve were applied by cutting individual scales out of the printed paper and adhering them with a warm tacking iron, following the general pattern of the surrounding snake skin. The largest fill on the PL sleeve was applied in one piece. The paper was aligned and adhered in place, first at the patch center. Working toward the edges, the perimeter of the patch was cut with curved cuticle scissors to conform to the loss (fig. 40 C & D).

Figure 40 A, B, C, & D: Tear on back of PL arm. A) After consolidating small losses along sides. B) After inserting overall patch with the large fragment. C) During insertion of digitally printed fill. The top of the patch is attached. D) After treatment.

6.5 Mounting

Building a Support Form

A torso was prepared for the jacket using heat welded Ethafoam®, thermal bonded polyester batting, cotton fabric and cotton thread. The hand carved foam mannequin was surrounded with batting and covered with a 12" W surgical cotton tubing. Extra batting was used to bulk the neck and shoulder area. The cotton tube was stitched to conform to the top of the mannequin along the shoulders, and tucked in a slit at the bottom of the mannequin. A neutral colored show fabric was stitched to the front and bottom edge of the mannequin with cotton thread (fig. 41). The polyester pillows that had been used for filling out the jacket arms during humidification and reshaping were adapted to make padded arm supports for the mannequin (fig. 41). These arm supports are stuffed with loose polyester batting, rather than the rolled sheet batting recommended in the literature (Flecker 2007, 103-110), because the stiff leather needed to be filled out rather than shaped like an arm; it was too stiff to be shaped like an arm. The arm supports are resting in the sleeves and are not attached to the interior Ethafoam® mount because attachment was unnecessary and omitting this step helps avoid unnecessary manipulation. The arms are pinned in place in the documentation photo below (figs. 41 & 42).

Figures 41 & 42: Mannequin with arms pinned in place (left). Jacket on the mannequin after conservation treatment (right).

6.6 Preventative Measures for Future Care

A muslin dust cover was made for the mannequin with a polyester zipper closure. The protective dust cover will help protect the jacket from dust and light in storage, but it will not be impervious and the jacket should be kept in a clean storage room that is dark or lowly lit.

In the future, the jacket should be protected from damage by either chemical or physical means. Ultraviolet radiation should be eliminated by filtration, as it is unnecessary for viewing artworks, and can cause severe chemical degradation to organic materials such as this jacket. When on display, lighting should be kept as low as possible. Fifty lux has been recommended for textile and leather display; however, this may need to be increased if the lighting is too low to adequately view artwork. Increasing the lighting will speed deterioration, but a balance must be met between protecting the artwork and making it accessible for viewing and appreciation. Environmental conditions of 60-64°C and 45-55%RH are recommended for both exhibit and storage. Reducing the temperature can slow degradation mechanisms, although care should be taken to avoid increasing the humidity when decreasing the temperature. Environments with relative humidity above 65% can foster mold growth, especially without ventilated air movement (Doyal and Kite 2006, 190; Tímár-Balázsy and Eastop 1998, 337-338, Schultz 1992, 150-151).

In order to prevent physical damage, the jacket should be vacuumed periodically while on display and whenever it is taken off display and placed in storage, as accumulated dust can be abrasive. The leather remains brittle and many of the extant keratinous scales remain vulnerable. The mannequin

made during treatment is designed to support the jacket while on display and in storage. If the jacket is ever removed from the mannequin to be placed in a storage container, the interior will need to be adequately supported to prevent worsening of the creases and distortions. Additionally, the storage container will need to be large enough to accommodate the jacket without folding, as the leather is too stiff to withstand folding without breaking. The lack of support prior to conservation was one of the key issues that caused the jacket to be so flat and distorted. If the jacket must be removed from the mannequin, the handler should slip his or her hands under the shoulders of the garment and carefully lift the jacket off the mannequin. Handling should be kept to an absolute minimum.

7. CONCLUSION

Peter Gruber's snake skin jacket is now cleaner, structurally more stable, and much closer to the shape of a wearable jacket than it formerly was. It is now more representative of the way the jacket looked when Gruber wore it. The investigation into Gruber's personal history provided historical context for the jacket. Analysis by PLM, FTIR, SEM-EDS, and Py-GC-MS helped identify the fibers, button material, and components of the soiling. The XRF analysis identified 13 elements that are likely to be part of mineral tannins, dye mordants, and pesticide residues. The jacket was found to be free of mercury and arsenic, which are both poisonous elements that could have been applied as pesticides. Successful cleaning and stabilization treatments followed analysis. The jacket is now supported with a custom-made interior form for both storage and display.

ACKNOWLEDGEMENTS

APPENDIX A

X-RAY FLUORESCENCE SPECTROSCOPY

X-ray fluorescence spectra for areas A, D and E were collected using a Bruker ARTAX energy dispersive x-ray spectrometer system at 15kV and 30kV energy settings, in order to identify higher and lower density atoms. The excitation source was a rhodium (Rh) target x-ray tube with a 0.2 mm thick beryllium (Be) window, operated at 15kV and 700µA or 30kV and1300µA current. The X-ray beam was directed at the artifact through a masked aperture of 3.000 mm in diameter. X-ray signals were detected using Peltier cooled XFlash 2001 silicon drift detector (SDD). Helium purging was used to enhance sensitivity to light elements. Spectral interpretation was performed using the ARTAX Control software. Spectra were collected over 60 seconds live time. The rhodium and zirconium in the spectra are attributed to the tube and detector, respectively.

The X-ray fluorescence spectra for areas B and C were collected using a Bruker Tracer III-SD handheld energy dispersive X-ray spectrometer. The excitation source was a Rhodium (Rh) target X-ray tube, operated at 15kV and 55µA or 40 kV and 25 µA current. Filters were used to reduce the background radiation and enhance the sensitivity in the energy range of interest: 1mil titanium at 15kV and 12 mil aluminum + 1 mil titanium at 40 kV. The X-ray beam interacts with sample at approximately a 4x5mm oval. X-ray signals were detected using a Peltier cooled XFlash silicon drift detector (SDD) with a resolution of 146.4eV. A vacuum was used to enhance sensitivity to light elements. Spectral interpretation was performed using the Sp1XRF software. Spectra were collected over 60 seconds live time.

Table 4: Summary of XRF data																	
Fig. #	Area	Sample Area (kV)	Al	Si	S	Cl	K	Ca	Ti	Cr	Fe	Cu	Zn	Pb	Br	Ba
43	A	Wool Interlining, PR arm (30kV)	-	-	m	M	m	m	m?	M	M	m	M	m	-	m?
		Wool Interlining, PR arm (15kV)	-	-	M	M	m	m	m?	M	M	m	M	-	-	m?
44	B	Leather, Interior Collar (40kV)	-	-	t	m	m	m	t?	t	M	M	M	m	m	t?
45		Leather, Interior Collar (15kV)	t	t	m	M	m	m	t?	t	M	M	M	m	m	t?
46	C	Button (40kV)	-	-	-	t	t	m	t?	M	m	m	m	m	m	t?
47	D	Leather PR Breast Pocket (30kV)	-	m	m	M	m	M	t?	m	M	m	M	t	t	t?
		Leather PR Breast Pocket (15kV)	t	m	M	M	m	M	t?	m	M	m	M	-	-	t?
48	E	Soiling, removed with deionized water (30kV)	-	-	-	m	m	m	m?	m	M	M	M	-	-	m?
M = major component m = minor component t = trace component																	
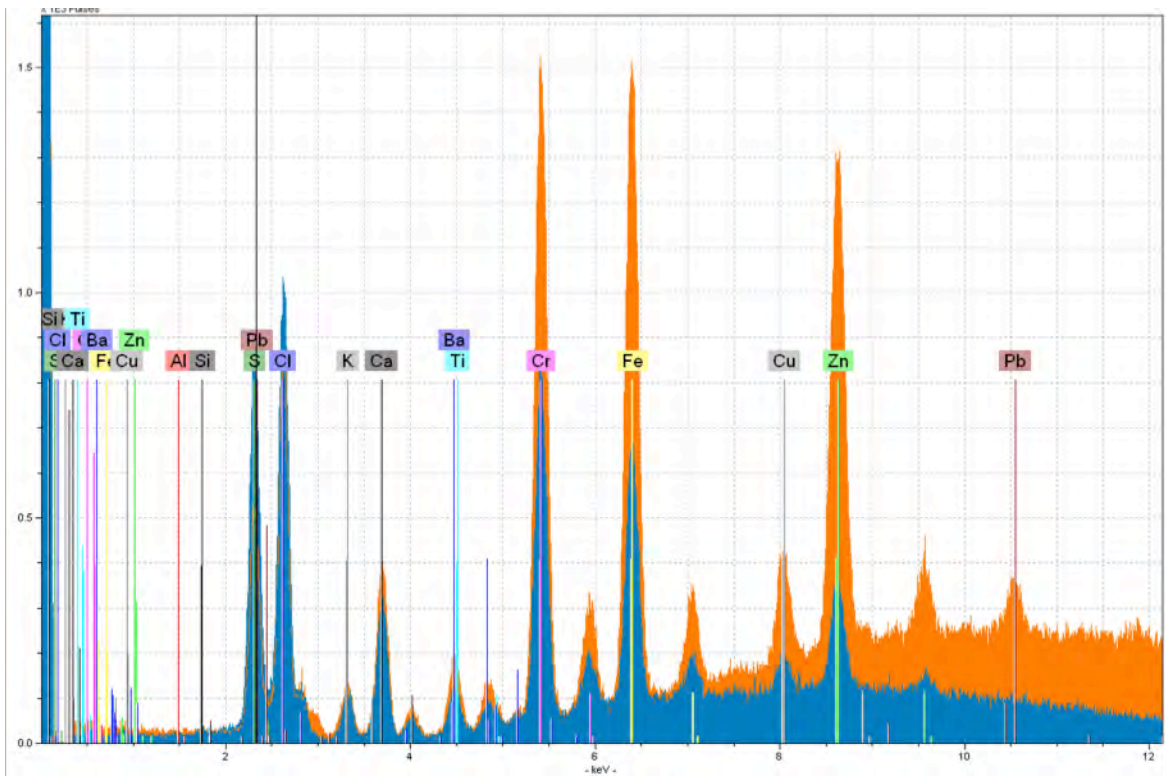
Figure 43: XRF spectra. Wool Interlining, proper right arm. [Orange – 30kV, 1300µA, no filter, 60s] [Blue – 15kV, 700µA, no filter, 60s].

Figure 44: XRF spectrum. Leather, interior collar. [40kV, 25 µA, 12 mil aluminum + 1 mil titanium filter, 60 seconds]
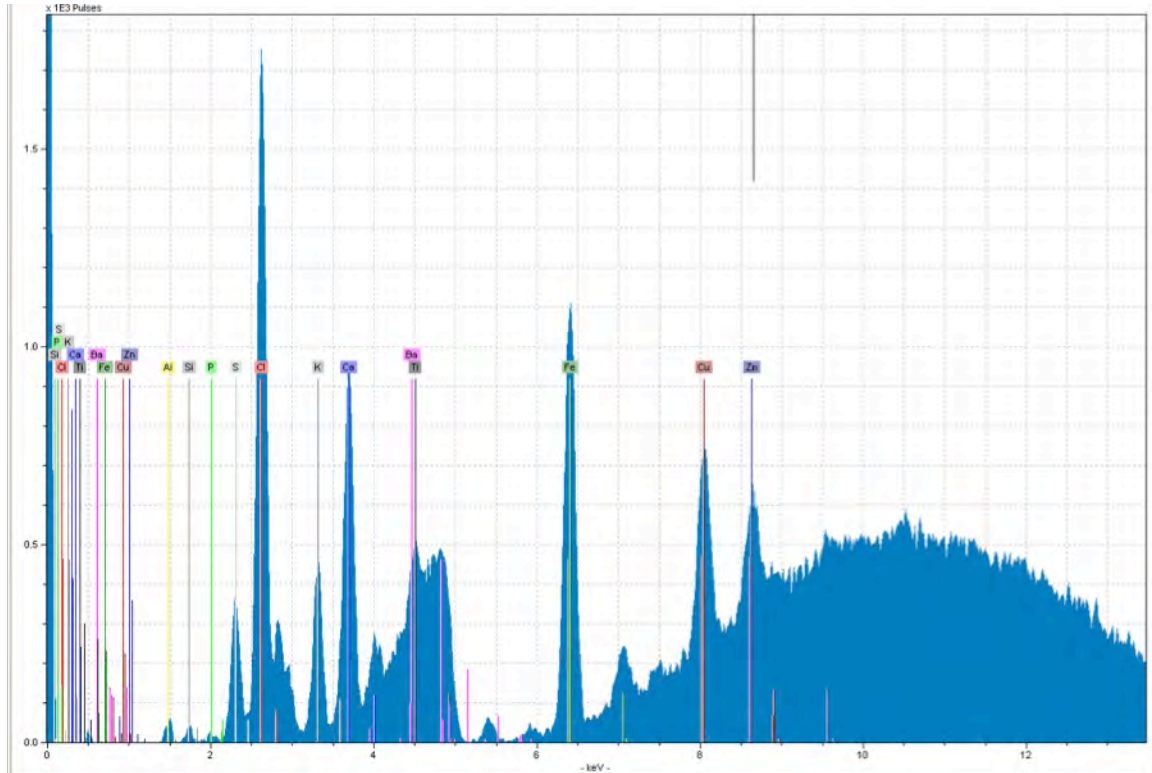
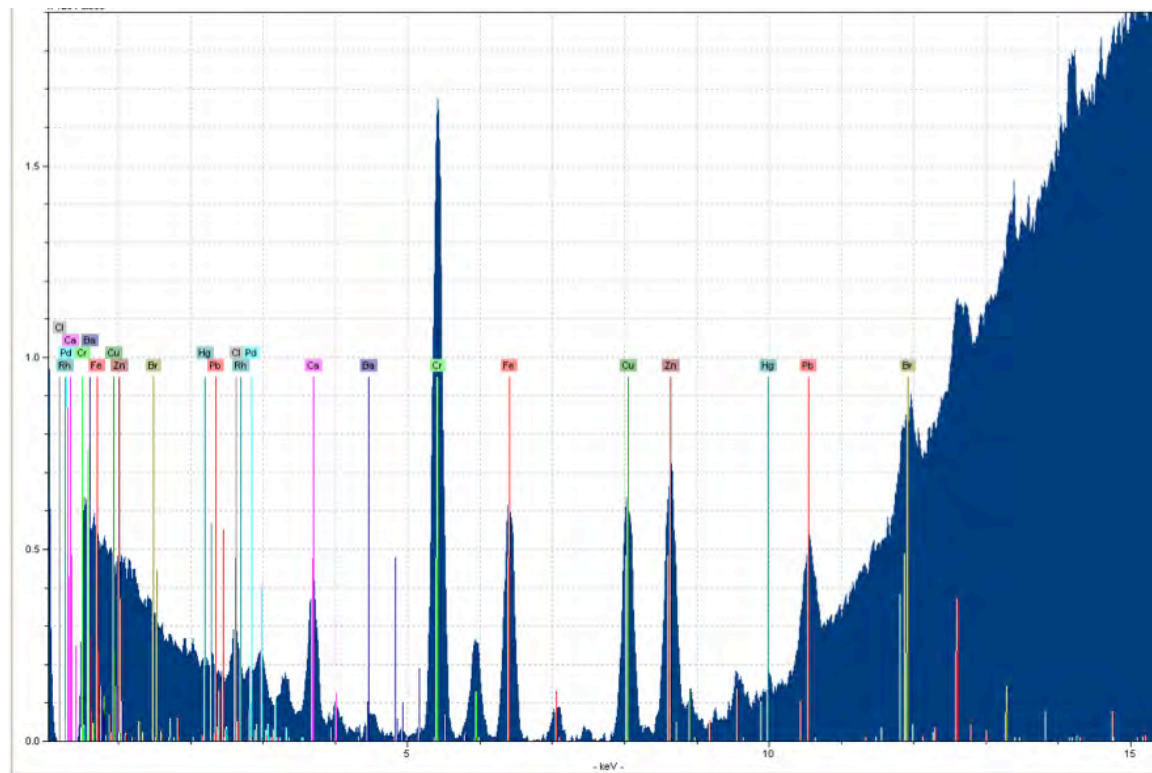Figure 45: XRF spectrum. Leather, interior collar. [15kV, 55µA, 1 mil titanium filter, 60 seconds]

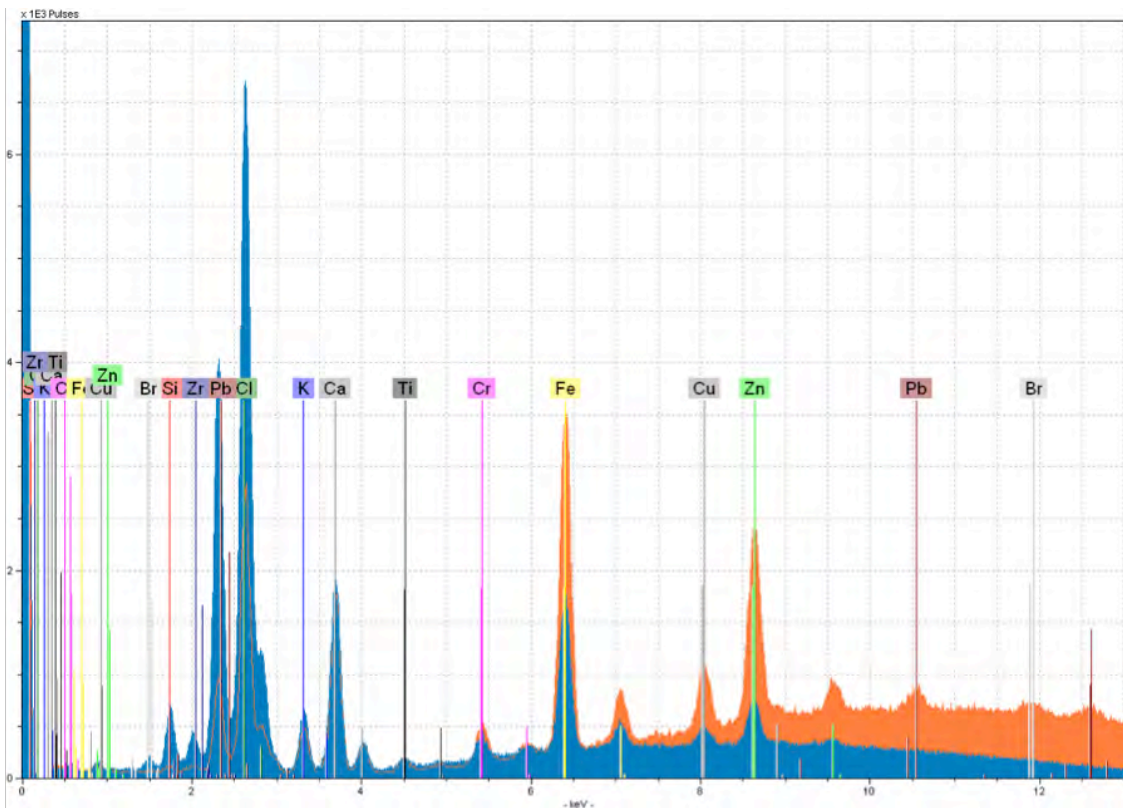Figure 46: XRF spectrum. Button. [40kV, 25 µA, 12 mil aluminum + 1 mil titanium filter, 60 seconds]

Figure 47: XRF spectra. Leather PR Breast. [Orange – 30kV, 1300µA, no filter, 60s] [Blue – 15kV, 700µA, no filter, 60s].

Figure 48: XRF spectrum. Soil removed with deionized water using a cotton swab. The spectrum for a clean cotton swab has been subtracted. [30kV, 1300µA, no filter, 60s]

APPENDIX B

FOURIER TRANSFORM INFRARED SPECTROSCOPY

Infrared spectra were collect by two methods. Spectra for the button and accretions were collected using a Continuum microscope coupled with a Magna 560 FTIR spectrometer (Thermo Nicolet). These samples were prepared by flattening them in a diamond compression cell (Thermo Spectra Tech), removing the top diamond window and analyzing the thin film in transmission mode on the bottom diamond window (2 x 2 mm surface area). An approximately 100 x 100 μm square microscope aperture was used to isolate the sample area for analysis. The spectra are the average of 32 scans at 4 cm^{-1} spectral resolution. Correction routines were applied to eliminate interference fringes and sloping baselines. The spectrum for the repair thread was collected using a Nicolet 6700 FTIR spectrometer (Thermo Scientific) with a Thermo Scientific Smart iTR ATR accessory. Samples were analyzed by pressing them against the Diamond ATR crystal. The spectra are the average of 16 scans at 4 cm^{-1} spectral resolution. An ATR correction routine was applied to compensate for variations in penetration depth with wavenumber. Identification for all samples was aided by searching a spectral library of common conservation and artists' materials (Infrared and Raman Users Group, http://www.irug.org) using Omnic software (Thermo Scientific). The button material was sampled by removing an approximately 2mm x 3mm sliver from the backside using a #15 scalpel blade. The accretions were sampled using a sharpened bamboo skewer. The long piece of repair tread that was trimmed from the PR arm was used for analysis.

| Table 5: Summary of FTIR Results			
Figure Number	**Area**	**Sample Area**	**Interpretation**
49	**A**	Button Material	Spectrum is nearly identical to the three vegetable ivory spectra. The spectra for *Phytelephas macrocarpa* (light blue) and *Metroxylon amicarum* (red) were collected from specimens in the study collection at Buffalo State College, following the same protocol that was used for the button spectra. Although the species and collection method for the vegetable ivory spectrum from the artist's materials database are unknown, this spectrum (dark blue) is also very similar to that of the button.
50	**B & C**	White accretions (top spectra) and accretions from the red-stained area (second from top).	The spectra for the white and red stained accretions are similar and both closely match the spectra for proteins, such as gelatin. The sharpness of the peaks around $2850cm^{-1}$ and $2915cm^{-1}$ suggests that fatty acids, such as stearic acid, are present. However, these peaks are due to CH_2 and CH_3 groups that are both found in proteins and fatty acids. Both materials are potentially present in the accretions. The presence of fatty acids was confirmed by Py-GC-MS. The crystalline form of the white accretions and the weak signal intensity of these spectra indicate that they also contain infrared-transparent material, which was identified as sodium chloride by SEM-EDS.
51	**D**	Silk Thread, PR arm	Spectrum closely matches spectra for silk. This, in combination with the fiber morphology identified by PLM, indicates that this is silk thread.
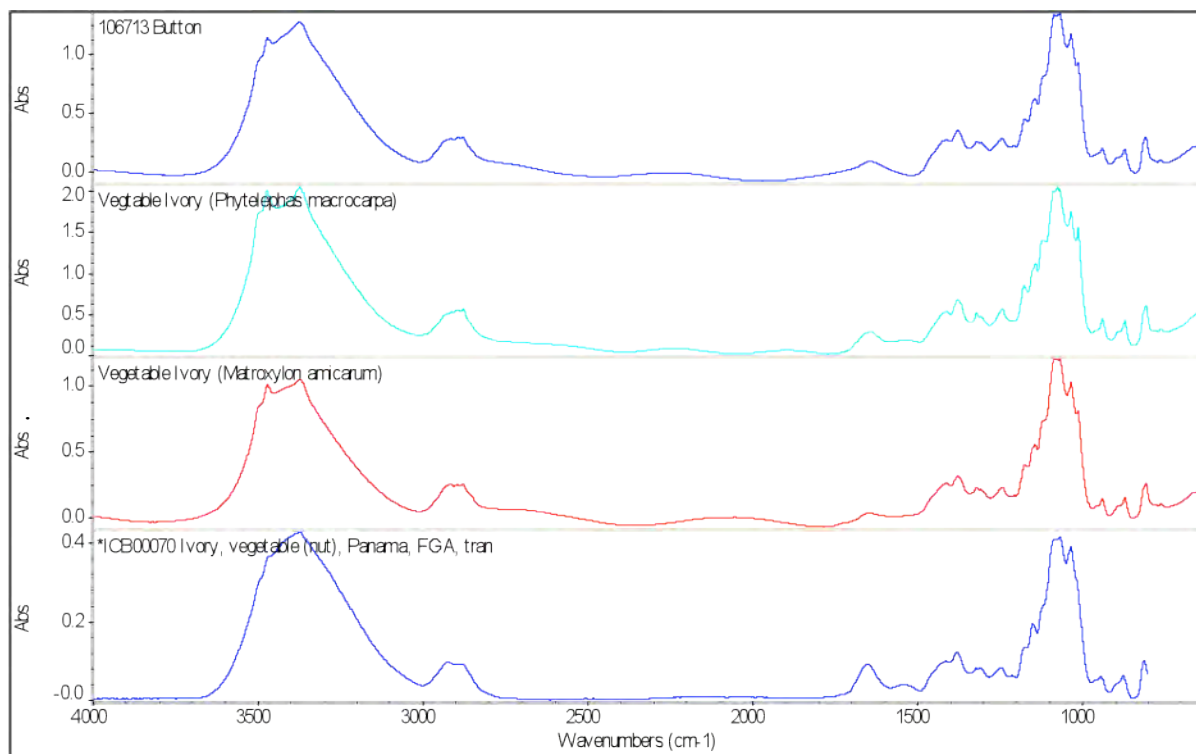
Figure 49: FTIR spectra of (top to bottom) the button material, *Phytelephas macrocarpa*, *Metroxylon amicarum*, and vegetable ivory (nut) from the IRUG library.
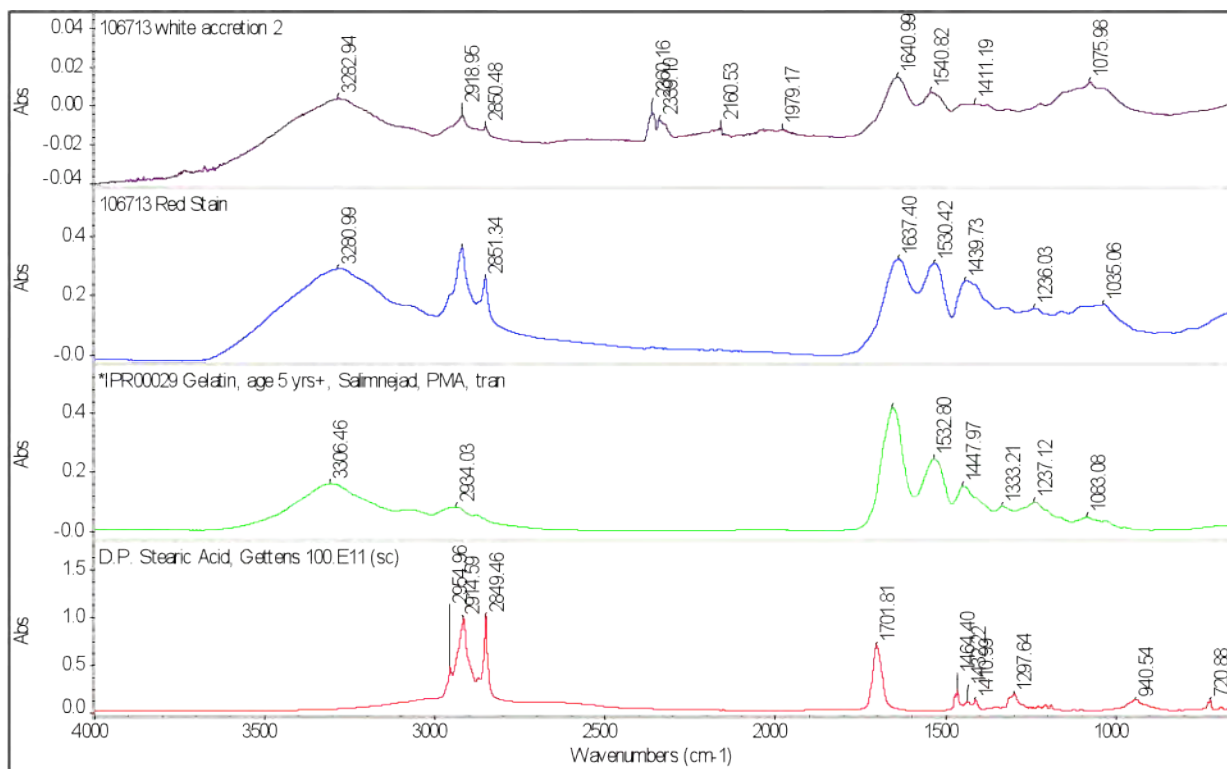

Figure 50: FTIR spectra of (top to bottom) the white accretion, accretion from red stained area*,* gelatin, and stearic acid.
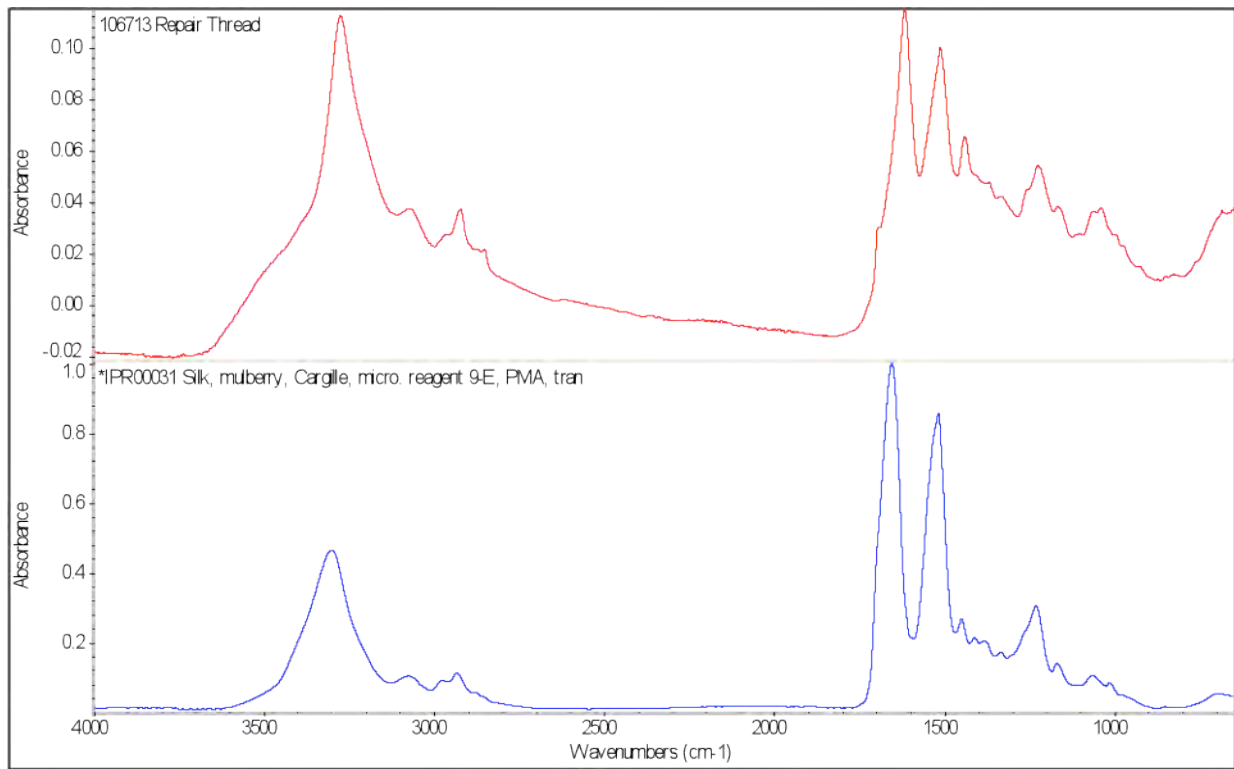
Figure 51: FTIR spectra of the repair thread (top) and silk (bottom).

APPENDIX C

SCANNING ELECTRON MICROSCOPY – ENERGY DISPERSIVE SPECTROSCOPY

Secondary electron images were obtained using a Hitachi s-400 field emission scanning electron microscope at the South Campus Instrumentation Center (SCIC) of the University of Buffalo. The accelerating voltage was 15 Kv. X-ray spectra and secondary electron images were collected and processed using an Oxford instruments Inca X-act silicon drift detector SDD with energy dispersive spectroscopy.

White accretions from the back of the jacket (area A) were mechanically removed from the leather using a sharpened bamboo skewer. The samples were adhered to a sample plate with double sided adhesive carbon conductive tape (25mm x 5mm, Ted Pella Inc.), and carbon coated with Aquadag® E Colloidal Graphite to reduce surface charging. The graphite was dispersed over the samples using a carbon evaporator.

The SEM spectra indicate that the inorganic component of the white accretions is predominantly sodium chloride. Calcium, potassium, sulfur, phosphorus, silicon, and aluminum are present in smaller quantities.
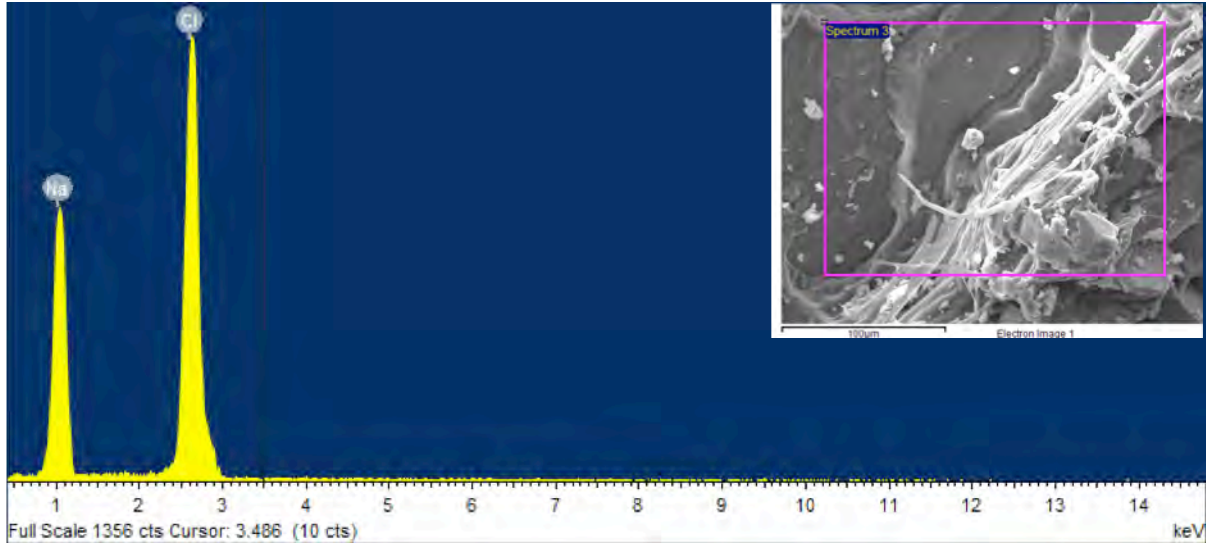
Figure 52: EDS spectrum and secondary electron image of white accretion from area A on the back of the jacket. 500X.
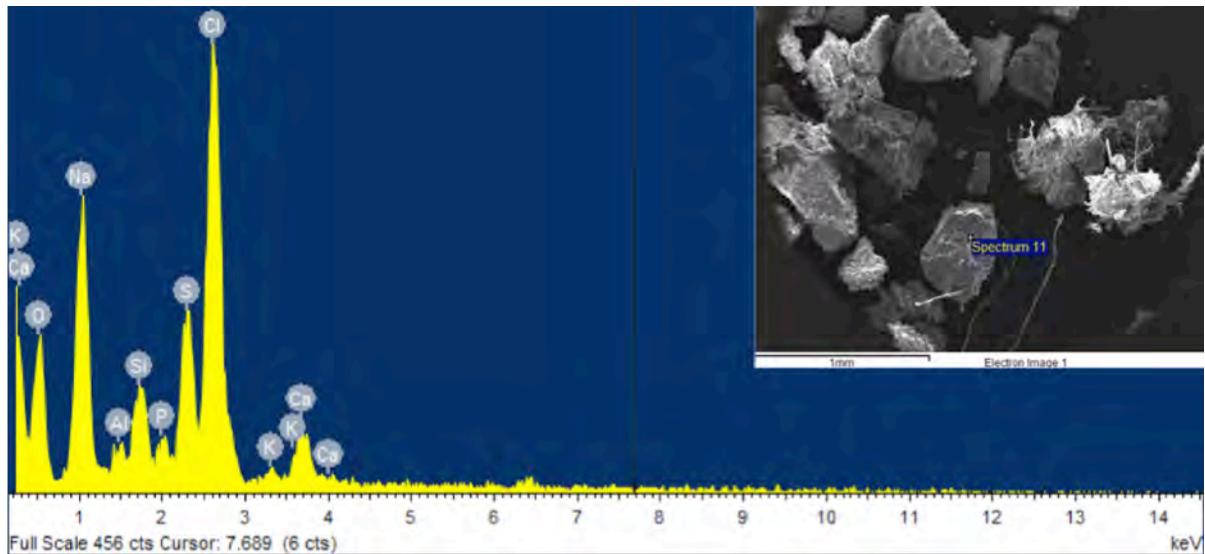

Figure 53: EDS spectrum and secondary electron image of white accretion from area A on the back of the jacket. 50X.

APPENDIX D

GAS CHROMATOGRAPHY – MASS SPECTROSCOPY – THE SCHILLING METHOD

Extraction of white accretions and red-brown stains on the lining fabric was performed using tetramethylammonium hydroxide (TMAH) as the derivatizing agent prior to analysis. These samples were placed into a 50 µL stainless steel Eco-cup and 3 µL of a 25% methanolic solution of TMAH was introduced for derivatization. After three minutes an Eco-stick was fitted into the cup, and the cup was placed into the pyrolysis interface where it was purged with helium for three minutes. Samples were pyrolyzed using a single-shot method at 550°C for six seconds. A Frontier Lab Py-2020D double-shot pyrolyzer system was used for pyrolysis and the pyrolysis interface was maintained at 320 °C. The pyrolyzer was interfaced to an Agilent Technologies 7820A gas chromatograph coupled to a 5975 mass spectrometer. An Agilent HP-5ms capillary column (30 m x 0.25 mm x 0.25µm) was used for the separation, with helium as the carrier gas set to 1 mL per minute. The split injector was set to 320 °C with a split ratio of 50:1 and no solvent delay was used. The GC oven temperature program was 40 °C for 2 minutes, ramped to 320 °C at 20 °C per minute, followed by a nine minute isothermal period. The MS transfer line was at 320 °C, the source at 230 °C, and the MS quadropole at 150 °C. The mass spectrometer was scanned from 33-600 amu at a rate of 2.59 scans per second. The electron multiplier was set to the autotune value. Sample identification was aided by searching the NIST MS library.

| Table 6: Summary of Py-GC-MS Results			
Figure Number	**Area**	**Sample Area**	**Interpretation**
54	**A**	White accretion	Dodecanoic, hexadecanoic, and octadecanoic acids are present.
		Red-stained fabric sample from interior of shoulder area.	The red stains are free of porphyrins, indicating that they do not contain blood.
		Magic Chemisorber L	No volatile organic pesticide residues were observed.
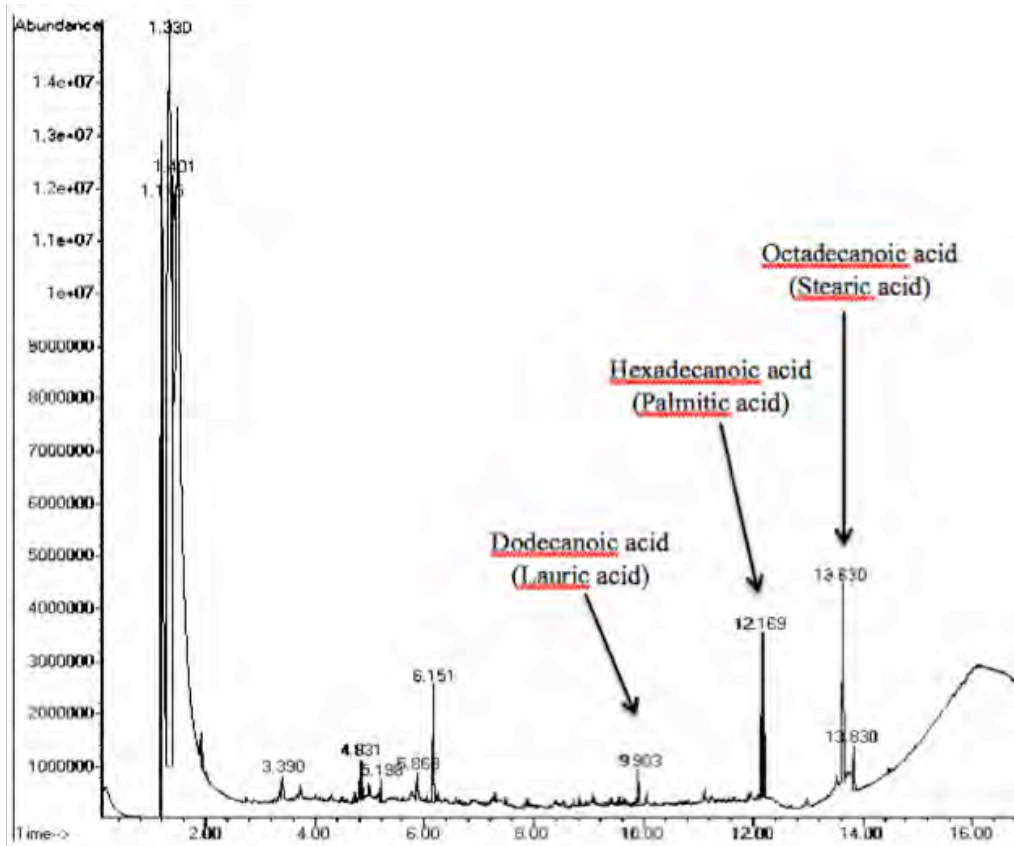
Figure 54: Total ion chromatogram showing fatty acid peaks.

REFERENCES

American Leather Chemists Association. 1907. "Use of Chrome Alum in Tanning." *The Journal of the American Leather Chemists Association.* Easton, PA: American Leather Chemists Association. 144-145.

Hall, D. M. 1982. *Practical fiber identification*. Auburn, AL: Dept. of Textile Engineering, Auburn University.

Barker, K. 2002. Iron gall and the textile conservator. In *Strengthening the bond: science & textiles: preprints, North American Textile Conservation Conference 2002, April 5 and 6, 2002, held at Philadelphia Museum of Art, Philadelphia, Pennsylvania, Winterthur Museum, Garden and Library, Winterthur, Delaware*. Philadelphia: North American Textile Conservation Conference. 7-13.

Calasibetta, C. M., and P. G. Tortora. 2003. *The Fairchild Dictionary of Fashion*. New York: Fairchild Publications.

Covington, A.D. 2006. The chemistry of tanning materials. In *Conservation of leather and related materials*. Ed. Kite, M., and R. Thomson. Amsterdam: Butterworth-Heinemann. 22-35.

Derrick, M. R., D. Stulik, and J. M. Landry. 1999. *Infrared spectroscopy in conservation science*. Los Angeles: Getty Conservation Institute.

Doyal, S. and M. Kite. 2006. Ethnographic leather and skin products. In *Conservation of leather and related materials*. Eds. M. Kite and R. Thomson. Butterworth-Heinemann series in conservation and museology. Amsterdam: Butterworth-Heinemann. 184-191.

Elevitch, C. R., I. A. Abbott, and R. R. B. Leakey. 2006. *Traditional trees of Pacific Islands: their culture, environment, and use*. Holualoa, Hawai'i: Permanent Agriculture Resources.

Flemming, L. A. 1916. *Practical tanning: a handbook of modern processes, receipts, and suggestions for the treatment of hides, skins and pelts of every description, including various patents relating to tanning, with specifications.* Philadelphia: H.C. Baird & Co.

Flecker, L. 2007. *A practical guide to costume mounting.* Amsterdam: Butterworth-Heinemann.

Fletcher, K. "Colombia Dispatch 8: The Tagua Industry," *Smithsonian.com*, 29 October 2008, accessed 8 May 2011, www.smithsonianmag.com/travel/Colombia-Dispatch-8-The-Tagua-Industry.html.

Florian, M. E. 2007. *Protein facts: fibrous proteins in cultural and natural history artifacts.* London: Archetype Publications.

Goldberg, L. 1996. A History of Pest Control Measures in the Anthropology Collections, National Museum of Natural History, Smithsonian Institution. *Journal of the American Institute for Conservation*. 35: 23-43.

Graemer, R. and M. Kite. 2006. The tanning, dressing, and conservation of exotic, aquatic and feathered skins. In *Conservation of leather and related materials.* Eds. M. Kite and R. Thomson. Butterworth-Heinemann series in conservation and museology. Amsterdam: Butterworth-Heinemann.

Greeley, H. 1872. *The Great industries of the United States: being an historical summary of the origin, growth, and perfection of the chief industrial arts of this country.* Hartford: J.B. Burr & Hyde.

Green, L. R. and V. D. Daniels. 1990. Identifications of mordants using analytical techniques. In *Dyes in history and archaeology: papers presented at the ninth annual meeting of the Association of Researchers into Dyes in History and Archaeology, York, 1990, with additional material provided by members of the Association*. York: Textile Research Associates.

Haines, B.M. 1987. Shrinkage Temperature in Collagen Fibres. *Leather Conservation News*. 3(2): 1-5.

Heald, S., L. Chang, and J. S. Johnson. 2005. Identification and Quantification of Organic Pesticides on Ethnographic Textiles during Treatment Phases. In *Recuperando el pasado: la conservación de textiles arqueológicos y etnográficos : prepublicación : Congreso de Conservación de Textiles de América del Norte - NATCC-2005 : Noviembre 9-12, 2005*: North American Textile Conservation Conference.

Holtzapffel, C. 1993. *Turning and mechanical manipulation.* Mendham, N.J.: Astragal Press.

Hornbeck, S. *Ivory: Identification and Regulation of a Precious Material*. National Museum of African Art Conservation Lab: Smithsonian *National Museum of Aftican Art*, accessed 23 April 2011, http://africa.si.edu/research/ivory.pdf.

Hubbs, B., and B. O'Connor. 2009. *A guide to the rattlesnakes of the United States.* Tempe, AZ: Tricolor Books.

Hunger, F. J. 1991. Tagua: The Vegetable Ivory Substitute. In *Lathes and turning techniques.* Newtown, CT: Taunton Press.

Janick, J., and R. E. Paull. 2008. *The encyclopedia of fruit & nuts.* Wallingford, UK: CABI North American Office.

Janssens, K, G. Vittiglio, I. Deraedt, Ann Aerts, B. Vekemans, L. Vincze, F. Wei, I. Deryck, O. Schalm, F. Adams, A. Rindby, A. Knöchel, A. Simionovici, and A. Snigirev. 2000. Use of microscopic XRF for nondestructive analysis in art and archaeometry. In *X-ray spectrometry* 29, no. 1. pp. 73-91.

Katayama, T., A. Ide-Ektessabi, K. Funahashi, and R. Nishimura. 2008. Application of XRF and AMS techniques to textiles in the Mongol Empire. In *Materials issues in art and archaeology*

VIII: symposium held November 26-28, 2007, Boston, Massachusetts, USA. Ed. P. B. Vandiver. Warrendale, PA: Materials research society. 321-329.

Kite, M., R. Thomson, and A. Angus. 2006. Materials and techniques: past and present. In *Conservation of leather: and related materials*. Eds. M. Kite and R. Thomson. Butterworth-Heinemann series in conservation and museology. Oxford: Elsevier Butterworth-Heinemann.

Klauber, L. M. 1972. *Rattlesnakes: their habits, life histories, and influence on mankind*. Berkeley: Published for the Zoological Society of San Diego by the University of California Press.

Matthews, J. M. 1920. *Application of dyestuffs to textiles, paper, leather and other materials*. New York: Wiley.

Mattison, C. 2007. *The new encyclopedia of snakes*. Princeton, N.J: Princeton University Press.

Merrill, A. 1946. *Rochester sketchbook*. Rochester, NY: Gannett.

Meyers, H. L. 2011. Chief Cornplanter. Pennsylvania Historical & Museum Commission. accessed 9 May 2011, www.portal.state.pa.us/portal/server.pt/community/people/4277/chief_cornplanter/443542.

Myers, B. 2011. Personal Communication. The American International Rattlesnake Museum. Albuquerque, NM.

Odegaard, N., and A. Sadongei. 2005. *Old poisons, new problems: a museum resource for managing contaminated cultural materials*. Walnut Creek, CA: AltaMira Press.

Odegaard, N., S. Carroll, W. S. Zimmt, D. G. Spurgeon, and S. K. Lane. 2000. *Material characterization tests for objects of art and archaeology*. London: Archetype Publications.

Podsiki, C. 2007. Beyond Pesticides: Toxins Found on Museum Objects. In *Preserving Aboriginal Heritage, Technical and Traditional Approaches: proceedings of a conference symposium 2007 : Preserving Aboriginal Heritage, Technical and Traditional Approaches, Ottawa, Canada, September 24-28, 2007*. Ottawa: Canadian Conservation Institute = Institut canadien de conservation. 393-394.

Poulin, C. 1953. Tailoring suits the professional way. Peoria, IL: C.A. Bennett Co.

Rochester Democrat and Chronicle 26 November 1932, 11 October 1932, 10 and 9 July 1933, 14 December 1952. Rochester, NY: Rochester Print Co.

Rogers, A., and L. A. Flemming. 1922. *Practical tanning; a handbook of modern practice and processes as applied in the manufacture of leather and allied products*. New York: H.C. Baird.

Schultz, A. W., and Huntington T. Block. 1992. *Caring for your collections*. New York: Abrams.

Sirois, P.J, J. Johnson, A. Shugar, J. Poulin, O. Madden. 2007. Pesticides Contamination: Working Together to Find a Common Solution. In *Preserving Aboriginal Heritage, Technical and Traditional Approaches: proceedings of a conference symposium 2007 : Preserving Aboriginal Heritage, Technical and Traditional Approaches, Ottawa, Canada, September 24-28, 2007*. Ottawa: Canadian Conservation Institute = Institut canadien de conservation. 175-186.

Society of Dyers and Colourists. 1899. *Journal of the Society of Dyers and Colourists*. Bradford, Yorkshire: Society of Dyers and Colourists.

Stilson, C. B., J. M. Robortella, R. Rosenberg-Naparsteck, and G. M. Tomczyk. 2007. *Biography of Rattlesnake Pete (Peter Gruber): a biography of Mr. Peter Gruber, detailing his experience in forty years study of the poisonous snakes of North America, with other Incidents of a life that has not been uneventful*. Gates, NY: Gates Historical Society.

Stuart, B. 2007. *Analytical techniques in materials conservation*. Chichester, England: John Wiley & Sons.

Textile Institute (Manchester, England). 1985. *Identification of textile materials.* Manchester, England: Textile Institute.

Tímár-Balázsy, Á., and D. Eastop. 1998. *Chemical principles of textile conservation.* Oxford: Butterworth-Heinemann.

Thomson, R. 2006. Testing leathers and related materials. In *Conservation of leather: and related materials.* Eds. M. Kite and R. Thomson. Butterworth-Heinemann series in conservation and museology. Oxford: Elsevier Butterworth-Heinemann.

Thornton, J. 2009. Unpublished class handouts. Leather History and Technology and Leather Conservation. Buffalo State College. Course: History and Technology of Objects I.

Young, G. S. Microscopical hydrothermal stability measurements of skin and semi-tanned leather. 1990. In *ICOM Committee for Conservation preprints, 9th Triennial Meeting, Dresden, Germany*. Paris: ICOM. 3:626-631.

FURTHER READING

American Chemical Society. 1918. *The Journal of industrial and engineering chemistry.* Easton, PA: American Chemical Society.

American Leather Chemists Association. 1913. "Problems for the Leather Chemist." *The Journal of the American Leather Chemists Association.* Easton, PA: American Leather Chemists Association. 196-208.

Angus, A., M. Kite and T. Sturge. 2006. General principles of care, storage and display. In *Conservation of leather and related materials*. Ed. Kite, M., and R. Thomson. Amsterdam: Butterworth-Heinemann. 113-120.

Brunn, M., and J. E. White. 2002. *Museum Mannequins: A Guide for Creating the Perfect Fit.* Edmonton: Alberta Regional Group of Conservators.

Dignard, C. 1992. Tear Repair of Skins with Minimal Access to Their Backs: The Treatment of a Kayak. *Leather Conservation News.* 7(2): 1-8.

Florian, M. E. 2006. The Mechanisms of Deterioration in Leather. in *Conservation of leather and related materials*. Ed. Kite, M., and R. Thomson. Amsterdam: Butterworth-Heinemann. 36-54.

Fourné, F. 1999. Synthetic fibers: machines and equipment, manufacture, properties: handbook for plant engineering, machine design, and operation. Munich: Hanser. http://www.knovel.com/knovel2/Toc.jsp?BookID=1005.

Fuchs, K., and M. Fuchs. 2003. *Die Reptilhaut: ein Wichtiger Merkmalsträger bei der Identifizierung von Echsen und Schlangen = The Reptile Skin: a key-feature in the identification of lizards and snakes*. Frankfurt am Main: Edition Chimaira.

Grattan, D. W., and S. Michalski. 2007. Environmental guidelines for museums temperature and relative humidity (RH). Ottawa: Canadian Conservation Institute. https://www.cciicc.gc.ca/crc/ articles/ enviro/index-eng.aspx.

Kaminitz, M., and J. Levinson. 1988. The conservation of ethnographic skin objects at the American Museum of Natural History. *Leather Conservation News*. 5(1): 1-7.

Kilmon, J, and H. Shelton. 1981. *Rattlesnakes in America*. Sweetwater, TX: Shelton Press.

Nieuwenhuizen, L. 1998. Synthetic Fill Materials for Skin, Leather, and Furs. *Journal of the American Institute for Conservation*. 37: 135-145.

Picken, M. B. 1973. *The fashion dictionary: fabric, sewing, and apparel as expressed in the language of fashion.* New York: Funk & Wagnalls.

Rattlesnake Pete. http://rocwiki.org/Rattlesnake_Pete. accessed 10/23/2010.

Socrates, G., and G. Socrates. 2000. *Infrared and Raman characteristic group frequencies: tables and charts*. Chichester: Wiley.

United States Department of Commerce and Labor. 1908. Monthly Consular and Trade Reports. Issue 337. Washington Government Printing Offices. 216-217.

United States Environmental Protection Agency. 2007. Zinc Borate Summary Document: Registration Review. Document Number: EPA-HQ-OPP-2007-0675. www.regulations.gov.

Wright, Margot M. 2002. *The conservation of fur, feather and skin*. London: Archetype Publications.

MATERIAL SOURCES

ACID-FREE TISSUE PAPER. Hollinger Corp. PO Box 83600, Fredricksburg, VA 22404 (800) 634-0491

BEVA FILM (an ethylene vinyl acetate based dry film adhesive) Conservator's Products Co. (CPC), P.O. Box 601, Flanders, NJ 07836. (201) 927-4855.

DRY-CLEANING SPONGES (DIRT ERASERS) also called "soot sponge" or "smoke sponge" (vulcanized rubber) Talas 330 Morgan Ave, Brooklyn, NY 11211, 212-219-0770.

EPSON ULTRACHROME K3™ pigment inks. http://www.cdwg.com/.

GOLDEN ACRYLIC PAINT (various pigments + acrylic dispersion) Golden Artist Colors, Inc., 188 Bell Road, New Berlin, NY 13411-9527; 607-847-6154

HERITAGE CORRUGATED BOARD (100% alpha cellulose). Distributed by Talas.

HON MINO (natural *kozo* Japanese paper) Hiromi Paper International, 2525 Michigan Ave Unit G-9, Santa Monica, CA 90404. 866-479-2744; 310-998-0098.

100% THERMAL BONDED POLYESTER BATTING. Talas 330 Morgan Ave, Brooklyn, NY 11211, (212)-219-0770

100% COTTON FABRIC, 100% COTTON *GUTTERMAN* THREAD, POLYESTER FABRIC (WASHED) available on hand in conservation department. Purchased at a local fabric store.

RHOPLEX N-580 ([butyl acrylate homopolymer] emulsion) Rohm & Haas, Philadelphia, PA. Avaliable from Talas or Conservator's Emporium, division of Museum Services Corporation, 385 Bridgepoint Drive, South St. Paul, MN 55075. 651-554-8954.

SILICONE COATED POLYESTER FILM (0.0005" thick); Conservator's Products Co. (CPC), P.O. Box 601, Flanders, NJ 07836. (201) 927-4855.

12" W SURGICAL 100% COTTON STOCKINETTE (WASHED). Available at local medical supply store, Sheridan Surgical, Inc. 4513 Bailey Ave. Amherst, NY 14226. 713-836-8780.

THERMAL BONDED POLYESTER BATTING. Talas 330 Morgan Ave, Brooklyn, NY 11211, (212)-219-0770

VOLARA (fine celled, irradiation crosslinked, polyolefin foam) manufactured by Voltek, 100 Shepard Street, Lawrence, MA 01843 [contact the manufacturer/importer for a distributor in your area.]

LIST OF FIGURES AND TABLES

Figure 21: Wool fibers from the black interlining fabric (left), cotton fibers from the white interlinig fabric (center), and silk fibers from the brown repair thread in proper right arm (right).

Figure 22: Shrinkage test set-up on the hot stage.

Figure 23: Corium fibers before and after shrinkage between 40-45°C.

Table 2: Summary of XRF data

Figure 24: XRF spectra taken on adjacent areas on the green interlining fabric (bright green) and leather (darker green). [15kV, 1500 μA, vacuum, 90 seconds, no filter].

Figure 25: White accretions on leather, back proper right shoulder.

Figure 26: Infrared Spectra for (top to bottom) the button material, two vegetable ivory species from the study collection at Buffalo State College, and an unknown species in the FGA library.

Figure 27: Infrared spectra for (top to bottom) the white accretion, red stain, gelatin, and stearic acid.

Figure 28: EDS spectrum and secondary electron image of white accretion.

Figure 29: Total ion chromatogram showing fatty acid peaks.

Table 3: Shrinkage Temperature (T_s) for Un-tanned Leathers (°C)

Table 4: Soil Solubility Testing

Figure 30: During cleaning. The proper left side of the collar is surface cleaned.

Figure 31: Photomacrographs of before and after cleaning white accretions.

Figure 32: Local clamping with rare earth magnets.

Figure 33: The largest fragment before (left) and after (right) humidification and flattening. Once flattened, it became clear that this fragment belonged in the largest loss on the back of the PL arm.

Figure 34: Overall humidification under acrylic dome.

Figure 35: Application of local humidification using the ultrasonic nebulizer wand. Although not pictured, a blotter paper was wrapped around the tip of the wand to prevent dripping.

Figure 36: A scale before (left) and after (right) reattachment of the keratinous scale with BEVA film. The color of the area with the missing scale on the left is lighter.

Figure 37: Repaired area on front of PR arm, before (top) and after (bottom).

Figure 38: Repair on front PR arm near the shoulder. Before (left) and after (right) patch was inserted along torn skin-to-skin seam. The patch within the oval on the right was adhered directly to the lighter colored scales visible within the oval on the left.

Figure 39: Area with small losses that are toned with acrylic paints.

Figure 40 A, B, C, & D: Tear on back of PL arm. A) After consolidating small losses along sides. B) After inserting overall patch with the large fragment. C) During insertion of digitally printed fill. The top of the patch is attached. D) After treatment.

Figure 41 & 42: Mannequin with arms pinned in place (left). Jacket on the mannequin after conservation treatment (right).

Table 4: Summary of XRF data

Figure 43: XRF spectra. Wool Interlining, proper right arm. Orange – 30kV, 1300μA, 60s; Blue – 15kV, 700μA, 60s.

Figure 44: XRF spectrum. Leather, interior collar. [40kV, 25 μA, 12 mil aluminum + 1 mil titanium filter, 60 seconds]

Figure 45: XRF spectrum. Leather, interior collar. [15kV, 55μA, 1 mil titanium filter, 60 seconds]

Figure 46: XRF spectrum. Button. [40kV, 25 μA, 12 mil aluminum + 1 mil titanium filter, 60 seconds]

Figure 47: XRF spectra. Leather PR Breast. Orange – 30kV, 1300μA, 60s; Blue – 15kV, 700μA, 60s.

Figure 48: XRF spectrum. Soil removed with deionized water using a cotton swab. The spectrum for a clean cotton swab has been subtracted. [30kV, 1300μA, no filter, 60s]

Table 5: Summary of FTIR Results

Figure 49: FTIR spectra of (top to bottom) the button material, *Phytelephas macrocarpa*, *Metroxylon amicarum*, and Vegetable Ivory (nut) from the IRUG library.

Figure 50: FTIR spectra of (top to bottom) the white accretion, accretion from red stained area, gelatin, and stearic acid.

Figure 51: FTIR spectra of the repair thread (top) and silk (bottom).

Figure 52: EDS spectrum and secondary electron image of white accretion from area A the back of the jacket. 500X.

Figure 53: EDS spectrum and secondary electron image of white accretion from area A on the back of the jacket. 50X.

Table 6: Summary of Py-GC-MS Results

Figure 54: Total ion chromatogram of white accretion showing fatty acid peaks.