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TECHNICAL ANALYSIS AND TREATMENT OF A SUDANESE KASKARA SWORD

ABSTRACT

This paper will present the treatment of and research into a proposed Sudanese Kaskara Sword and companion scabbard. Technical analysis of the sword and scabbard was performed to gain a better understanding of the materials and method of fabrication of the piece. Conservation treatment was completed to structurally stabilize the sword and scabbard for display and storage, and lessen the visual impact of damage and corrosion.

1. INTRODUCTION

To complete my course work in the Buffalo State Art conservation program, I under took the treatment and attribution of a sword and scabbard of unknown provenance from the Buffalo Museum of Science.   It had been donated to the science museum in 1955 by the Buffalo and Erie County Historical Society, and was thought to be Middle Eastern. However, the science museum was unable to accession the set into the museum's collection because it lacked a verifiable provenance. Further, the set showed significant damage and wear. The steel blade is sunk into a shaped wooden grip, covered with monitor lizard skin. The skin is sewn around the grip with waxed black plant cordage. The cross guard is made of a copper alloy. The scabbard is composed of two pieces of shaped wood covered entirely with monitor lizard skin. The skin is sewn around the scabbard with black cordage similar to that found on the grip, and further secured with a thick, yellowed adhesive. There are remnants of two red leather straps wrapped around the body of the scabbard. The uppermost strap is wound around a small piece of monitor lizard skin, tied into a 3" long tube. (fig.1 and fig.2)

Fig.1 and Fig. 2 Front and back of the sword and scabbard, before treatment

The goal of the treatment was to remove metallic corrosion products from the surface of the blade and cross-guard, remove a disfiguring and unstable glue layer from the surface of the skin and wooden scabbard, and stabilize the sword and scabbard to allow for minimal future degradation in a typical museum storage environment. The second goal of the treatment was to provide accurate and detailed information about the materials, fabrication method and cultural import of the piece.

2. DESCRIPTION

2.1 SWORD

The steel blade is thin with an acid etched inscription. It is slightly bent toward the center, probably from long-term storage without proper support. The blade and guard were both cast, and later shaped by draw filing. The regular tool marks left in the metal by this process can be seen on the surface of both with minimal magnification. Wax, dirt, and grime have become embedded in these tool marks. (fig.3) The steel sword is covered with iron corrosion products, mostly iron oxides goethite, FeO(OH), and magnetite, Fe_3O_4, obscuring the etching and further pitting the surface of the blade. The corrosion is most prevalent along the edges of the

Fig.3 detail of the surface of the cross guard, before treatment 6x magnification

Fig.4 detail of the surface of the blade, before treatment 6x magnification

engraved design. (fig.4) The surface of the blade has become particularly pitted along the attachment to the grip. The cross-guard has crystalline copper carbonate corrosion products forming along the quillon over the blade, and the seam where the guard meets the skin on the grip. (fig. 3)

The corrosion on the blade can be related to environmental exposure, however much of the remaining damage can be directly related to its use. The increased humidity it the environment, after the blade left Sudan lead to the expansion of the wooden sheath, decreasing the space available to the blade inside the scabbard. Being sheathed and unsheathed led to significant wear on the edges of the blade. Additionally, the blade was waxed repeatedly during its use lifetime, and excess residue accumulated at the point of insertion of the blade into the grip.

Fig.5 detail of the surface of the blade, during treatment

During examination remnants of a blue heat-tempered surface, often refer to as “heat bluing” or “fire-bluing,” was discovered on the etched inscription. (fig.5) In this process regulated heating is used to form a thin layer of magnetite, Fe_3O_4, on the surface of the metal. The magnetite layer causes an interference effect in which some of the incident light is reflected off the surface of the metal out of phase, thereby producing color. By controlling the temperature and length of heating, a layer can be formed with colors varying from a sandy yellow to peacock blue. It is likely the entire surface of the blade was “blued,” and then the inscription was acid etched into the surface. In the etching process, a design is applied onto the substrate with a resist material, such as mastic resin, and then exposed to acid. The acid pits the exposed metal, leaving a raised design where the resist was applied. The fluid application of the design is apparent on the sword in the slight variations in the arabesque motif. When the sword was finished it would have been bright with dark blue etched writing. (fig.7) Mock-ups of the surface of the blade were made by heating steel coupons to form the blued surface and then etching them with crushed lemon poultices. (fig.6 and fig.7)

Fig.6 creating the blued layer on the mock-up steel coupon

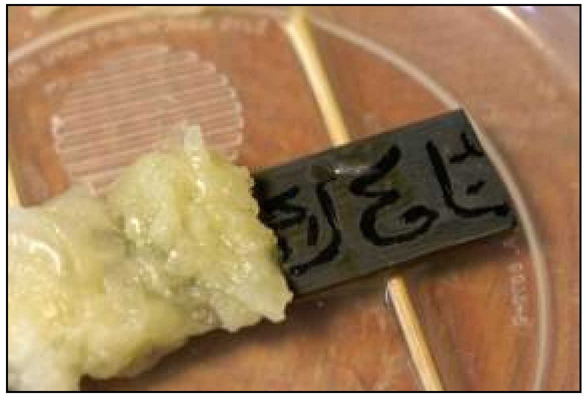


Fig.7 etching the surface of the mock-up with a crushed lemon poultice

The blade was secured into the grip with a triangular metal extension on the end of the blade called the tang. The tang was sunk into the center of the grip, which was then tightly wrapped with skin. Xero-Radiographs taken of the grip show that a mineral mortar was used to further secure the tang in place.

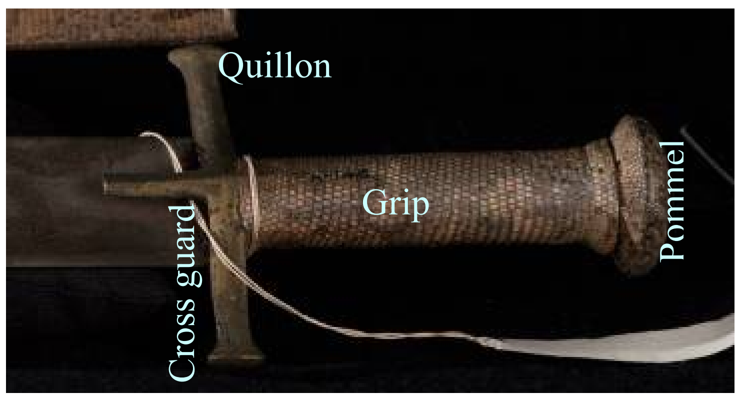


Fig.8 detail of the hilt of the sword

Additionally, the radiographs reveal that the grip and pommel are made of one piece of carved wood, and a drilling tool was used to make room for the blade and mortar. (fig. 10) The sides of the wooden grip were cut back to allow the two prongs at the bottom of the cross-guard to slip in and be secured.(fig.9 and fig.10) The pommel was covered first, by wrapping it with a piece of skin that extended onto the shaft of the grip and was secured with a piece of string. A larger skin was then wrapped around the entire grip, secured with an adhesive and sewn together with the black cordage.
(see fig.8)

Fig. 9 X-Radiograph of the blade and cross guard attachment into the grip

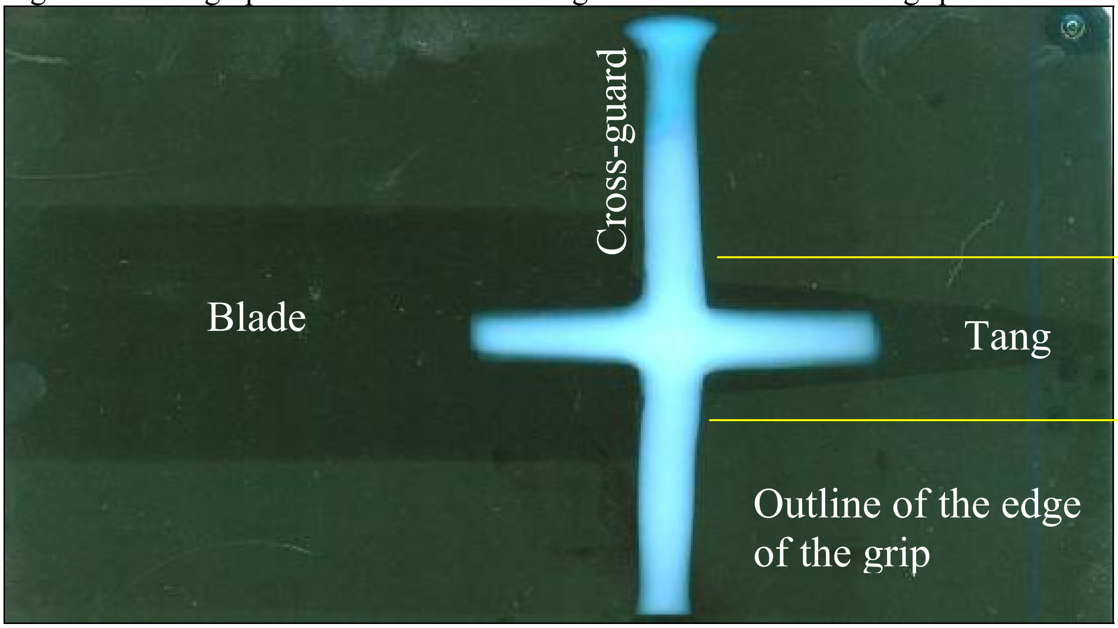
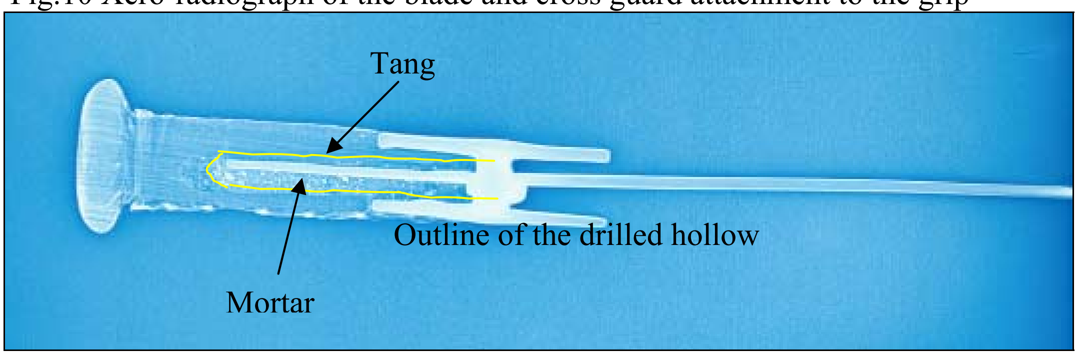


Fig.10 Xero-radiograph of the blade and cross guard attachment to the grip



The grip and pommel are in good condition, except for minor wear on the skin and the black cordage. There are remnants of a glue coating on the surface of the grip in the areas where the two ends of the skin meet.

2.2 SCABBARD

The scabbard was a wooden sheath wrapped with three pieces of skin and secured with black cordage, composed of a thin fibered plant material coated with wax. (fig.12) The holes in the skin were sewn through multiple times creating a pattern of crosses down the center of the back of the scabbard. (fig. 11)

An adhesive coating was heavily applied under to further secure the skin onto the wooden substrate. This coating did not have an induced fluorescence when exposed to ultra-violet radiation, but accumulated dirt and grime may have prevented fluorescence. The areas of skin not coated or only minimally coated produced a bright blue fluorescence. (fig.14) There were remnants of red leather strapping wrapped around the body of the scabbard, which may indicate the original location of the attachment of a shoulder strap. (fig.13)

Fig.11 detail of the back of the scabbard, before treatment

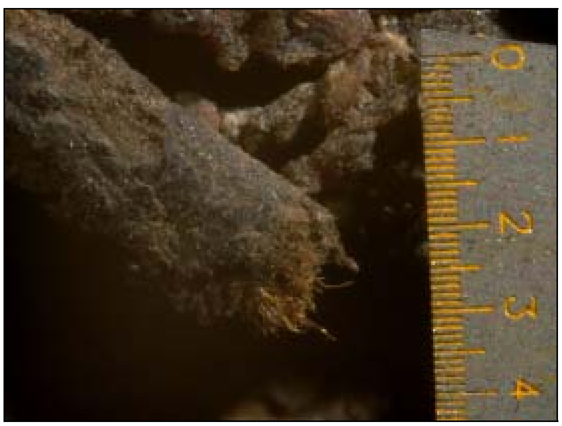


Fig.12 detail of the black cordage, before treatment ($^{1}/_{10}{}^{\text{th}}$ mm)

Fig.13 detail of the red leather strapping, before treatment ($^{1}/_{10}{}^{\text{th}}$ mm)

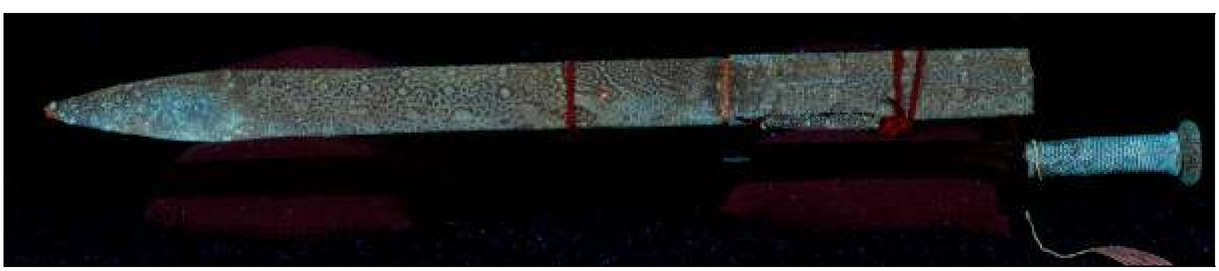


Fig.14 Front and Back of the Sword and Scabbard, ultra-violet radiation

The scabbard has suffered considerable mechanical damage due to fluctuations in humidity, which led to differential expansion of the various materials composing the whole. The glue on top of the skin has further complicated this material's response to its environment. Increased humidity caused the wood to swell, and the skin was not able to accommodate the new dimensions of the sheath, due to its own stiffness and that of the glue layer on top of it. The plant cordage, as the weakest part of the attachment between the skin and the substrate, broke as the wood pushed against it. Only the sewing attachment along the top 3 in. and bottom 6 in of the scabbard are still intact. Periods of low humidity and oxidation contributed to the reduced plasticity of the skin. Oxidation caused the glue to contract and the skin was not pliable enough to adjust to this pressure. This has resulted in cracking and spalling of the top layer of the skin. The damaged areas appear powdery to the naked eye. However, when viewed under magnification, the powdered appearance is due to light scattering at the edges of the broken skin. (fig.15-17) Testing showed the glue layer to be soluble in de-ionized water, it is likely it is a locally produced hide glue.

Fig.15 detail of spalling, (${}^{1}/_{10}{}^{th}$ mm), before treatment

Fig.16 detail of spalling 6x magnification, before treatment

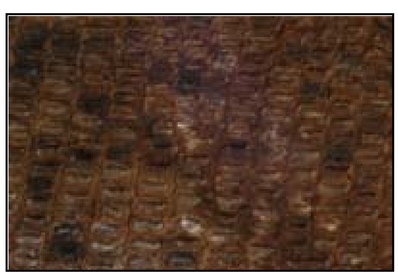


Fig.17 detail of cracks, before treatment

There is a significant amount of dirt and dust embedded in the glue layer. There was evidence of insect grazing and a beetle casing was found on the surface of the scabbard. (fig.18) There was a small cut in the skin on the back of the scabbard 4” from the tip. The cut is sewn together with string similar to that used to secure the skin onto the pommel. This cut may have been made when limbs were removed from the body of the monitor lizard. Some of the skin from the underbelly of the lizard found on the back of the scabbard has become relatively soft and spongy. It is unclear what has caused this condition.

Fig.18 detail of insect damage, 6x magnification before treatment

The remnants of the black cordage do not appear to be overly brittle, however their age has made them fragile and in need of consolidation. The red leather straps are worn, but are not suffering from red rot.

2.3 MONITOR LIZARD SKIN

Fig.19 varanus *exanthematicus*
http://www.reptilespark.com/home/varanus/4.htm , 4/13/05

There are multiple species and subspecies of Monitor lizards, all with distinctive skin patterns. The skin on this sword is from varanus *exanthematicus*, also known as the Savannah Monitor, common to North Africa from Senegal to Sudan. (fig.19) This monitor is squat with grayish brown skin spotted with yellow circles rimmed in black on its back, and with yellow-white scales on its underside. The tail is round with a small double-toothed crest running down the upper side. Adults are about 1.5-2 meters in length and weigh around .73 kilograms. (De Lisle 1996)

The scales that make up the top surface of reptile skins are actually connected folds of skin. The outermost surface is composed of a hard layer of keratin, which is extremely water resistant due to dithiol linkages between polymer chains. The scales on the back the savannah monitor are oval with a small ridge in the center, while the scales from the underside are smooth and square.

The skin used on the top of the scabbard, where the sword is inserted, is from the tail of the lizard. The characteristic crest can be seen in the center of the front of the scabbard. As the piece wraps around it has the yellowish stripes characteristic of the side the tail. The larger piece, covering most of the body of the scabbard, is probably from the back and side of the lizard, ending just at the beginning of the belly. The darker scales and yellow spots characteristic of the back of the monitor can be seen as the piece wraps around the wooden substrate, and the stripes and square scales of the side of the lizard can be seen where the skins are sewn together. (Diemer 2006) (fig.20)

Fig.20 detail of markings on the skin, during treatment

The skin is extremely stiff and appears to be untanned. It tested negative for the presence of metallic salts and vegetable tannins. (Appendix E) Rather, it may have been stretched over the wooden scabbard while it was still pliable, and allowed to dry. The environment in Sudan would have been dry enough to discourage rotting from biological attack. Drying without tanning may also have added to the longevity of the skin. Historical evidence indicates that untreated skin may have more long term stability than some treated specimens. This may be because the structure of the untreated skin becomes extremely compact upon drying. This reduces the surface area available for reaction with the surrounding environment, as well as making it more difficult for reactants to penetrate that body of the skin. (Wills 2000)

3. ATTRIBUTION

The label attached to the piece when it was chosen for conservation, indicated that the exact origin of the sword was unknown, but it was thought to be from Jordan. However, there are several aspects of the design of this blade that are strongly characteristic of a straight blade, double edge Sudanese sword called the Kaskara, which is common to Eastern and Central Sudan. (Stone 1961.) Production of the Kaskara began after the 16th century, and its popularity peaked during the Mahdist revolt in the early 19th century. (Spring 1993) The shape of the blade, cross-guard, and scabbard of the piece owned by the Buffalo Museum of Science are similar to the design of the Kaskara. Kaskara swords have long blades with parallel sides, which taper into a point at the tip of the sword. (fig.1 and fig.2) The sides of the blade are relatively blunt compared to European blades, because these weapons were generally used for thrusting rather than slashing. The cruciform shape of the cross-guard and the flat disk shaped pommel are also common elements in all Kaskara blades. (fig.8) (Alexander 1992, Spring 1993, Jones 2001)

The scabbard owned by the science museum expands at the bottom into the leaf shape seen on most Kaskaras, though the flare is significantly less exaggerated than most examples of this type of blade. (Alexander 1992, Spring 1993, Jones 2001) (fig.21 and fig.22) Additionally, the species of monitor lizard found on the scabbard is common to Sudan, but not Jordan. The sword has an Arabic etching across the face of both sides of the blade. Inscribing or etching a phrase from the Koran onto arms and armor is a common practice throughout the Arab world. It imparts spiritual power to the weapon, as well as inspires the bearer to fight for Allah. (Alexander 1992)

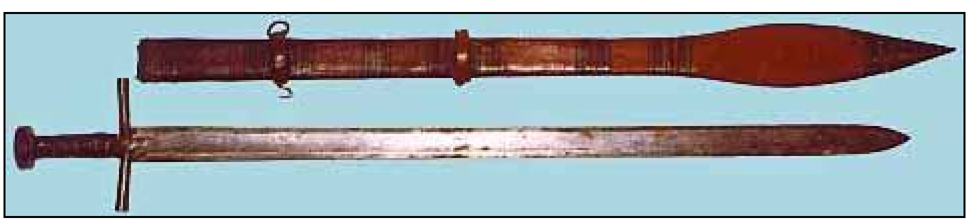


Fig.21
detail of the shape of a typical Kaskara scabbard www.aiusa.com/medsword/ethsword/kaskara/index.html (accessed 12/08/05)

Fig.22
detail of the tip of the scabbard

The most atypical aspect of the scabbard is that it is covered entirely with monitor lizard skin. Typically these scabbards were covered with red leather and then accented with skin from other animals, most often crocodiles. The tips of the scabbards of finer Kaskaras blades usually had a pointed metal tip. This scabbard is damaged at the tip, and it cannot be determined if it ever had this point. Additionally, the cross-guard was made from a copper alloy, which is unusual but not unknown for this type of weapon. (Alexander 1992)

4. FABRICATION

Though the various elements of this sword and European swords are similar, the fabrication methods are distinct. Kaskara blades tend to be thinner and more lightweight than European blades; therefore the pommel does not need to function as a counterweight to the blade, as it does in European swords. This allowed for the use of smaller pommels made out of lighter weight materials. The tang tends to be wide and short, set into the grip at an angle to the blade. The blade is secured by gluing or riveting through the pommel and the tang. This attachment may seem weak in comparison to European swords, but was extremely effective at holding the blade in place. Further, the simplicity of this design allowed for easy repair if the grip needed to be replaced. (North 1989) The xero-radiograph for this sword shows the attachment of the tang. It is set at a slight angle to the blade and embedded in a mineral mortar. (see fig.10)

5. HISTORICAL BACKGROUND

19th and 20th century Sudanese swords have a hybrid history; local sword design was heavily influenced by other Islamic and African weaponry traditions as well as the influx of materials from Europe. Production of these swords was originally prompted by an increase in the exportation of steel blades from Europe to North Africa during the sixteenth century. The blades were mostly produced in Solingen, Germany; Toledo, Spain; and Belluno, Italy; and then shipped to the ports of Tunis, Tripoli, Alexandria, and the Moroccan Coast to be traded.

The scabbard and grips were manufactured locally. There are records of local blacksmiths fabricating blades as well, but locally produced blades are difficult to distinguish from imports, because they were close imitations. The sword would be worn with a shoulder strap parallel to the ground, either across the wearer's back or under their arm pressed against the torso. (Spring 1993)

The spear was the most popular offensive weapon for warfare, while the sword had more prominence as a domestic weapon. The Kaskara was a prized possession, carried whenever the owner was outside his home. The Ansars, the followers of Mohammed Ahmad, the Mahdi, were issued this sword during revolts against Egypt and subsequently the British. (Wilkinson-Latham and Roffe 1976) The popularity of the Mahdi with the Sudanese people added to the cultural significance of the sword. Older members of Sudanese society in rural parts of the country continued to carry these weapons until the late 20th century. (Spring 1989, 1993)

Kaskara swords tended to be more unadorned than contemporary swords from other African nations. The continued use of swords well into the 19th century, when it had been relegated to ceremonial status in surrounding African nations, likely influenced the practical design of these blades. Men in Sudanese society did not begin to carry firearms regularly until the late 19th century. This situation may have been the result of an inability in the region to properly maintain firearms with parts and technical expertise. Other theories have postulated that the elite of the Sudanese tribes and freeman soldiers disdained firearms on moral grounds. Mercenaries and slave foot soldiers would be issued firearms, while the elite would fight from their horses with swords and spears.(Spring 1989)

It has been reported that the cruciform grips of Kaskara blades, are a reference to swords left behind by Europeans during the crusades. However, this theory has fallen out of favor because of a general lack of viable evidence. Kaskaras were not produced until well after the last crusade ended. Further, thirteenth and fourteenth century Arabic swords also had straight blades and grips, and cross guards with long quillons with flattened ends. (North 1989) Archeological finds of weaponry from that period indicate the Kaskara may be one of the most direct modern descendants of these historic Arabic swords. The round disc pommel of the modern Kaskara is the major difference between the two traditions. (North 1985)

6. EXAMINATION AND MATERIAL ANALYSIS

6.1 TECHNICAL ANALYSIS OF THE SURFACE OF THE SWORD

Examination of the blade with X-ray fluorescence spectroscopy (XRF) showed that it is mostly composed of iron with minor amounts of lead, manganese, and copper. (Appendix D) Analysis of the cross guard indicated that it was likely made out of recycled brass and bronze materials, since it contained copper, tin, zinc, nickel, iron, and lead. (Appendix D)

6.2 TECHNICAL ANALYSIS OF THE SCABBARD

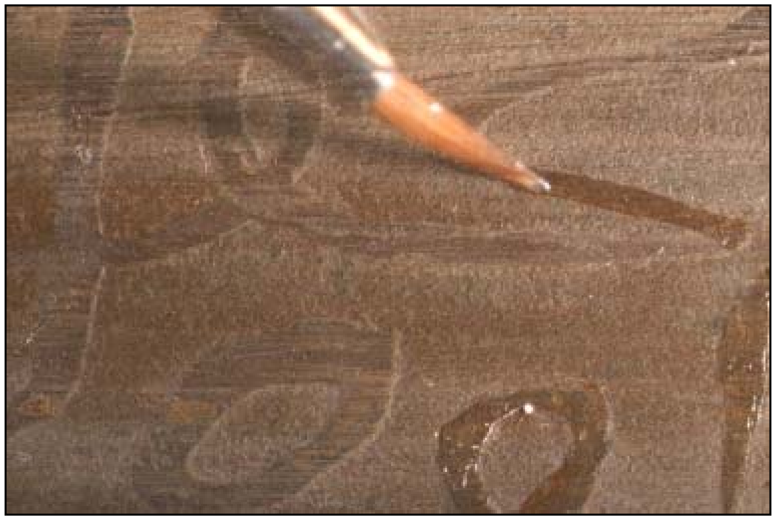
Samples of the adhesive coating on the surface of the skin were analyzed with transmission Fourier transform infrared spectroscopy (FTIR), but the results were inconclusive. The coating had too many intractable impurities to develop a useable spectrum.

Both the black cordage used to secure the skins onto the wooden scabbard, and the red leather straps found wrapped around the scabbard were examined with FTIR spectroscopy. The black cord was found to be composed of cellulosic material, most closely related to ramie or flax fibers coated with wax. Samples of the monitor lizard skin analyzed by FTIR did not show the presence of any metallic salts, which may have indicated chrome or salt tanning. A test for vegetable tannins using lead acetate and another using ferric chloride were used to detect the presence of vegetable tannins in the monitor lizard skin and the red leather straps. (Caroll, Odegaard, and Zimmt 2000. Thomson 2006) The monitor lizard skin tested negative in both tests, while the red leather straps tested positive in both tests. (Appendix C)

7. TREATMENT

SWORD

Fig.23 detail of application of protective layer on the etched inscription



In order to protect the tempered layer on the surface of the blade two coats of a solution of 15% B-72 in 50:50 acetone: ethanol was applied onto the etched inscription with a brush under a stereomicroscope. (fig.23) Initially, this layer would not adhere to the surface. Upon further examination it was determined that the sword had been repeatedly waxed. Xylene was applied to the surface with cotton swabs to remove this layer, and then the B-72 solution was applied again.

Fig.24 cleaning the surface of the blade

Topical application of a corrosion remover was determined to be the most controllable method for removal of the corrosion on the surface of the blade. Immersion would not have allowed for appropriate monitoring of the tempered layer. The B-72 solution was applied to the mock-up first, to ensure that it would be a lasting protection layer during treatment. An organic acid gel corrosion remover and a dilute citric acid solution were both tested on the mock-ups, and were effective at removing corrosion from the surface of the coupon. The organic acid gel corrosion remover was selected for treatment because it was the least aggressive. The gel was applied across the entire surface of the blade three times, for intervals of 10 min, and cleared with de-ionized water. (fig. 24) After the final application, the water clearance was followed by clearance with acetone to prevent the formation of flash rust.(fig. 25, 26, and 27) After corrosion removal the

B-72 protective layer was removed with xylene. A thin layer of microcrystalline wax in petroleum benzine was applied to the surface of the blade. This treatment will protect the surface of the blade from humidity fluctuations, which might have induced corrosion in the future.

fig 25 and 26 details of the surface of the blade before and after corrosion removal

Fig 27 detail of the blued decoration after treatment

The same organic acid gel corrosion remover was used to clean the surface of the cross guard. The remover was applied to the surface with a cotton swabs and cleared with water immediately after application. The cross guard did not have a thick enough layer of corrosion on its surface to warrant extended exposure to the gel. Further, the gel may have effected the color of the cross guard if left on the surface for too long.

SCABBARD

Cleaning tests determined that the adhesive on the skin was soluble in de-ionized water. All the skins were cleaned by rolling a dampened swab across the surface. Examination of the surface under ultra-violet radiation was used to monitor the progress of the removal process.(fig 28 and 29)

Fig. 28 and 29 front and back of the scabbard after removal of the glue layer, ultra-violet Radiation

Fig.30 detail of restraining the scabbard during drying

Fig.31 scabbard in the humidification chamber

The scabbard was placed in a humidification chamber to plasticize the skin. After two hours it was removed and the skin was reshaped around the wooden substrate. The skin was restrained during drying by a pliable polyethylene film, which was crimped into a band and wrapped around the scabbard in regular intervals, allowing space for ventilation. (fig.30 and fig.31) The film was removed after several days.

Before treatment, the plant cordage and glue layer were primarily responsible for holding the skin onto the wooden substrate. The stress of this attachment caused significant damage to these materials, as detailed earlier. After the skin was reshaped, a thin layer of a 25% (w/v) solution of B-72 in acetone was applied under the skin at the back of the scabbard and held in place until dry. This will place the pressure of attachment on the glue join rather than on the fragile ties.

The red leather straps and black plant cordage were consolidated with a 3% solution of Klucel G in ethanol. Before consolidation they were both cleaned of excess dust and grime with a cotton swab dampened with ethanol. Ethanol was used as a cleaning agent, because the pigment in the black plant cordage was found to be water-soluble during removal of the glue layer.

8. STORAGE AND DISPLAY

Slight modifications of the current storage system will better protect the piece from sources of degradation in the environment. The piece now has a box designed specifically to provide appropriate support during long-term storage. The corrugated card box will reduce the accumulation of dust and dirt on the surface of the piece, and will be able to mitigate fluctuations in humidity and temperature. The sword should remain in its box when it is not in use for exhibition or research. Ideally, the box should be kept in a relatively cool, dry environment. If this box cannot be used for long-term storage, the sword should still be stored separately from the scabbard, as they no longer fit together. Closed shelving would be beneficial, as dust and dirt are difficult to remove from the interstices of this piece. The blade should be supported to prevent further bending. The monitor lizard skin's exposure to light, particularly natural light, should be limited, because fading and degradation of organic materials is accelerated by light exposure. An ideal light level for incandescent display is 50 lux or below. As noted early there was evidence of insect damage to the scabbard; regular monitoring of collections and the use of traps can help prevent infestation.

9. CONCLUSION AND EVALUATION OF TREATMENT

The stabilization and research goals of this treatment were reached, though ongoing research into the grain structure of the sword will reveal more information about its manufacture. The owing institution now has significantly more detail about the manufacture and probable history of the piece. The surface of both the sword and scabbard have been cleaned and stabilized.

This piece can be safely displayed and stored. (fig 32, 33, 34, and 35) The treatment is largely reversible. The coating on the surface of the blade, and adhesive on the underside of the scabbard can be removed with common solvents. There are aspects of the treatment that were not completely satisfying. The consolidation of the leather straps and black plant cordage is not reversible. There was minor darkening and accumulation of a slight residue on the plant cordage, particularly on the waxed side. However, this residue layer cannot be seen without magnification, and the support provided by the consolidating agent is essential to allowing this fragile material to last. Lastly, much of the damage to the monitor lizard skin could not be addressed by this treatment, though cleaning has lessened the visual impact of this damage.

fig. 32 and 33 front and back of the sword after treatment

fig. 34 and 35 front and back of the scabbard after treatment

ACKNOWLEDGMENTS

I would like to thank all of the people whose support and expertise contributed to the completion of this project, particularly Jonathan Thornton, Dr. Gregory Smith, and Dan Kushel.

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AUTOBIOGRAPHICAL STATEMENT

Anne R. Grady received her bachelor's degree from Oberlin College in Oberlin Ohio. She is currently a master's degree candidate at the Buffalo State Art Conservation Program. She has completed internships at the Metropolitan Museum Art in New York City, and the Worcester Art Museum in Worcester Massachusetts. She will be completing her gradate degree with a yearlong internship at the Los Angeles County Museum of Art, beginning in the fall.

APPENDICES

A. MATERIALS SOURCES

Organic Acid Gel Rust Remover VpCL-423
Cortec Corporation
4119 White Bear Parkway
St. Paul, MN 55110
(651) 429-1100

Renaissance Microcrystalline Wax
Picreator Renaissance Products
  by Picreator Enterprises Ltd.
44 Park View Gardens,
London, England NW4 2PN

KLUCEL G (hydroxypropyl cellulose)
Talas
20 West 20th Street, 5th floor
New York, NY 10011
212-219-0770
[manufactured by Hercules Inc., Wilmington, DE]

Japanese Paper
Talas
20 West 20th Street, 5th floor
New York, NY 10011
212-219-0770

Dry pigments
Conservator's Emporium
100 Standing Rock Circle
Reno, NV 89511
(702) 852-0404

B. ANALYTICAL EQUIPMENT

Transmission FTIR Microscopy

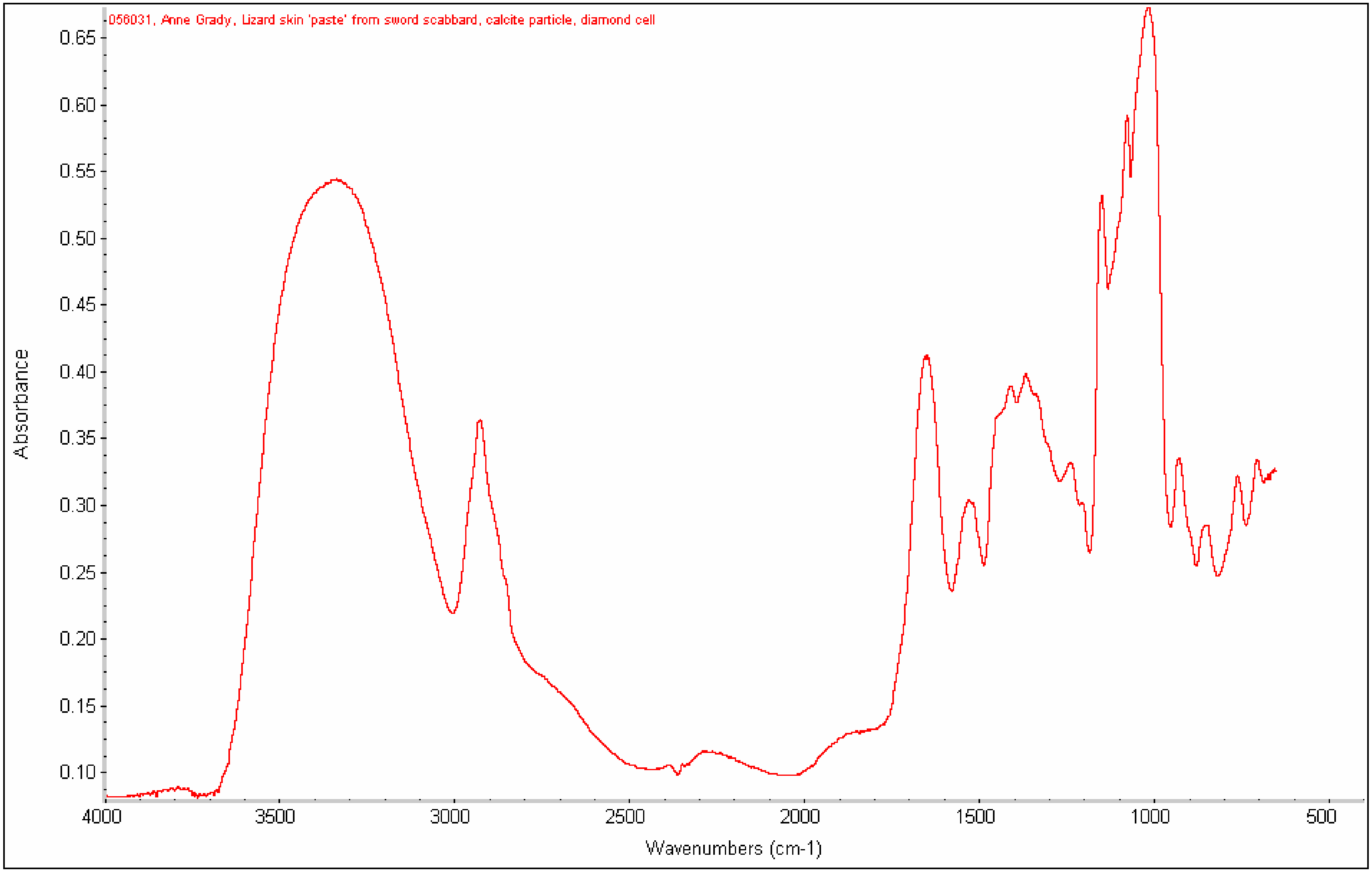
Infrared spectra were collected using a Continuum microscope coupled to a Magna 560 FTIR spectrometer (Nicolet). Samples were prepared by flattening them in a diamond compression cell (Thermo Spectra Tech), removing the top window, and analyzing the thin film in transmission mode on the bottom diamond window (2 mm x 2 mm surface area) using an approximately 100 μm x 100 μm square microscope aperture. The spectra are the average of

32 scans at 4 cm-1 spectral resolution. Correction routines were applied as needed to eliminate interference fringes and sloping baselines. Sample identification 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 Nicolet).

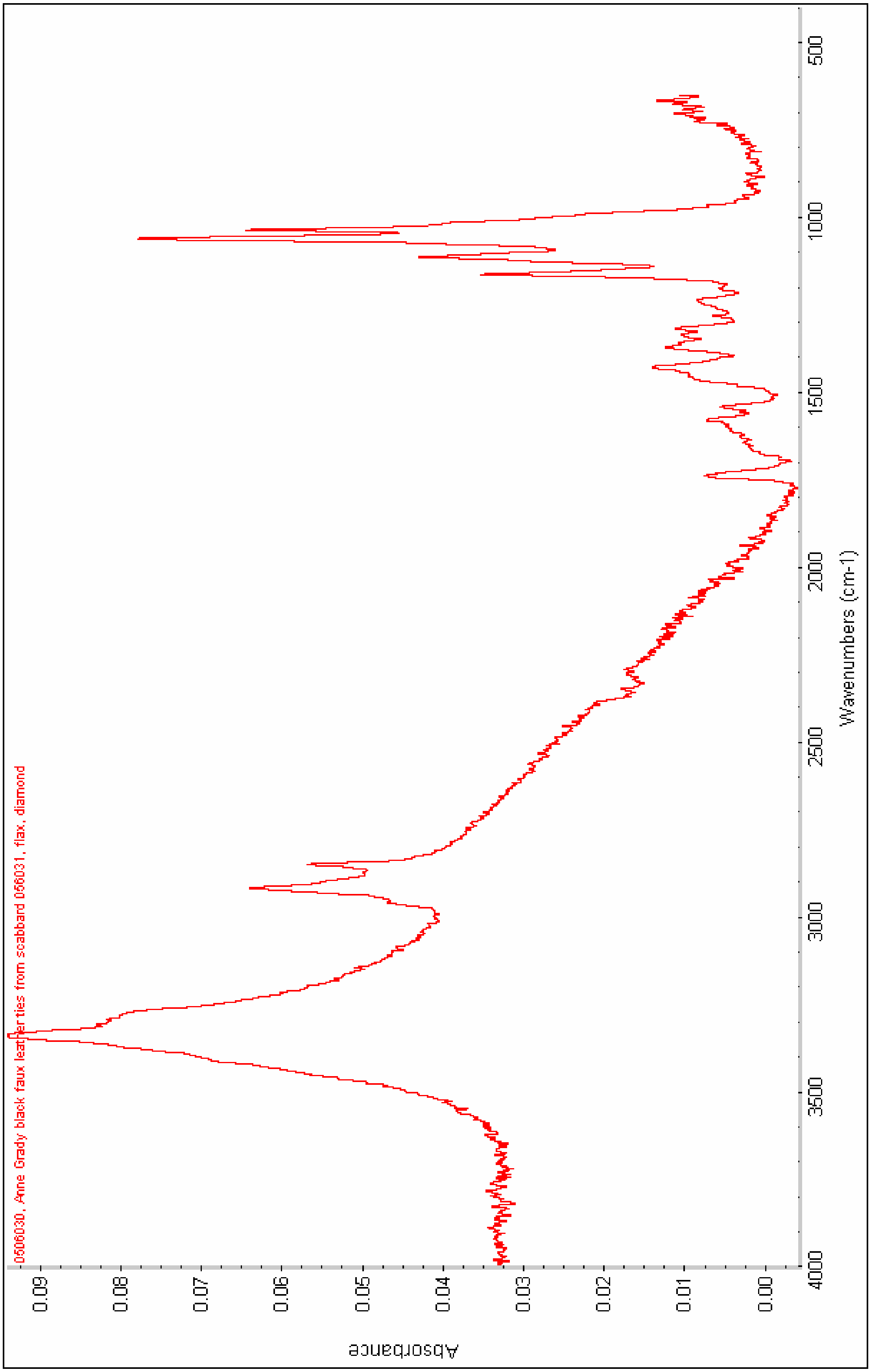
X-ray Fluorescence Spectroscopy

X-ray fluorescence spectra were collected using a Röntec ArtTAX energy dispersive x-ray spectrometer system. The excitation source was an x-ray tube with a molybdenum (Mo) target [*or* a tungsten (W) target] and a 0.2 mm thick beryllium (Be) window, operated at 50 kV voltage and 600 mA current. The x-ray beam was directed at the artifact through a beam-limiting device with an aperture of 0.65 mm [*or* 0.200, 1.0, 2.0 mm] in diameter. X-ray signals were detected using Peltier cooled XFlash 2001 silicon drift detector (SDD). [*Optional:* Helium purging was used to enhance sensitivity to light elements.] Spectral interpretation was performed using the ArtTAX Control software.

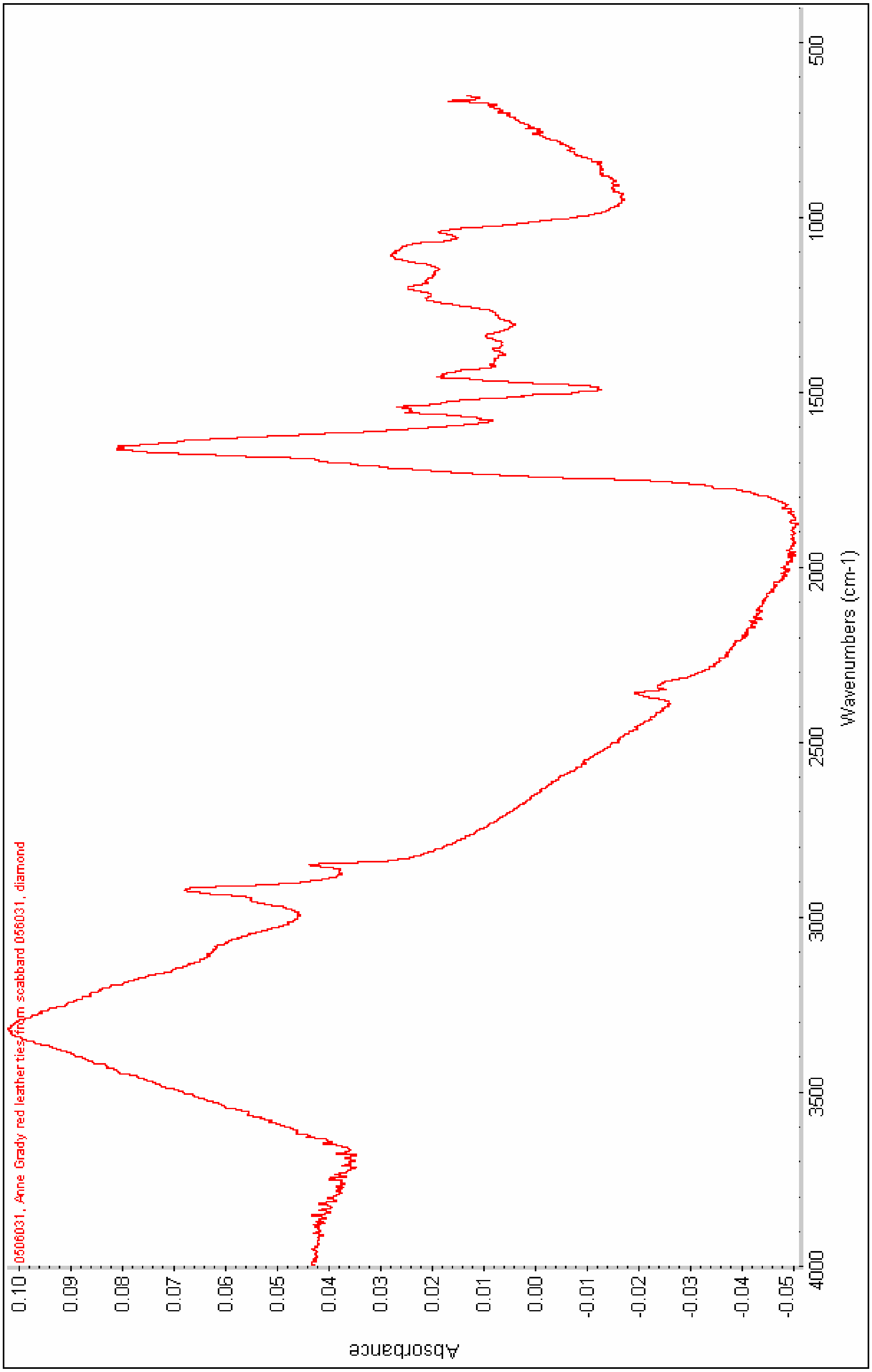
C. TRANSMISSION FTIR SPECTRA



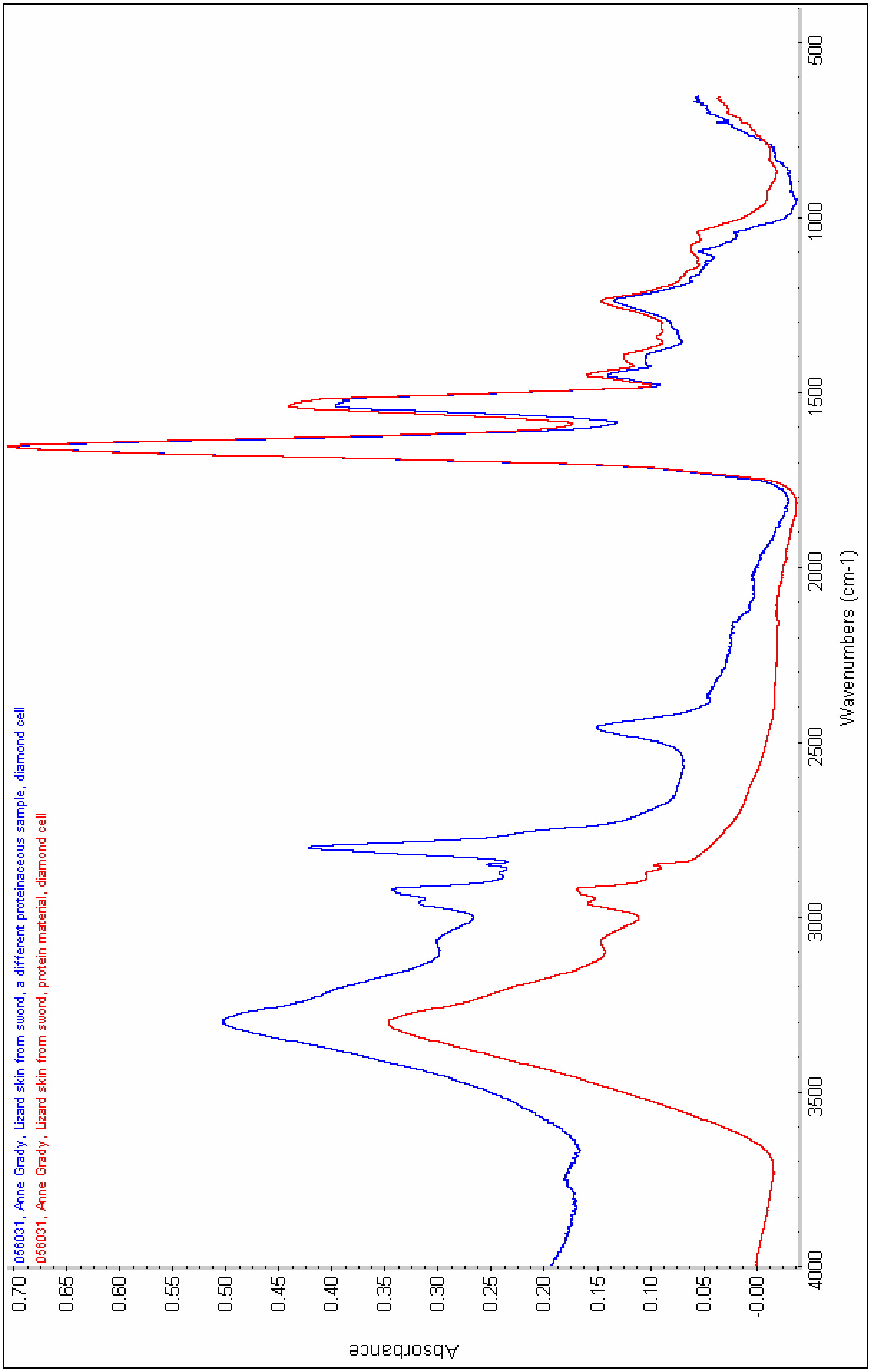
1. Spectrum for unknown coating on the surface of the scabbard



2. Spectrum for the black plant cord

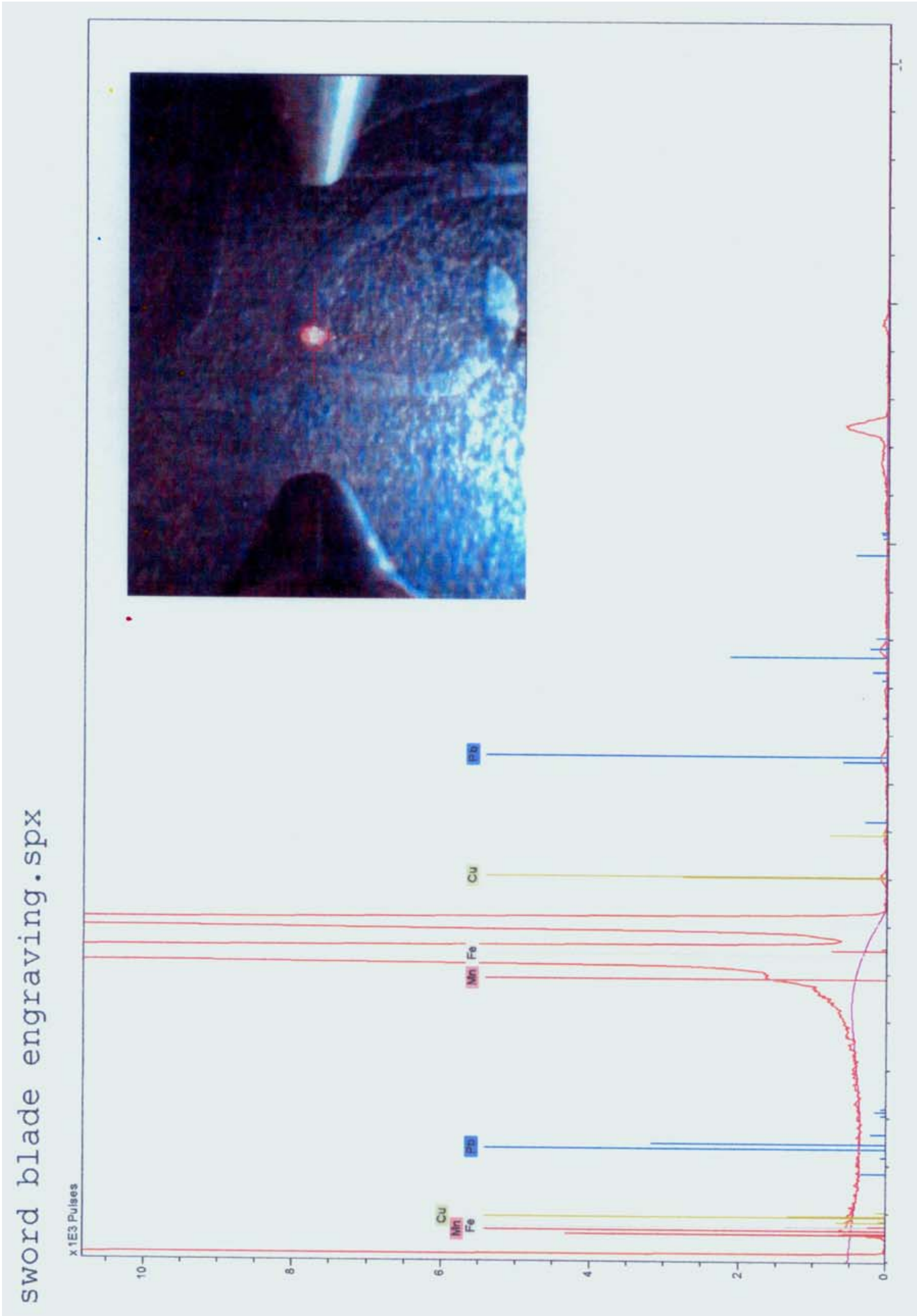


3. Spectrum for the red leather straps

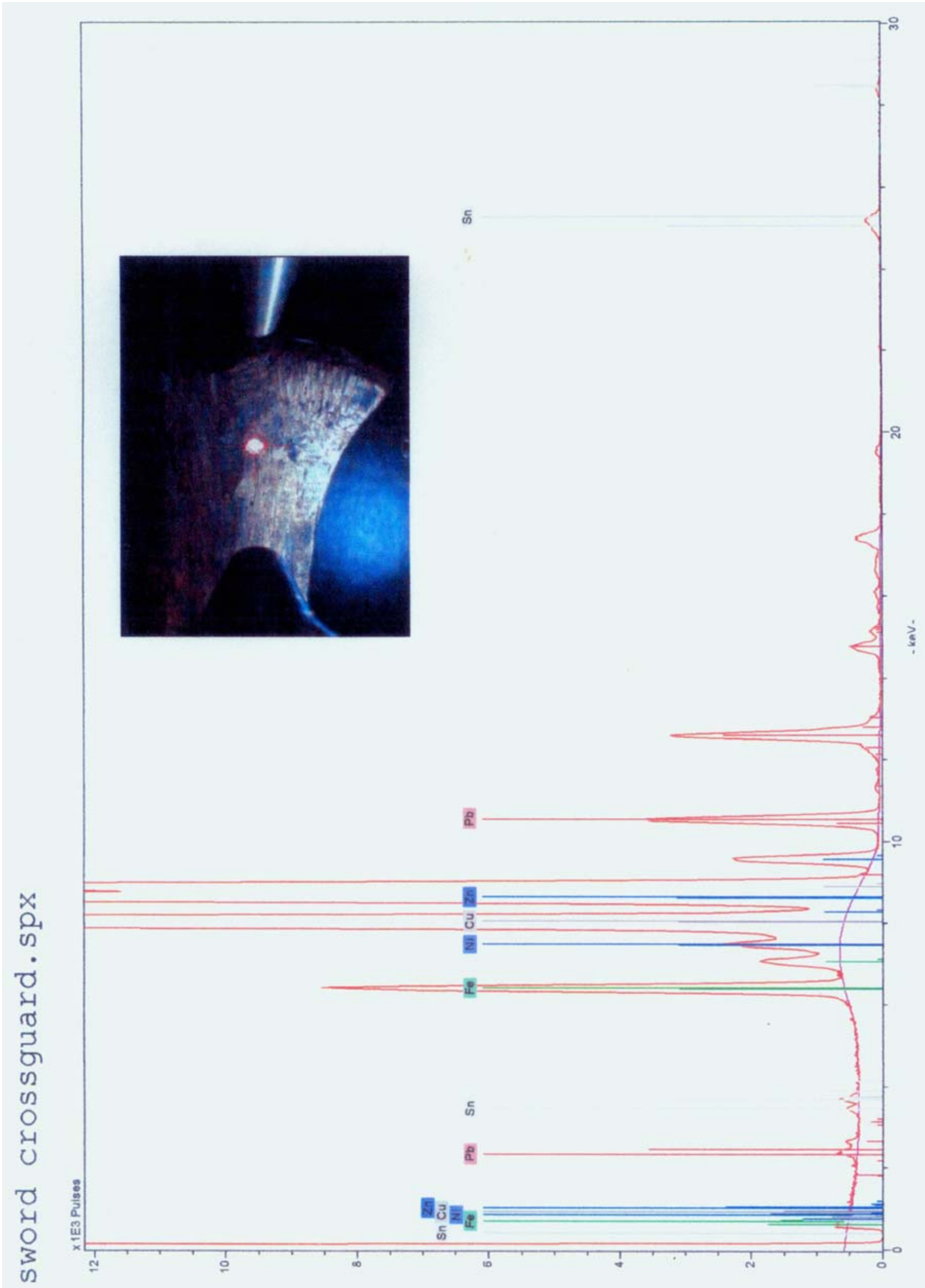


4. Spectrum for the monitor lizard skin

D. X-RAY FLUORESCENCE SPECTRA



1. Spectrum for the surface of the blade



2. Spectrum for the cross-guard

E. MICRO-CHEMICAL TESING

1. Test for vegetable tannins using ferric chloride

In this test samples of the skin are dampened with de-ionized water and placed in a spot test well with several of drops of a 1% (wt/vol) aqueous solution of ferric chloride. If tannins are present the solution will turn dark green or dark blue. The results for the samples of monitor lizard skin and the red leather straps were compared to that of a skin known to be vegetable tanned. The monitor lizard skin tested negative, while the red leather straps tested positive for the presence of vegetable tannins.

2. Test for phenols in vegetable-tanned leather using lead acetate

In this test a metallic salt precipitate will form between the lead and the phenolic hydroxyl groups present in the tannins. Results for the monitor lizard skin and the red leather straps were compared to the result for leather known to be vegetable tanned. The red leather straps and the known positive both formed the metallic salt precipitate, while the monitor lizard skin did not.