WINTERTHUR / UNIVERSITY OF DELAWARE
PROGRAM IN ART CONSERVATION

EAMINATION REPORT AND TREATMENT PROPOSAL

Identifying number(s): U. Penn: AF 3364 (ACP 1267c)
Owner: University of Pennsylvania Museum of Archaeology and Anthropology
Permanent location in the museum: UPMAA storage
Date of examination: February 13, 2008
Name of examiner: Lauren Fair
Dimensions: Sword: L. 23 ¾” (60.3cm), W. 3 3/8” (8.6cm)
Blade: L. 17 7/8” (45.4cm), W. 2 1/8” (5.4cm)
Sheath L. 18 3/8” (46.7cm), W. 2 ¾” (7cm)
Date: Unknown. Date of collection is July 1912.
Place of origin: Africa, possibly from the Sudan

Description:
According to the UPMAA catalog records, the sword and sheath are said to be from the Sudan. The object was purchased from W. O. Oldman, in July of 1912. William Oldman was a collector in London during the years of the late 1890s to before WWI. He had a large collection of archeological and ethnographic objects from Asia, the Middle East, Africa, Melanesia, Polynesia, the Pre-Columbian and North American Indian cultures, and Europe. Oldman also had an extensive collection of Maori art, which he sold to the government of New Zealand in the 1930s.

The sword consists of a steel blade and a wooden hilt, which is carved and partly wound with metal wires. It has a wooden sheath that is covered with what appears to be a blue paper followed by dark red leather that is decorated with blind tooling. For purposes of this examination report, “Side A” will refer to the side of the sword not labeled with the catalog number and to the side of the sheath that is more heavily decorated. “Side B” will refer to the labeled sides of both the sword and its sheath (figs 1 and 2).

Fig. 1: Side A

Fig. 2: Side B

Blade –

The blade is double edged and is constructed from a ferrous metal, probably steel. The sides run roughly parallel to one another along the length of the blade for 13 ½" then taper to a sharp point for the remaining 4 3/8". A beveled fuller is carved down the center on both faces of the blade, beginning at the hilt and tapering to a point 6 ¾" down the length. Both carved fullers are bordered by a raised rib line: the two sides of the raised border join at the bottom of the fuller and merge into one raised rib that continues straight along the center of the remaining length of the blade to the tip.

On both faces, the blade has many scratch marks that run parallel to the length of the sword as well as many short scratches that run perpendicular to its length. These marks could be evidence of the blade's construction. Small matte stippling marks are also evident on certain areas of the blade, especially in the fuller, also likely evidence of blade construction. The stipple marks appear to have been present on the surface first, as the scratch marks all seem to be going over them (fig 3). In addition, roughly 1" from the hilt on each side of the blade, there are three short grooves cut into the steel, running perpendicular to the length of the blade. Both Side A and B are the same: there are two grooves on the left and one on the right, all of which are no more than ¼"- ½" in length.

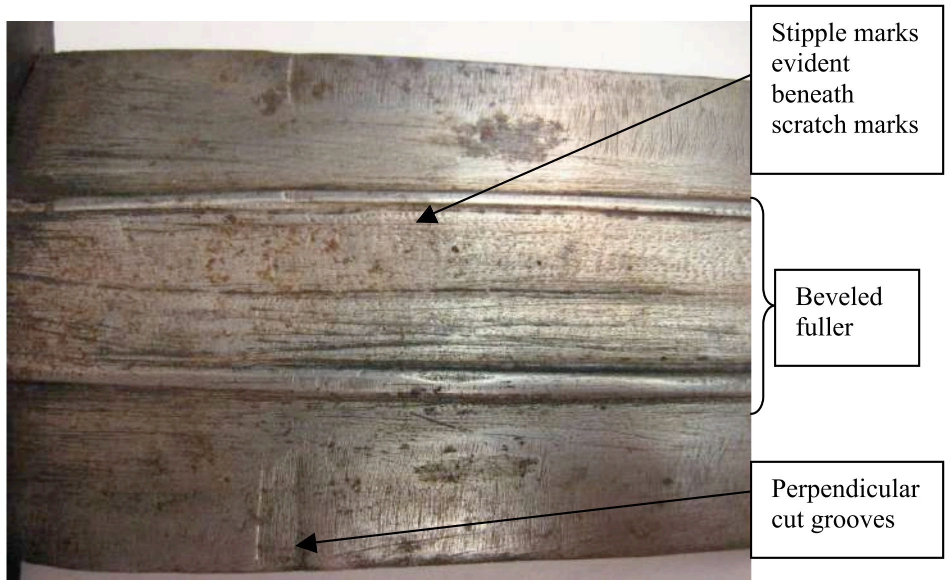

Fig. 3: Detail of blade

Hilt –

The hilt is most likely carved from a tropical hardwood. The wood appears red in color, and under examination with a stereomicroscope, the red appears to be the natural color of the wood, as no particulates are evident. There does seem, however, to be a thin, transparent surface coating, possibly wax, over the wood.

The shape of the hilt is cruciform in nature. The lower and upper crossguards are roughly 3" wide but slope smoothly inward to a grip that is 1 ½" wide. Metal wires, possibly copper or brass, are wrapped around the slender center of the grip, extending 2 1/8" along its length. A twisted ferrous metal band, alternating in copper and silver colors, is also wrapped around the center ten times, between the copper or brass wires. The left and right sides of the upper guard extend slightly upward, forming a Y-shape, the grip being the central part of the Y. The two sides of the upper guard are rounded on the bottom and flattened on the top, carved coarsely with a chisel. Hatch marks are cut into the wood, 3-6 on either side of the upper guard, on both the front and back, together totaling 17 markings (fig 4).

Fig. 4: Hilt, side B

The pommel extends vertically from the Y-shape created by the upper guard, and the tip consists of a separate piece of wood, joined by a ferrous metal pin, around which it freely rotates. This separate wooden piece has a different grain direction than the remainder of the hilt and it is a light brown color. At the base of the metal pin is a non-ferrous metal ring, copper in color and with hatch marks around its base. Overall, the hilt has a very anthropomorphic appearance; the separate piece of wood at the top is akin to a human head, the upper guard like two arms, and the wire-wrapped grip like a waist.

Sheath –

The shape of the sheath follows the shape of the metal blade. It is constructed primarily of four layers. First is a structure made of wooden splints. Second, in some areas adhered to the wood substrate, there appears to be a woven textile. This is visible in an area of damage near to the hilt. Next, over the wood and the sparse areas of textile, there appear to be two layers of paper adhering the wood structure to the overlying leather covering. The first seems to be a white, coarsely ground paper followed by a blue, coarsely ground paper, both of which are visible through areas of damage to the sheath. The final layer is a red leather overlay that is heavily decorated by blind tooling (fig 5).

Fig. 5: Sheath, side A

It seems that one piece of dark red leather, about 14” long, was cut to fit the majority of the length of the blade, and it wraps around the inner structure, joining to itself by adhesion. At the tip of the sheath, there are two cut strips of bright red leather coiled around the point, holding the joined leather piece together.

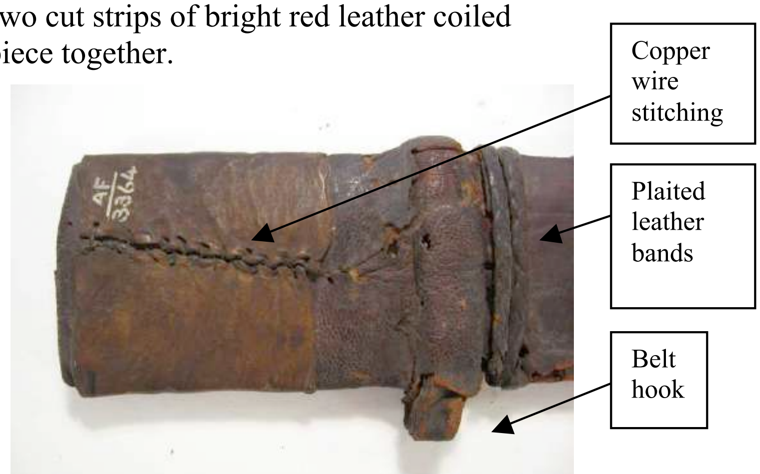

Fig. 6: Top of sheath, side B

About 3” from the top of the sheath, strips of leather that are 3/8” wide are wrapped around the width and stick out ½” from the right side of Side A, forming a loop that probably serves as a method of belt attachment. Below this belt hook is a thinly plaited band of red leather wrapped twice around the width of the sheath, and stuffed underneath it to tie it off. It appears that two pieces of red leather are wrapped around the belt hook and continue over the top of the sheath, adhering to the top of the interior. On the exterior, the piece is joined together by a rough running stitch with what appears to be cotton or linen thread. A brown strip of rawhide, extending about 2” on the length of the sheath, wraps only around the exterior, and it is joined to itself by a rough running stitch of what appears to be a copper wire (fig 6).

Both sides of the sheath are decorated with marks of blind tooling and embossing. All tooling marks appear to have been done by working the surface from the show side of the leather. Side A is the more elaborate of the two. All tooling marks are confined to the area below the belt hook. The design of Side A is fairly symmetrical. At the top near the belt hook there is a band of zigzag tooling and straight lines, running the width of the sheath. Below this, a long raised line extends 10 ½” down the length of the sheath with the line branching to a Y at the top and a curved hook at the bottom. On either side of this line, tooling marks roughly mirror each other down the length of the sheath. They consist primarily of circular and semi-circular designs. Side B is less elaborate, but the tooling fills the entire area of the sheath below the belt hook. The length of the leather is tooled with parallel lines. Crossing these lines is a wide zigzag band that runs from the belt hook to the tip, getting more narrow to fit in the space that tapers to a point.

Materials and Technique:

Blade –
The blade is a ferrous metal, most likely steel. It would have been created by smelting and forging. Smelting is the process whereby iron ore is heated without oxygen to about 1200-1300˚C, until the raw metal separates from the soil it is in, and metallic iron is released from other compounds found within the ore. The metal that separates out forms a horseshoe-shaped bloom of raw iron. Smelting furnaces in Africa varied in type across the continent, but they generally consisted of a column made of mud or clay that is about

one meter high with holes near the base to allow air entry from bellows, which were made of either sheep or goat skin.[1] Once the raw iron was obtained through this method, forging would be done by the blacksmith, who would deliver heavy blows to the iron using hammers of stone or iron against an anvil made of stone. This needed to be done over the constant heat of a fire; thus it usually required two or three people to carry out heavy forging.

This particular blade has many markings on its surface, including stippling and numerous scratch marks. These could be evidence of the blade's construction, possibly from the blacksmith's finishing and shaping on an anvil. It is also possible that some of the marks are from a reworking of the blade's surface at some point after it was forged. The perpendicularly cut grooves near the handle of the weapon appear to have been cut using a mechanized rotary wheel.[2]

Hilt –

The hilt is likely hand-carved from a tropical hardwood. As noted above, the red color of the wood appears to be its natural shade. All the gouge marks evident on the wood do not appear to be caused by machines but rather by hand tools such as sharp implements and chisels. The freely rotating tip of the pommel, if original to the piece, may have been a part of the intended construction. The hilt is decorated with copper and wires as well as twisted wires of copper and steel.

Sheath –

African-made sheaths were often composite objects of wood and leather, such as this one. The sheath is made primarily of leather, both processed (tanned) and unprocessed (rawhide or skin) that is wrapped around a base made from wood splints, paper, and textile. A small sample was taken from a splinter of wood that became detached, and this was examined using a polarized light microscope.[3] From this analysis, the material is determined to be a softwood species. The presence of the paper and textile elements, which are in between the wood and leather, may be serving to provide better adherence of the leather over the wood substrate.

It is often possible to determine the animal from which the leather has come from by examining the grain patterns under magnification. The strips wrapped around the tip of the sheath retain some of the animal hair on the grain layer. The images below (figs 7 and 8) are two photomicrographs of the leather surface, and an image of the sheath indicates where the detail shots are from.

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[1] Kense, Francois J. "The Initial Diffusion of Iron to Africa." *African Iron Working – Ancient and Traditional*, Randi Haaland and Peter Shinnie, eds. (Oslo: Norwegian University Press, 1985) p. 53-54.

[2] This theory is supported by Mark J. Anderson, professor and conservator of furniture at Winterthur Museum/ University of Delaware Program in Art Conservation.

[3] Polarized light microscopy carried out by Lauren Fair with a *Nikon Labophot2-Pol* microscope under 400X magnification

Fig. 7:
Dark red leather in area above belt hook

Fig. 8:
Bright red leather of strip at tip of sheath

Fig. 7: *100X, visible light*

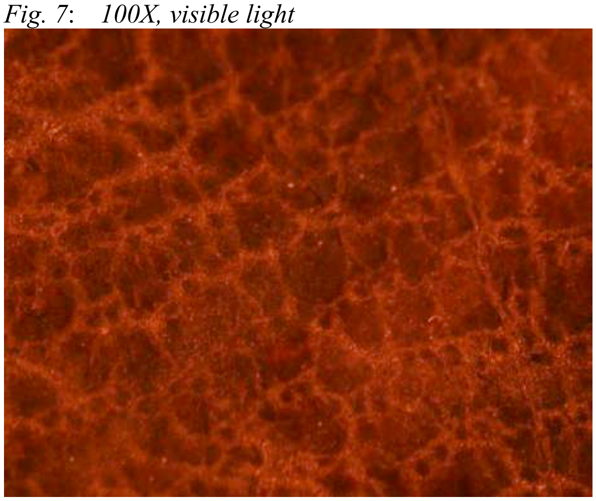
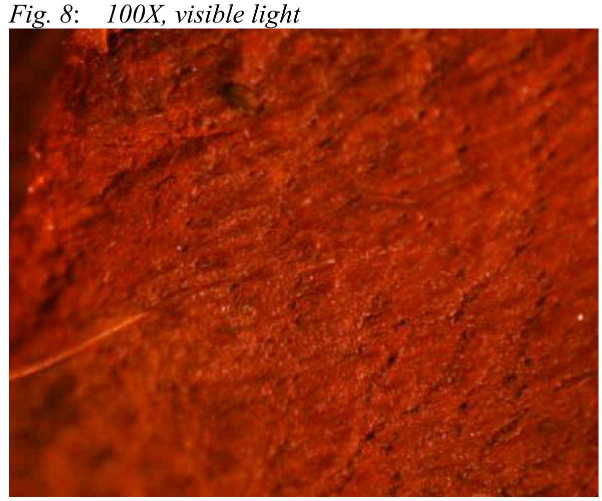


Fig. 8: *100X, visible light*



The leather of the sheath was studied carefully under a stereomicroscope and the grain pattern was compared to known samples of cow, goat, and sheep leather. In addition, the thickness of a strip on the tip of the sheath was measured with a micro caliper and found to be 1oz.[4] Based these examinations, it can be said the leather used to make the sheath is either from goat or sheep, with a higher probability, given the density of the grain, that it is goat.

The brown piece of hide wrapped around the top of the sheath is not processed. However, the red leather of the main body of the sheath is tanned. Judging by the characteristics of its deterioration, i.e. the presence of red rot (acidic degradation), as well as the extensive embossed surface decoration, it is most likely that this red leather was processed by vegetable tanning. Further testing, for instance with microchemical spot tests, would need to be done in order to confirm this.

The general process of vegetable tanning leather involves first preparing the hides by dehairing them by soaking in scalding water, ashes, lime, or urine. The hides are then sufficiently scraped, then fleshed. Sometimes they are split before deliming, bating, and making final preparations for tanning. The prepared hides are then soaked in vats of tannins, which can be found in the wood, bark, fruit, and roots of many plants around the world. One common source of vegetable tanning extract that can be found in East Africa in particular is the wattle (*Acacia mollissima*), a condensed tannin that comes from the bark of the tree.[5] The hides are immersed for several weeks at a time, and agitation at a higher pH is essential to swell the skins and allow the tannins to react with them. The

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[4] One ounce = 1/64 inch thickness
[5] Pouliot, Bruno P. "Skin, Leather and Related Materials," ARTC 655 Class Notes, 1/28/2008, p. 3.

process draws the collagen fibers of the skin together through ionic attraction, and the tannins efficiently replace the hydrogen bonds between the fibers to render the leather firm and resistant to moisture penetration.

Finishing processes of vegetable tanned leather often include fat-liquoring, coloring, texturing, and embossing. The leather sheath is decorated by tooling and embossing. This would be done with heat and pressure, impressing the designs into the surface of the leather.

Historical Background:

The earliest metalworking in Africa is in iron, dating to about 800 BC. By the 3rd and 4th centuries, the trade had spread all over the continent. The blacksmiths produced iron objects such as farm implements and weapons, as well as important ritual objects. Copper, a material not as readily available as iron, was considered a luxury in Africa, and thus was often reserved for use on prestigious objects or as decorative embellishments only.[6]

Because of the sense of power that exists in using fire to extract ore and forge the material into objects of use and beauty, blacksmiths were often associated with the supernatural, and were regarded with a sense of mystery. Within various tribes, the blacksmiths were either revered or ostracized; often they would live in different areas, separated from the rest of their community, and would form themselves into guilds to maintain control of the commerce.[7]

Although iron objects were being manufactured within Africa, by the sixteenth century iron was also being imported to the region from Europe. Sword blades were forged in the great centers of Solingen in Germany, Toledo in Spain, and Belluno in Italy, and they were brought to Africa by trade routes via Tunis, Tripoli, and Alexandria.[8] Whether this particular blade was made in Africa or brought to the continent from outside sources is not certain. It is not an easy task to determine provenance based only on blade style or shape alone. Often, even if the blades were not imported from Europe, African blacksmiths would copy European or Islamic blade styles to sell to tourists.[9]

Fig. 9: Hilt of a Tuareg Takouba sword, www.oriental-arms.co.il/item.php?id=774

The cruciform nature of the hilt is a handle style used extensively by the Tuareg people from an area to the west of the Niger, that can now be found in central Sudan (fig 9). The shape of the blade bears a likeness to those of the Shona tribe in

[6] Brincard, Marie-Thérese, ed. *The Art of Metal in Africa.* (New York: The African-American Institute, 1982) p. 15.
[7] Spring, Christopher. *African Arms and Armor.* (London: British Museum Press, 1993) p. 16-18.
[8] *Ibid.* 41.
[9] *Ibid.* 42.

Fig. 10: Shona sword, www.tamerrian.com/Photos%20.html

Southeast Africa (fig 10).[10] One must bear in mind, however, that trading among different geographic regions was common.[11] Iron carried much importance throughout Africa; not only for the objects it could be made into, but for the raw material itself. Iron served as currency throughout much of pre-colonial Africa; thus even sword blades themselves would frequently be used as money.[12] This promoted a great deal of trading, as well as re-working of blades, and it was even common practice to fit traded blades with locally made hilts and sheaths.[13] These factors make interpretation of a specific geographical and cultural origin of the sword and sheath difficult.

Sheaths were often made of leather, as the technology of leather manufacture was well established in Africa. The trade of curing skins and finishing them by vegetable tanning is an ancient technique, present in Egypt and throughout the Near East by 3,000 BC. The practice continued to grow, but with little change to the fundamental technology of leather manufacture until the Industrial Revolution in the 19th century.[14] Vegetable tanned leather was a popular material for this purpose because it could be easily embossed and decorated. Decorative elements on the sheaths often carried cultural or religious meaning. For instance, the Dogon and Bamana people of Mali in West Africa made many art objects for the gods, and in Dogon philosophy, the common zigzag as a decorative element calls to mind water, speech, and the creator god Amma.[15]

Condition:

The blade and its hilt are in relatively good condition; the sheath, however, is highly degraded and unstable.

Blade –

The steel blade has a moderate amount of surface dirt, as well as various accretions, which are probably corrosion products.[16] They are dark to light brown in color, and are most concentrated just below where the horizontal grooves are cut into the metal. A few smaller accretions are scattered on the remaining length of the blade. Further analysis of this material would need to be conducted to determine whether it is corrosion product or surface dirt and other accretions.

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[10] *Ibid.* 41.

[11] Consultation with Wallace Gusler, former Master Gunsmith, Curator of Furniture, and Director of Conservation at Colonial Williamsburg Foundation

[12] Webb, James L.A., Jr. "Toward a comparative study of money: a reconsideration of West African currencies and neoclassical monetary concepts." *International Journal of African Historical Studies.* 15, 3 (1982) p. 457.

[13] Spring, 41.

[14] Kite, Marion, and Roy Thomson. *Conservation of Leather and Related Materials.* (New York: Butterworth-Heinemann, 2006) p. 68.

[15] Brincard, 19.

[16] Consultation with Margaret Little, Objects Conservator at Winterthur Museum/ University of Delaware Graduate Program in Art Conservation

Hilt –
The main wooden body of the hilt sustains two small vertical cracks in the center of each side of the handle that begin at the base of the hilt (fig 11). The ends of the cracks are obscured by the decorative wirework on the grip. The cracking was probably caused by the cross-grain expansion and shrinkage of the wood with fluctuations in relative humidity while over a rigid metal blade. While the cracks do not seem to be causing any immediate structural concerns to the object, they should be monitored, and the object should be kept in an environment of controlled relative humidity in order to prevent further cracking. The remainder of the hilt appears to be in good condition. The metal components have oxidized to a dark brown color, but show no signs of corrosion, and surface dirt is minimal.

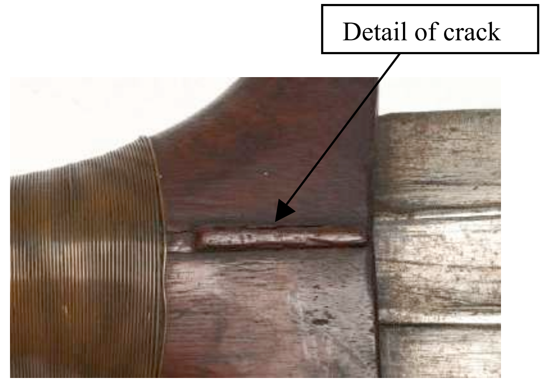

Fig. 11: Detail of hilt, side A

Side B has the accession number written in yellow paint on the bottom right portion of the hilt: “AF/3364.” On the bottom left portion, there are remnants of numbers written in yellow paint that seem to make out, “1138/203.”

Sheath –
The sheath is in poor condition. The wooden splints, as well as the remnants of paper, are brittle and cracking. The adhesive joining two pieces of wood to the leather has failed, and these pieces are now completely detached. Repeated removal of the blade from its sheath has created stress in the wooden structure and has caused the leather to split longitudinally down both edges. The splits extend almost the entire length on the right edge of Side A and the leather is only intact on the left edge for 4” at the tip. Thus, the structural stability of the sheath is tenuous, as the wooden and leather components are held together only at the top near the belt hook and for this small section at the tip.

The leather covering is dry, highly deteriorated, and suffers from red rot, which is causing pieces to actively crumble. On some areas of the surface are white blooms, which under magnification, appear to be remnants of mold growth (fig 12).

There are multiple areas of loss, including a large area about 1 ½ inches long, spanning the width of the sheath on Side B. There are small deposits of a resinous material, visible at the edge of this loss, as indicated in this photograph below by the black arrow. This resinous material may be extant from a past repair, although there is no record of former conservation treatment at the UPMAA.

Fig. 12: Detail of damage to sheath, side B

In addition, there are several small areas of insect damage that consist of small holes, scattered in different areas of the leather sheath, but not affecting the piece of rawhide. The damage appears to be from a past insect infestation, which is no longer active. The rawhide is in excellent condition, compared to the tanned leather, indicating how in this case the processing of the tanned leather is directly related to the deterioration the leather later suffered.

On Side B of this piece of leather, the accession number is written in yellow paint: "AF/3364." No other remnants of yellow paint are visible.

Analysis and Testing:

Ultraviolet Examination –
Examination under both short-wave and long-wave ultraviolet light shows the red leather elements fluorescing a deep red color, and the white paper material fluorescing a dull orange. The orange fluorescence may indicate an applied adhesive or coating, possibly shellac. The wood brightly fluoresces white, which is to be expected, due to the high content of cellulose. The textile material fluoresces bright white as well, which could indicate that it too is cellulosic. The resinous material seen in the large area of loss on the sheath fluoresces bright white, possibly indicating the presence of animal glue.

The accession numbers in yellow paint on both the sword hilt and sheath fluoresce brightly, but no other elements on the sword exhibit fluorescence under examination in ultraviolet light.

Arsenic and Mercury Testing –
In the past, many archeological and ethnographic artifacts with organic components were treated with arsenic or mercury as a method of providing protection from pests. As a

safety precaution, the presence of these potentially toxic elements was tested. The presence of arsenic compounds was tested using arsenic test papers (Macherey-Nagel).[17] The presence of mercury salts was tested using diphenylcarbazone.[18] Both tests had negative results for the presence of arsenic and mercury.

Further analysis desired –

1. Sampling and analysis of paper components of sheath:
   Revealing specific materials used for construction of the sheath will hopefully aid in determining a date of manufacture and possibly offer insight into its provenance.
2. pH test on leather, collagen shrinkage temperature test on leather:
   These tests will provide information on the degree of deterioration of the leather and will help dictate possible treatment options and materials acceptable to use.
3. Testing of leather tanning process with microchemical spot tests:
   To know what chemicals may be present on the leather and assess what materials may be brought to it
4. X-ray Fluorescence Spectroscopy of metal components:
   To determine if the steel is actively corroding and what the treatment should be
   To determine the exact composition of the metal components

Purpose of Treatment:

The goal of conservation treatment for this African steel sword and wood/paper/leather sheath has two main objectives: first, to stabilize the deteriorating leather, wood, and paper components of the sheath by consolidation and repairing splits and significantly damaged areas, while also attending to the less urgent needs of the steel blade; and secondly, to provide adequate housing for the object in order to maintain the best environment possible.

Treatment Proposal:

Treatment of blade and hilt –

1. Surface clean with a soft bristle brush and a vacuum cleaner equipped with a HEPA filter to collect any loose surface dirt. If desired, dry surface cleaning methods could be tested, such as the use of cosmetic and polyurethane sponges, to gently clean the surface of the blade and hilt, in hopes of removing more surface dirt.
2. To stabilize the blade, corrosion products can be cleaned using methods tested to be effective and not significantly scratch the metal. Organic solvents (e.g. acetone, Stoddard's solvent) and a light abrasive, such as 0000 steel wool, could be used, or by mechanical methods could be applied such as gentle scraping with

[17] Odegaard, Nancy, Scott Carroll, and Werner S. Zimmt, *Material characterization tests for objects of art and archaeology, 2nd ed*. (London: Archetype Publications Ltd, 2000) p. 40-43.
[18] *Ibid*. 72-73.

a bamboo skewer. Use of an organic solvent in conjunction with corrosion removal will degrease the metal, preventing further corrosion. To ensure further stabilization, the blade can be coated with a microcrystalline wax.

Treatment of leather/ wood sheath –

1. Surface clean using a soft bristle brush and a vacuum cleaner equipped with a HEPA filter. Several dry cleaning methods can be tested for safety and effectiveness, such as the use of cosmetic or polyurethane sponges, in hopes of removing more surface dirt.
2. Consolidate the leather. A consolidant such as 1-2% Klucel G (hydroxypropylcellulose) in ethanol or isopropanol would be directly applied to the leather. Another appropriate consolidant would be what is known as the "red-rot cocktail," which is a mixture of equal parts (1:1:1) of SC6000 (acrylic polymer and wax emulsion), 2% Klucel G in ethanol solution, and ethanol.[19] These consolidants would be tested to observe changes in resilience, strength, stability, flexibility, and color.
3. Re-adhere all loose wooden splints to the newly consolidated leather covering with a chosen adhesive that would be viscous enough to not carry through the leather. Two possibilities are Beva 371 (ethylene vinyl acetate co-polymer) and Lascaux 360 and/or 489 HV (butyl methacrylate co-polymer). If necessary, provide a reinforcing layer of Japanese tissue paper.
4. Secure all other loose elements, such as the plaited leather band below the belt hook and the red strips of leather at the tip of the sheath, with an appropriate adhesive material (Beva 371 or Lascaux, possibly).
5. The splits along each side of the sheath should be sealed and reinforced with the application of an adhesive (Beva 371 or Lascaux, possibly). Again, if necessary, providing reinforcement with Japanese tissue.
6. If desired, the area of loss can be filled. This decision will be made by the museum curator. The fill material would need to be weaker than the surrounding areas of leather. Materials to be tested for use would be Japanese tissue paper, Gold beater's skin, Reemay, or other synthetic polyester fabrics, all of which would be toned with acrylic paints to match the color and surface treatment of the surrounding leather. The chosen material would be applied with an appropriate adhesive. If the decision is made to fill the large loss on the sheath, it is suggested that the interior be photographed and documented prior to this as record of this part of its construction.

Storage recommendations –

An enclosure should be constructed for the object that will keep the sword and sheath together but not one within the other, as the continued use and study of this piece by removing/ reinserting the sword in its holder is damaging to the sheath's structural integrity. This could be done by creating separate enclosures with acid-free materials for

[19] Kite, Marion, and Roy Thomson, *Conservation of Leather and related materials.* 231-232.

the sword and sheath, and housing these compartments together within a larger container. This will allow all parts of each piece to be studied, while limiting handling of the object. Mounts of acid-free blueboard lined with Ethafoam or Volara could be constructed in order to provide added ease in handling as well as additional stability to the object while in storage. Providing enclosures will also limit exposure to light, dust, and air pollutants.

Recommended RH levels for this object are 35-50% at 68˚F (+/- 5˚). Storage options will be discussed with the keeper to determine what is best for the object given the climate conditions of the UPMAA storage facility.

Conservator, UPMAA: **Date:**

Lynn A. Grant, Interim Head of Conservation

Conservation Student: **Date:**

Lauren Fair, WUDPAC Graduate Fellow

Supervising Conservator: **Date:**

Lara Kaplan, Objects Conservator, Winterthur/UD

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Treatment Report:
The major steps of treatment are as follows. See "Analysis and Testing" section for discussion of testing performed on materials used for treatment.

Treatment of blade and hilt –

1. Surface cleaning was carried out with the use of a vacuum cleaner equipped with a HEPA filter and soft brushes as well as dry cleaning using polyurethane sponges and swabs. The blade and metal wire wrappings were also cleaned with Stoddard solvent and acetone in order to remove additional surface dirt and grime as well as a previously applied wax coating that had greatly discolored.

2. Corrosion products on the blade were cleaned and reduced for stabilization using Stoddard solvent and Grade 0000 steel wool in combination with gentle scraping using a bamboo skewer. Gentle scraping with a bamboo skewer was also employed to lessen corrosion products in the interstices of the metal wire wrappings.

Removal of corrosion products

3. The steel blade and metal wire wrappings[20] on the hilt were coated with Renaissance microcrystalline wax that was applied with a brush. A small amount of heat was used to facilitate the coating application on the blade.

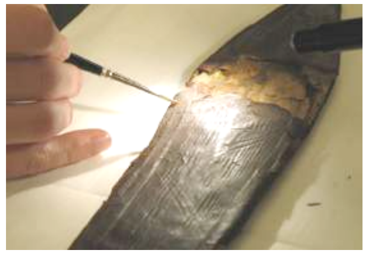
Coating blade with wax

[20] See Appendix for record of authorization for application of coating to metal wire wrappings on hilt.

Treatment of leather/wood sheath –

1. Surface cleaning was carried out with the use of a vacuum cleaner equipped with a HEPA filter and soft brushes, as well as dry cleaning using polyurethane sponges and swabs.

2. The leather was consolidated with a solution of 1.5% (w/v) Klucel G (hydroxyproplycellulose) in isopropanol; this was applied using small brushes, and two coats were found to be adequate to consolidate the leather. This consolidant was tested and found to be effective and to only slightly darken (saturate) the leather.



Leather consolidation

3. Loose wooden splints were secured by adhering a bridge of Japanese tissue paper with Lascaux 498HV (a water dispersion of methyl methacrylate and butyl acrylate) across the splints perpendicularly.

Japanese tissue bridge to stabilize wood splints

4. Minogami HM-3 Japanese tissue paper was chosen as a backing material to line the splits on either edge of the sheath. The paper was toned to match the color of the leather with Golden acrylic paints. A large enough piece was cut to line the interior of the entire width of the sheath and wrap around the interior of each edge. In this way, the paper also served to act as a cradle to the loose wooden splints. Lascaux 498HV was brushed onto the backing paper before application. The adhesive was reactivated with isopropanol and attached with gentle pressure.

Coating backing with Lascaux 498HV

Backing inserted into sheath

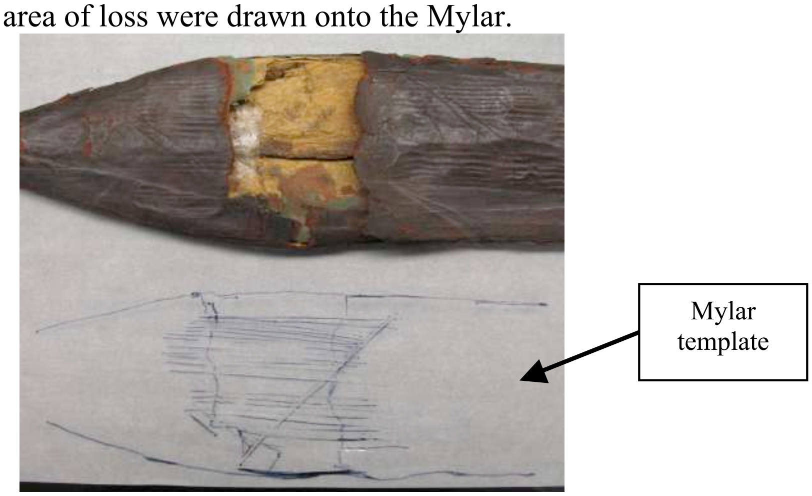
5. The sword was carefully inserted into the sheath prior to adhering backing paper and fill insert in place (see below). This decision was made so that the mends could be executed on the sheath in the form that it would take if the sword were inserted. Therefore, if the sword were to ever be inserted into the sheath at some point in the future, the repairs done at this time would accommodate this. In addition, the sword served as an excellent support while placing the backing material and fill insert.

Sword inserted into sheath to carry out repairs

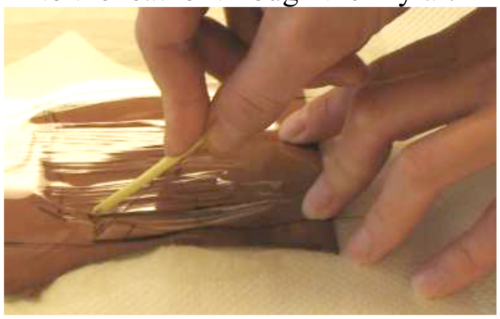
Backing put into place along inner edge of sheath

6. BEVA 371 film was used to prepare a fill insert for the area of loss on the sheath. This was done in the following steps:

    - A template was made by placing a piece of Mylar over the area of loss on the sheath. Using the existing tool marks on the sheath as a guide, the tool marks in the area of loss were drawn onto the Mylar.



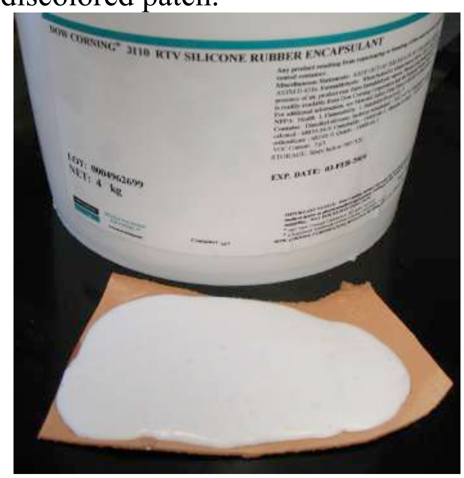
- The Mylar, with tool mark decoration drawn on, was placed over a piece of wet cow leather, and a bone folder was used to emboss the tool marks into the leather through the Mylar. The tooled leather was allowed to dry.



Tooling marks into wet leather

Dry tooled leather ready to be cast

- A mold was then taken of the impressions on this piece of tooled leather using Dow Corning 3110 RTV silicone rubber. The silicone molding material was not applied directly to the object, as some of the components of the mold material are absorbed in a material as porous as leather, leaving behind a discolored patch.

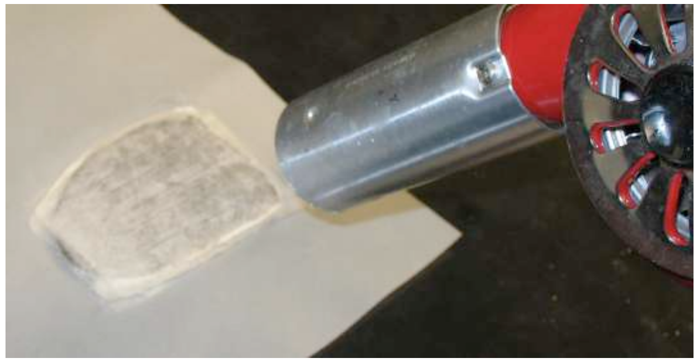


Mold taken of tooled leather

- The silicone rubber mold was allowed to cure, and Golden acrylic paints, mixed to match the color of the leather sheath, were used to paint the surface of the mold.

Painting silicone mold with acrylics

- Sheets of BEVA 371 film and Tengujo HM-1 Japanese tissue paper were interleaved over the painted silicone mold. Heat from a heat gun was used to melt the BEVA and adhere it to the acrylic paint and sheets of Japanese tissue paper. Once cooled, the BEVA and paper layers were peeled away from the silicone rubber mold, with the acrylic paint now adhered to the surface of the BEVA film.



Using heat to melt and adhere BEVA to acrylic paint and paper

Peeling layers away from mold

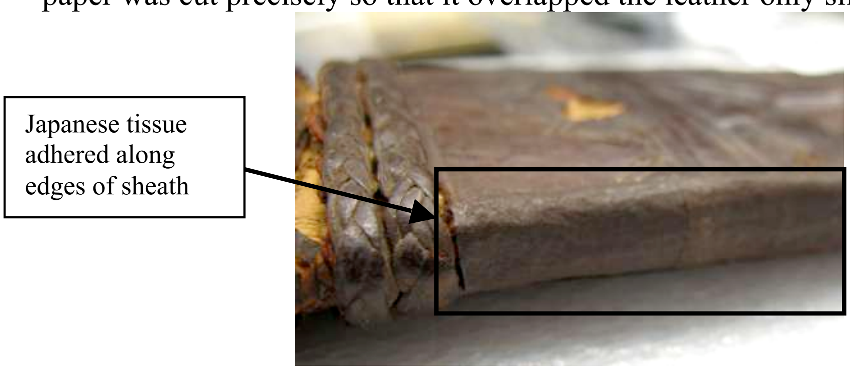
7. A support piece of toned Minogami HM-3 Japanese tissue paper was inserted into the area of loss and adhered to the underside of the loss edges using Lascaux 498HV. This served as a backing for the BEVA fill insert.

Paper support inserted and adhered beneath loss

8. The BEVA fill insert was cut exactly fit to the area of loss on the sheath. It was then adhered to the backing and to the edges of loss, overlapping them slightly, with Lascaux 498HV.

Leather insert adhered to backing over area of loss

9. Because the edges of the sheath were still fragile and brittle, toned Minogami HM-3 Japanese tissue paper were adhered along each side of the sheath's exterior for added support and stabilization using Lascaux 498HV as the adhesive. The paper was cut precisely so that it overlapped the leather only slightly.



10. The sword was carefully removed from its sheath. Storage containers were created using archival and acid-free materials, keeping the sword and sheath together, but not one within the other. Housing was constructed based on measurements suggested by the UPenn Museum's Keeper of the African Collection, Dwaune Latimer.

11. After treatment photography was carried out.

Treatment Time:

Hilt and blade: 20 hours
Sheath: 44 hours
Photodocumentation: 6 hours
Total treatment time: 70 hours total

Analysis and Testing:

pH test on leather sheath:
A pH test was conducted to determine the acidity of the leather components and to confirm the presence of acidic degradation. A small piece of leather (0.02g) that had become detached from the sheath was collected and placed in a small test tube with 1mL of tap water (pH 6.5). After six hours the pH of the water was measured using pH test strips and was found to be 3.3-3.5. After twenty-four hours the pH of the water was measured again using pH test strips and was found to be 3.0-3.3. This low pH indicates a degree of degradation to the leather sheath, as a pH at least above 3.2 is a sign that there is no significant deterioration of vegetable-tanned leather.[21]

Collagen shrinkage temperature (CST) testing:
Because collagen fibers deform over a distinct temperature interval when heated, a diagnostic test can be performed whereby fibers are heated and the temperature at which the collagen helices unravel can be recorded. This temperature range is defined as the collagen shrinkage temperature (Ts). Tiny bundles of fibers were taken from three areas on the sheath (see diagram below) with tweezers under magnification. These fibers were then placed on a hot stage of a microscope equipped with a thermometer in order to simultaneously observe the temperature increase as well as the act of the fibers shrinking and unraveling. Characteristic shrinkage temperatures (Ts) of vegetable-tanned leather in good condition range from 70-90˚C. Below 70˚C in new vegetable-tanned leather usually indicates a poorly tanned specimen, while in older or degraded leathers, a low collagen shrinkage temperature indicates a greater degree of degradation. A temperature above 90˚C indicates the presence of aluminum or chromium compounds. The chart to the right of the sample diagram shows average temperature ranges for the fibers tested. Multiple ranges indicate fibers from the same sample location were divided and tested twice for greater accuracy and representation.

SAMPLE #	TS RANGE (˚C)
1	50-?*
2	62-74 57-63
3	74-77 66-83.3
4	55-57
5	60-67.8

* Endpoint was not clearly observed

4 & 5: samples taken from detached bits of leather

Based on the results of all CST tests conducted, an average collagen shrinkage temperature range of 60.6-70.4˚C can be attributed to the leather of this sheath. This indicates the leather is slightly degraded.

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[21] Thomson. *Conservation of Leather and Related Materials*. London: Butterworth-Heinemann. p. 62.

<u>*Microchemical spot tests to determine type of tannins*</u>[22]:
From its physical characteristics, the leather of the sheath appeared to be vegetable tanned. Microchemical spot tests were conducted on leather pieces that had become detached from the object to confirm this and gain more information about the tannins used in the process. These, along with their results, are listed below:

1. Ferric test to detect the presence of vegetable tannins → **positive**

    Based on the principle that phenolic-based vegetable tannins react with iron salts to form a dark gray-blue or –green to black reaction product. A positive reaction result confirms the presence of vegetable tannins, therefore the leather of the sheath is definitely vegetable tanned.
2. Vanillin test to differentiate between condensed and hydrolysable tannins in vegetable tanned leather → **negative**

    Based on the principle that acidified vanillin reacts with condensed tannins to form a red reaction product. A positive reaction result means there is a presence of condensed tannins. The negative reaction obtained here indicates that the leather of the sheath does not contain the presence of condensed tannins.
3. Rhodanine test to identify hydrolysable gallo tannins and gallic acid in deteriorated leather → **positive for gallo tannins and gallic acid**

    Based on the principle that rhodanine reacts with the vicinal hydroxyl groups of gallic acid to give a red reaction product. A positive reaction result can confirm the presence of hydrolysable tannins as well as the presence of gallic acid, which is a deterioration product of vegetable tanned leather. Therefore, the sheath was likely processed with hydrolysable tannins.

<u>*Leather consolidation testing*</u>:
Small areas of the leather sheath were tested with the following consolidants in order to determine the best option. From these tests, 1.5% (w/v) Klucel G in isopropanol was determined to be the best option. It offered effective consolidation at a low concentration, and isopropanol as the solvent did not darken the leather and its slow evaporation allowed for adequate penetration of the consolidant. The materials tested, along with the observed results, are listed below.

1. 0.5% (w/v) Klucel G/isopropanol → no discoloration; leather still seemed fragile after two coats
2. 1.5% (w/v) Klucel G/1:1 water/ethanol → no discoloration; effectively consolidated
2. 2.5% (w/v) Klucel G in 1:1 water/ethanol → almost no discoloration; too thick and did not flow well into the leather
3. The "red-rot cocktail" (see description in treatment proposal above) → darkened the surface and left a waxy appearance; thick and did not flow well
4. 20% (w/v) B67 in petroleum benzine → significant darkening of surface
5. 1:6 Lascaux 498HV/isopropanol → significant darkening of surface

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[22] Pouliot, B., and L. Kaplan. Notes from 2008-2009 Seminar for Objects Majors: Tests to Determine Type of Tannins and Condition in Tanned and Semi-Tanned Skins/Hides. Winterthur/University of Delaware, 2008.

Testing for backing materials and method of attachment:
To work out the best method for applying a backing material to support the leather sheath structurally, a mock-up was created using wooden tongue depressors, Japanese tissue paper, and scraps of upholstery leather. Since it had been determined from tests of consolidating materials that isopropanol did not darken the leather of the sheath, Lascaux 498HV was applied to toned Japanese tissue and adhered to the leather by reactivating the adhesive with isopropanol. This proved to be a successful way to stabilize the leather of the sheath; thus a similar technique was used in treatment.

Energy-dispersive X-ray Fluorescence Spectroscopy (XRF):
XRF was performed in the Winterthur Scientific Research Analytical Laboratory under the supervision of Catherine Matsen in order to determine the composition of the metal components of the hilt.

The results were as follows:

- The blade contains mostly iron with trace amounts of manganese
- The copper-colored wire wrappings are copper
- The copper-colored parts of the twisted wire wrappings contain mostly copper with trace amounts of iron
- The silver-colored parts of the twisted wire wrappings contain mostly iron with trace amounts of manganese and copper present

See attached XRF spectra.

Appendix:

1. Approval from Lynn Grant, UPenn Senior Conservator, to coat metal wires on hilt: email correspondence.

2. Approval for request for analysis, signed by: Lauren Fair, Conservation Student; Bruno Pouliot, Supervising Conservator; Jennifer Mass, Supervising Scientist; and Lynn Grant, UPenn Senior Conservator.

3. XRF spectra for metal components of sword: blade and metal wire wrappings.

From: "Lynn Grant" <lgrant0@sas.upenn.edu>
Date: December 18, 2008 4:33:33 PM EST
To: "'Lauren Fair'" <laurenfair@comcast.net>
Cc: "'Bruno Pouliot'" <bpouliot@winterthur.org>, "'Dwaune Latimer'" <dlatimer@sas.upenn.edu>
Subject: RE: Question: AF3364

Lauren - we would like to have the wire areas coated as well, given our problematic environmental condition.

Thanks, and have a happy holiday,
Lynn

Lynn A. Grant
Interim Head of Conservation
U of Pennsylvania Museum of
Archaeology and Anthropology
3260 South St.
Philadelphia, PA 19104
lgrant0@sas.upenn.edu

-----Original Message-----
From: Lauren Fair [mailto:laurenfair@comcast.net]
Sent: Thursday, December 18, 2008 4:28 PM
To: lgrant0@sas.upenn.edu
Cc: Bruno Pouliot
Subject: Question: AF3364

Dear Lynn,

I am a second year WUDPAC objects major currently treating African sword, AF3364 (see images below). As discussed in my treatment proposal, after cleaning and removing corrosion products on the steel
blade, I will be coating the blade with wax for further protection.
The metal wires, which you can see in the detail image below, are copper, and copper/steel twisted together. I have successfully cleaned these decorative wires, and removed a discolored previously- applied wax coating.

My question to you is this: do you wish to have these wires coated at this point in time? The wax coating will provide adequate protection from corrosion, and although it will not last forever, because the sword is not handled frequently and it will be kept in storage, the coating should last longer than it would on metal items that were handled or displayed.

I had not mentioned this in my report or proposal, so I am bringing it to you now. Please let me know your decision on this matter. Thank you!

Best,
Lauren Fair

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