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# Metal Ion Catalysed Oxidation of Skin: Treatment of the Fur Trim and Collar on a Velvet Cape

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*The black furskin trim and collar on a velvet cape from the late nineteenth or early twentieth century showed extensive tears and severe loss of tensile strength. The probable cause of degradation was metal ion catalysed oxidation. The furskin contained approximately 6,000 ppm of copper and 20,000 ppm of iron, most probably present as mordants. The dye could not be identified, but black dyes typically used on fur during this period were oxidation dyes such as Ursol D, or a combination of aniline black for the hair and logwood or an oxidation dye for the skin. Treatment consisted of physical stabilization through mechanical cleaning, backing with a Tetex polyester fabric sprayed with Beva 371 solution, and infilling with suede or dyed sheepskin. Various other treatment options, such as the use of stabilizers and metal chelates, are discussed even though they were not used. Oxygen depletion is suggested as a possible method of preventing future degradation, and the Russell effect discussed as a means of monitoring degradation.*

*La fourrure noire dont sont faits le col et la garniture d'une cape de velours datant de la fin du XIX<sup>e</sup> ou du début du XX<sup>e</sup> siècle était déchirée en de nombreux endroits et avait perdu toute résistance à la traction. La dégradation de la fourrure, qui contenait environ 6 000 ppm de cuivre et 20 000 ppm de fer, résulte probablement d'une oxydation catalysée par des ions métalliques. Il est probable que les métaux aient servi de mordant lors de la teinture de la fourrure. Les teintures noires typiques de l'époque pour les fourrures étaient des colorants d'oxydation (par exemple l'Ursol D), ou le noir d'aniline pour les poils et le campêche ou un colorant d'oxydation pour la peau. Le traitement a consisté essentiellement en une stabilisation physique de la fourrure : nettoyage mécanique superficiel, suivi de l'application à chaud de renforts de tissu de polyester Tetex encollé, par pulvérisation, de Beva 371 et comblement des lacunes à l'aide de suède ou de fourrure de mouton teinte. Diverses possibilités de traitement à l'aide d'antioxydants ou d'agents de chélation sont présentées mais n'ont pas été utilisées. L'entreposage dans un milieu privé d'oxygène est présenté comme une possibilité future de prévention, et l'effet Russell comme un moyen de mesurer l'évolution de la dégradation.*

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## Introduction

A black velvet cape from the J.A. Victor David Museum in Killarney, Manitoba, was treated by the authors at the Canadian Conservation Institute (CCI). The cape originally belonged to Mrs. Mary Magwood, who was born in Ireland in 1849 and emigrated to the United States with her parents when she was three years old. She married William A. Magwood in 1870 and moved first to Fort Erie, USA, then nine years later to Nelsonville, Manitoba. It is not known when she acquired the cape, or if she inherited it from earlier family members. Her descendants donated it to the J.A. Victor David Museum. Stylistically, the cape appears to be from the last quarter of the nineteenth century or the early twentieth century. It was sent to the CCI for treatment to stabilize it and allow it to be displayed, in a vertical position, on a mannequin.

The cape (**Figure 1**), measuring approximately one metre in radius, is made of black silk velvet with a brocaded silk lining, an interfacing, and two interlining layers. It is lavishly beaded and decorated with a black fur trim and collar. Although unstitched and torn in some areas around the collar, the textile components were generally in excellent condition. However, the beads and fur trim and collar were significantly deteriorated. The

analysis and deterioration problems of the glass beads have been described elsewhere.<sup>1</sup> This article describes metal ion catalysed oxidation as the probable degradation mechanism of the furskin, and presents dye and metal content analyses as compared with information from the literature. A discussion of possible treatments, including the use of antioxidants and metal chelates, is also presented. The chosen treatment (cleaning, physical stabilization, and infilling) is described and its rationale is explained.

## Condition

The fur trim and collar, probably of goat or sheep hair, consists of skin approximately 1 mm thick with black hair of roughly 10 cm in length. The hair itself was secure and in good condition, except for a greenish tinge at the roots in some areas. The silk thread holding the skin to the velvet cape was in good condition. The skin, however, had little tensile strength and was torn in many areas (**Figure 2**), and its surface, on the flesh side, was powdering. Its shrinkage temperature ranged from room temperature to 60 °C, representing the extreme in measurable heterogeneity in the collagen and severe, visible damage of some of the collagen fibres.<sup>2</sup> The pH, both surface and extracted, was  $3.8 \pm 0.1$ .<sup>3</sup> This is not unduly acidic for a processed skin.<sup>4</sup>

### *Metal Ion Catalysed Oxidation of Collagen*

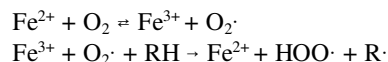
We suspected that the furskin was suffering from oxidative degradation catalysed by metal ions, or what is sometimes called "black rot."<sup>4</sup> The symptoms of black rot include loss of strength, brittleness, and the powdering of the fibres. Unlike red rot, however, the pH remains within the stable range of 3.5-5.0.<sup>4</sup> The furskin of this cape did not feel brittle, but its fibres were powdery, perhaps indicating a brittleness at the fibre level.

There have been a few reports of objects in museum collections made of collagenous materials suffering from metal ion catalysed oxidation. The degradation of parchment caused by the presence of iron and copper pigments<sup>5</sup> or by iron gall ink<sup>6</sup> is a well-known example. A similar phenomenon is the depolymerization of parchment caused by trace levels of copper or iron during hydrogen peroxide bleaching.<sup>7</sup> Stambolov<sup>8</sup> discusses the degradative effect of metal compounds on leather, stating that iron compounds such as iron oxide ( $\text{Fe}_2\text{O}_3$ ) in amounts as small as 0.1%, and copper compounds in concentrations less than 0.02%, deteriorate leather either by contributing to the formation of sulfuric acid within the leather, by reacting with the tannins to cause the detanning of the leather, or by creating a pressure on the fibres through hydrolytic swelling that promotes the disintegration of the fibre network.<sup>9</sup> Native-Indian black skins which have been coloured traditionally with mud rich in organic

acids and in iron, or with vegetable extracts mixed with either this mud or with a concoction derived from boiling nails, often suffer from black rot as well.<sup>10</sup> Fenn reports examples of these in the ethnographic collection of the Royal Ontario Museum.<sup>11</sup>

The catalytic effect of transition metals such as iron on the oxidation of natural polymers such as collagen, cellulose, fibroin, and keratin, and the resulting degradation are well discussed in the conservation literature. Two processes have been described:<sup>6</sup>

(1) production of organic radicals:



The perhydroxyl radicals ( $\text{HOO}\cdot$ ) and organic radicals ( $\text{R}\cdot$ ), once formed, initiate further radical chain reactions leading to polymer decomposition:



**Figure 1.** Velvet cape, beaded and fur-trimmed, from the J.A. Victor David Museum in Killarney, Manitoba, before treatment.

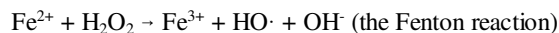


**Figure 2.** Detail of the skin side of the furskin as it was unstitched from the top of the trim. The furskin was torn or completely detached in numerous areas. Because of its curvature, the furskin was also unstitched from the bottom of the trim for stabilization treatment.

(2) production of hydrogen peroxide:



The hydrogen peroxide subsequently is decomposed by  $\text{Fe}^{2+}$ :



The hydroxyl radical is very reactive and will react with organic polymers to form organic radicals, leading to depolymerization.

As early as 1905, the Royal Society of Arts' *Report of the Committee on Leather Bookbinding* discouraged the use of black dyes based on iron salts for dyeing leather because of their link to deterioration.<sup>12</sup> In 1933, Innes reported that "the presence of iron in association with catechol tan may lead to premature rotting" and that "rotting of leather by the (accelerated ageing) peroxide test is greatly accelerated by the presence of small quantities of iron."<sup>13</sup> Following this work, in 1946 Cheshire reported that "ionic iron (...) catalyses the oxidation of leather or pelt by hydrogen peroxide in the presence of sulphuric acid, the rate of degradation being a function of the quantity of iron present."<sup>14</sup> In studies on the mechanism of free radical catalysed depolymerization of collagen through metal ion-hydrogen peroxide systems, Deasy<sup>15</sup> and Deasy and Ernst<sup>16</sup> found that in the presence of a 1% solution of  $\text{H}_2\text{O}_2$ , free radical depolymerization of collagen was catalyzed by as little as 32 ppm (0.0032%) of  $\text{Cu}^{+2}$  or by 28 ppm (0.0028%) of  $\text{Fe}^{+2}$ . At higher concentrations of  $\text{Cu}^{+2}$  (e.g. 3,200 ppm or 0.32%), damage could occur at  $\text{H}_2\text{O}_2$  solution concentrations as low as 0.06%. If  $\text{Fe}^{+2}$  and  $\text{Cu}^{+2}$  are present together,  $\text{Fe}^{+2}$  inhibits the depolymerization action of  $\text{Cu}^{+2}$  but is still active in itself, while  $\text{Cu}^{+2}$  acts as a promoter of  $\text{Fe}^{+2}$ 's decomposition of hydrogen peroxide (the Fenton reaction).

Hydro peroxides, which react in much the same manner as hydrogen peroxide, can be formed in low concentrations in a skin by oxidation of the unsaturated oils used in dressings and fat-liquoring.<sup>14,15</sup> Their decomposition will lead to the formation of more hydro peroxides. Although peroxides can also form in skins through the action of ultraviolet light on water, this mechanism seems unlikely in the case of the cape because the black hairs shield the skin side from light.

#### *Analysis of Metal Content in the Furskin*

Qualitative energy dispersive x-ray microanalysis of the hairs revealed that iron and copper were present in quantities below the detection limits, namely below 450 ppm (or 0.045%) for iron and 600 ppm (or 0.06%) for copper; but in the skin, these metals were present in levels well above the detection limits.<sup>17</sup> Atomic absorption spectrophotometry was undertaken on a 0.165 g sample of furskin, and although there were difficulties in the sample preparation because part of the sample would continually precipitate out, copper was found to be present at approximately 6,000 ppm (0.6%), and iron at 20,000 ppm (2%).<sup>18</sup> It is worth noting that this method of analysis does not establish whether or not the metals are in a catalytically active form.

In comparison, contaminant levels of iron or copper (due, for example, to contact with metal equipment during skin processing) are typically between 1 and 1,000 ppm.<sup>7,14,19,20</sup> Stains can have much higher levels, for example Tang and Troyer found a rust-coloured stain on parchment to contain up to 14,000 ppm of iron and 720 ppm of copper.<sup>20</sup> The extremely high levels of iron and copper found in the furskin of the cape seem to indicate that the metals were deliberately added in the dyeing process, although we could find no data on the expected metal content in skins after mordanting and dyeing.

#### *Dye Analysis of the Furskin*

Dye analysis was attempted, but the furskin was so degraded that separation of its black dye from the collagen fibres was impossible. Analysis was pursued on the hair. Comparative reference material were not available for dyed fur except for that of logwood-dyed wool. Microchemical tests confirmed that the fur hairs were not dyed with logwood.<sup>21</sup>

#### *Historical Furskin Dyes and Mordants*

Historical information on dyes that can produce the deep, rich black colour of the cape's hair and the brownish-black matt colour of the skin points to the possibility that the hairs were dyed using an aniline black topping (first patented for furs in 1888). The skin could have been dyed either with logwood or an oxidation dye such as Ursol D (first used on furs in 1890), although an oxidation dye for both the hairs and the skin cannot be excluded.<sup>22,23</sup> All of these dyes were typically used with iron and copper salts as mordants. Copper salts, in particular, are said to have outstanding abilities to accelerate the dyeing reactions and particularly oxidation reactions. As copper salts intensify colours, they were restricted to dark tints, especially black.<sup>24</sup>

Washing after mordanting with either ferrous or copper salts does not reduce the amount of metals fixed to the furskin, suggesting that the metal-protein links are stable.<sup>25</sup> It is known that only metals in an ionic form can catalyse the skin's oxidation<sup>14</sup> and that only protein complexed with metal can undergo oxidative degradation.<sup>26</sup>

#### **Preventing Metal Ion Catalysed Degradation of Skin**

Various stabilizers can prevent metal ion catalysed oxidation; they act by chelating metal ions (metal chelates), by intercepting free radicals or peroxides (antioxidants), or by screening ultraviolet radiation (UV absorbers).<sup>15</sup> The last option was not relevant for this cape as it is improbable that free radicals were created by exposure of the skin to UV light.

#### *Antioxidants*

De la Rie published a review of antioxidants that are promising for conservation; some of the most interesting are the hindered amine light stabilizers (HALS) because they work catalytically, at least in part, and, therefore, have stabilizing mechanisms that can be regenerated.<sup>27</sup> HALS can also complex with transition

metal ions to prevent the formation of metal ion-hydrogen peroxide interactions.<sup>28</sup> Tinuvin 292 and Tinuvin 144 are two examples. However, when Rouy and Chahine tested whether or not Tinuvin 292 could prevent depolymerization of parchment exposed to  $\text{Cu}^{2+}$  and a 5% hydrogen peroxide bleach, it was found ineffective under the conditions of their experiments.<sup>7</sup> Deasy found that hydroquinone and diphenylamine, which are known to act as free radical sinks, could inhibit the free radical catalysed depolymerization of collagen.<sup>15</sup> However, Rouy and Chahine, in the same series of experiments previously mentioned, did not find hydroquinone effective.<sup>7</sup> Sanders points out that hydroquinone, being a phenol, could lower the shrinkage temperature of a skin, and that diphenylamine produces a bright blue-violet colour.<sup>19</sup> Disadvantages of using free radical scavenging antioxidants include possible discolourations, as well as possible interference or antagonistic effects from other components in the skin such as acids or sulphur compounds.<sup>27</sup>

### *Metal Chelates*

Chelating agents have often been used to remove metal contaminants from skins and leathers.<sup>7,15,19,29-34</sup> Chelating agents are known to abstract metal ions from less stable complexes or compounds already formed.<sup>35</sup> For this treatment, we were, therefore, concerned that the use of chelating agents might alter the colour of the cape's furskin if the metal ions were indeed present as a mordant. Ganiaris *et al.* found that textile samples dyed with several different natural dyes faded or changed colour over a period of days after being soaked in 5% disodium EDTA; only indigo remained colourfast.<sup>32</sup> Furthermore, chelating agents are usually applied by bath and rinsed out, and we considered aqueous baths to be a risk to the furskin because of its physical fragility and low shrinkage temperature. Tests showed that the furskin shrunk upon immersion in water by approximately 5-10%, and by 10-25% upon air-drying.<sup>3</sup> Shrinkage as well as stiffening on drying would not only alter the skin, it would also make it difficult to repair and correctly reposition the skin back onto the cape's circular trim. Application of non-aqueous chelating agent solutions can also result in significant shrinkage.<sup>36</sup> The application of a chelating agent solution onto the skin with a brush, which would react *in situ*,<sup>33</sup> will not entirely prevent shrinkage.

Furthermore, recent research suggests that only a few complexing agents are able to work *in situ* to block the catalytic activity of  $\text{Fe}^{2+}$  ions.<sup>37,38</sup> The risk of increasing the depolymerization of collagen when using some chelating agents has been reported,<sup>7,19,34</sup> and as well, more specifically, the possibility of accelerating metal-catalysed degradation.<sup>39</sup> Recently, phytate has been used to reduce the degradation of paper by iron gall ink: it is reported that this metal chelate can be left *in situ*, has no deleterious effect on the stability or colour of iron gall ink, and has been found to react with  $\text{Fe}^{2+}$  in such a way as to block future reactions of the ion with hydrogen peroxide, and to reduce the concentration of free  $\text{Fe}^{2+}$  by accelerating its air-oxidation into  $\text{Fe}^{3+}$ .<sup>38</sup> However, the iron-phytate complexes have a white colour,<sup>37</sup> which could be a problem for coloured substrates.

Given all of these considerations, it was decided that there were too many risks and unknowns to warrant the use of antioxidants or chelating agents in the treatment of this cape.

### **Treatment**

The treatment we chose consisted of surface cleaning and physical stabilization of the furskin through the use of local and overall backings, and of fur or suede infills in areas with visibly noticeable losses.

### *Documentation and Unstitching*

Because of the numerous tears and the curvature of both the trim and the collar, we needed access to the back of the furskin for repair. The furskin had to be completely unstitched from the velvet cape because a partial unstitching of only the top or bottom parts would create buckling and stresses that could lead to further tears. Before unstitching, the position and shape of the furskin pieces were recorded using Mylar tracings, as well as by stitching coloured thread markers periodically through the furskin and the corresponding adjacent velvet.

### *Cleaning*

Initially, we believed that it would be necessary to clean the black dust on the powdery furskin to ensure that the backing adhesive would bond well to the skin. However, even after vacuum cleaning, the skin remained slightly powdery to the touch, and cleaning with Groom Stick or with brushes removed black dust at every application, as if slowly peeling away layers of fibres. We decided to clean the skin overall using a very soft Japanese natural-bristle brush, and to find a backing adhesive that would bond well to the powdery skin surface.

### *Consolidation*

We considered consolidation, but were concerned about the stiffening that could result from this treatment. It was necessary that the skin remain supple in order to be restitched onto the velvet. Tests were performed using one and two applications of a 3% w/v solution of Acryloid B72 and Acryloid F10, 1:1, in methyl ethyl ketone (butan-2-one), a solution that had worked well for red rot.<sup>40</sup> After these tests, there was a very slight stiffening and the fibres remained weak and brittle if brushed. Further tests indicated that the furskin could be successfully adhered onto a backing despite its powdery nature, so consolidation was not carried out.

### *Backing*

#### **Choice of Substrate**

We considered Hollytex and Reemay, both non-woven materials, as backing substrates because they are thin, flexible, and have a non-directional weave. However, they are opaque, which proved to be a practical disadvantage. We finally chose Tetex (formerly known as Stabiltex), a thin, flexible, polyester fabric with an open



weave structure, because it allowed us to see through the backing material in order to make sure the furskin pieces were accurately aligned during tear repair. We thought that the directionality of Tetex might be a handicap, but in fact it did not interfere with the treatment. An additional advantage was that it was available in black, thereby eliminating the need for dyeing.

#### Choice of Adhesive and Application Method

We tested the application of various backing adhesives in staggered lines of 1 or 2 mm diameter dots, 5 mm apart, as this method is said to maintain flexibility and drape of backed leathers and to allow for movement in changing environmental conditions, although it does create a weaker bond than continuous films.<sup>41</sup> Due to the lack of inherent strength of the furskin, we were concerned that the individual dots of adhesive holding the backing to the skin would cause local stresses. In comparison, we found that a continuous film of adhesive gave the overall, intimate contact necessary to produce a strong bond, especially around the seams. The strong bond was important in this treatment because of the powdery surface of the furskin and the need to display the cape vertically.

The following properties were sought in the backing adhesive:

- adhesion through nap-bonding, without stiffening the skin;
- sufficient adhesive strength to hold the powdery skin and sustain the load of the cape when exhibited vertically;
- stability (in particular, continued strength with ageing);
- removability with minimal harm to the skin;
- minimal adverse effects to the skin (in particular, avoiding water and excessive heat if possible, due to the skin's broad shrinkage temperature range), and;
- sufficient work time for the application of the backings (*e.g.*, avoiding fast-evaporating solvents).

Beva 371 met most of these criteria. It has been rated favourably in conservation testing<sup>42</sup> and used reliably for many years in numerous conservation treatments. A very thin film could be produced by spraying (or "flocking") in a spray booth the Beva 371 stock solution, diluted 1:1 in toluene, onto the Tetex-stretched frame from approximately one metre. The adhesive was almost dry as it reached the Tetex, creating fine web-like filaments on the surface.

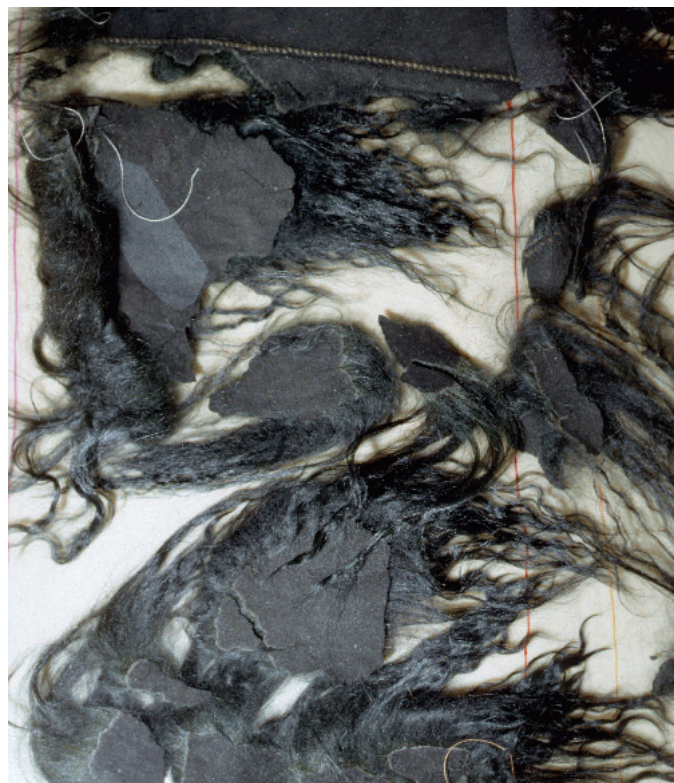
We were concerned about applying heat to the weak and degraded skin. Although Thomson found no physical damage to new and old skin products with shrinkage temperatures of 50 °C or higher after undergoing the Thermo-Lignum pest eradication method<sup>43</sup> (the skins are kept at 50-60% RH throughout the treatment and heated during 11 hours to 52 °C, maintained at that temperature for 2 hours, then cooled back to 20 °C during 10 hours), Gorham *et al.* have shown that dry collagen exposed under vacuum to 60 °C for 24 hours undergoes measurable chemical degradation, which is expected to be more severe if moisture is present in the sample,<sup>44</sup> as would be the case for this treatment (from the skin's equilibrium with the air at 50% RH). As well, Larsen *et al.* have stated that stable radicals can be formed in

untanned hide collagen exposed to 50 °C after less than one minute, but they do not provide further data or information.<sup>45</sup> In the end, we decided to use Beva 371 heat-set at 60 °C because the exposure to heat would remain very brief (up to 20 seconds), and because it successfully produced the required strong, nap-bond despite the skin's powdery surface, without visible signs of damage such as stiffening.

#### Backing Method

The backing treatment strategy was first to apply small localized backings ("band-aids") tailored to each individual tear, which allowed individual, careful realignment, and then to adhere large overall backings.

The "band-aids" applications were the most time-consuming part of the treatment. The steps are illustrated in **Figures 3 and 4**. The furskin was pieced together like a puzzle, and the long hair seeping in through the tears was pushed away with a spatula as the pieces were closely butted together. A "band-aid" was cut out following a Mylar tracing of the tear, then positioned over the tear and set for approximately 10-20 seconds using a heat spatula monitored at 60 °C coupled to an autotransformer. The Beva 371 on the Tetex backings became visibly darker when properly heat-set, as shown in **Figure 5a**. Tetex "band-aids" were applied to join all the tears, and they overlapped if the tears were close to one another.



**Figure 3.** Detail of some of the furskin pieces, before stabilization treatment.

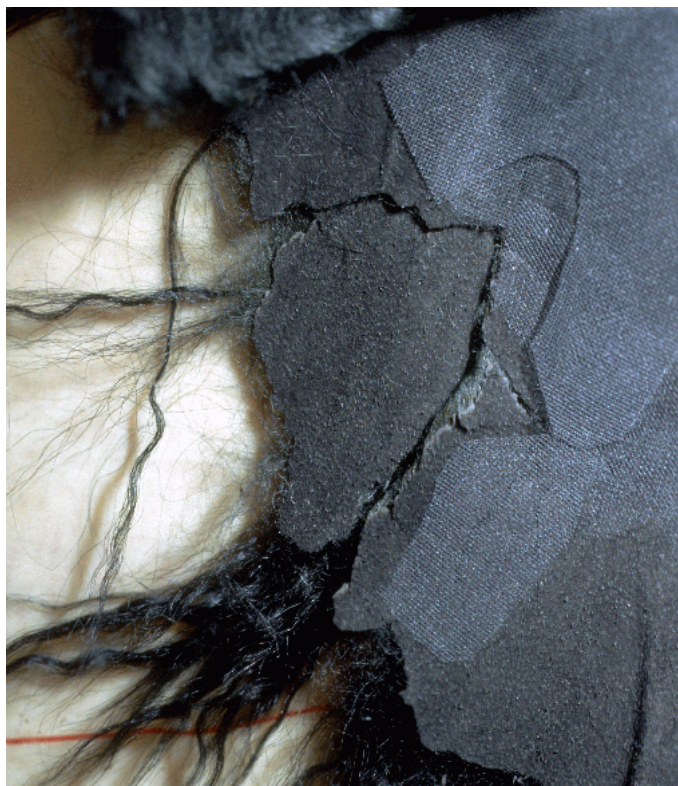




**Figure 4a.** The furskin pieces are sorted out and accurately positioned. Some areas shown have already been repaired using the Beva 371-Tetex “band-aids”.



**Figure 4b.** An outline of the tear is traced on Mylar.



**Figure 4c.** The Beva 371-Tetex “band-aid” (on the right), tailored to follow the outline of the tear, is cut out from the Mylar tracing. It was typically 1 cm wide on each side of tear. The pieces of fur are closely joined together in preparation for backing.



**Figure 4d.** The Tetex “band-aid” is positioned over the furskin, silicone release paper is superimposed, and the “band-aid” is heat-set. In this example, several Tetex “band-aids” overlap.



The “band-aids” treatment was followed by the heat-setting of larger backings that provided overall reinforcement to the weak furskin. Five Beva 371-Tetex backings, each covering an area of approximately 1 m by 20 cm, were applied on the bias to cover the entire fur trim (**Figure 5a and b**). The collar was similarly reinforced with one overall backing. The overall bias backings were larger than the width of the trim, as shown in **Figure 5b**. The excess at the top and bottom was used to stitch the backings to the velvet cape, with minimal risk of fraying. **Figure 5b** illustrates the same fur segment seen in **Figure 2**, but after stabilization.

#### *Loss Compensation*

The larger gaps in the fur trim and collar were infilled, as they would have been visibly distracting when the cape was on display, but mainly because the infills secured and strengthened the backing.

Two infill methods were used. For loss areas that were small and not very noticeable because they were masked by the long hairs from the fur above, a piece of commercial mineral-tanned black suede was used. The suede was cut out in the shape of the loss and heat-set to a Beva 371-Tetex backing of the same outline but with a 1 cm excess all around; this excess was used next to heat-set the backed fill to the edges of the furskin around the loss area.

For the three larger areas of loss that were not masked by adjacent hairs, two on the trim and one on the collar (**Figure 6a**), fur infills were made using a commercial white sheep fur dyed black with commercial hair dye. Hair dye was recommended by the furrier, and we chose Clairol Lasting Colour Type 2 No. 628 Natural Black because it does not contain any ammonia. The sheepskin hair was thicker than the original fur hair, even with thinning of the hair mass, and the black colour produced by the hair dye was a matt brownish-black, somewhat in contrast



**Figure 5a.** A Beva 371-Tetex backing, approximately 1 m by 20 cm, is applied on the bias to cover a large segment of the furskin trim. The Beva 371 becomes visibly darker when heat-set.



**Figure 5b.** The back of the furskin segment (illustrated before treatment in Figure 2), after stabilization.



with the lustrous black hairs of the furskin (**Figure 6b**). The infills were, therefore, noticeable at close range, but from a normal viewing distance, they blended well. The fur infill was set inside the area of loss in the furskin and adhered using a Beva 371-Tetex backing.

### *Restitching*

After backing and infilling, the furskin trim and collar were repositioned onto the cape, and the top and bottom edges of each of the five Tetex-backed pieces of fur were whip-stitched individually to the velvet cape. We chose a black polyester thread that was thinner and slightly weaker than the original two-ply silk thread, but also potentially less reactive than cotton or silk. We did not attempt to use the original stitching holes, as it was more important to stitch through strong areas of the velvet and furskin. The bottom edge of the furskin was stitched first, then the top, following the original order (the bottom edge had been machine stitched, and the top edge stitched by hand).



**Figure 6a.** One of the three large areas of loss that could not be masked by adjacent hairs.

## **Future Options**

### *Oxygen Depletion*

If an actively oxidizing skin were stored in an oxygen-free environment, it is possible that not only would the oxidation of the oils forming the peroxides be arrested, but the free radicals might ultimately react with themselves and be self-destroyed; when unbagged, the free radicals in the skin would start forming again, but at a slower rate.<sup>46</sup> Research is required to validate this hypothesis and to determine how long the oxygen-free conditions would be needed before a significant concentration of free radicals was self-destroyed, and how fast the free radicals would form again after unbagging. But bagging to create an oxygen-free environment was not an option for the cape at this time, as it was to go on permanent display, and a hermetically sealed, low oxygen display case was not financially feasible.



**Figure 6b.** A fur infill was made using a commercial white sheep fur, dyed black. The fur infill was thicker than the original fur hair and had a brownish-black matt colour, but from a normal viewing distance it blended in well with the original.

### *The Russell Effect*

Another option that could be investigated in the future is to monitor the oxidation of the skin using the Russell effect, which is a photographic effect on pre-sensitized film that is believed to be produced by the evolution of hydrogen peroxide.<sup>47</sup> Leckie and Williams have studied its use to assess oxidizing skins.<sup>48,49</sup> If oxygen-free conditions or peroxide-scavenging antioxidants were used in an attempt to stabilize actively the deteriorating skin, the Russell effect could be used to monitor the change in peroxide content, before and after treatment.

### **Conclusion**

The degraded furskin trim and collar on a velvet cape were physically stabilized. The cause of the degradation was probably metal catalysed oxidation, as a high iron and copper content was found in the skin. Chemical stabilization through the use of chelating agents or antioxidants was not attempted. After treatment, the furskin was secure and the cape could be safely handled, shipped, and exhibited vertically (**Figure 7**). Just as the original silk thread joining the skin to the cape remained essentially undamaged despite the intimate contact with the



**Figure 7.** The cape, after treatment, in its display position.

degrading skin, it is hoped that the Tetex woven polyester, the Beva 371 adhesive, and the polyester stitching thread used in the treatment will also remain effective for many years to come.

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### **Materials**

Acryloid B72, methyl acrylate/ethyl methacrylate copolymer: A.A.C.S. International Gilders' Supplies, 12-1541 Star Top Road, Gloucester ON K1B 5P2, Canada, (613) 744-4282.

Acryloid F10, a butyl methacrylate solution: A.A.C.S. International Gilders' Supplies, 12-1541 Star Top Road, Gloucester ON K1B 5P2, Canada, (613) 744-4282.

Beva 371, an ethylene vinyl acetate copolymer paste: Conservation Products Canada Co. Ltd., 23 Morrow Avenue, Toronto ON M6R 2H9, Canada, (416) 539-8069.

Clairol Lasting Colour Type 2 No. 628 Natural Black commercial hair dye: local drugstores.

Groom Stick, a natural rubber cleaning aid: Gaylord Bros. Canada, 1100 Gorham Street, Unit 11B, Newmarket ON L3Y 7V1, Canada, 1-800-667-1252.

Hollytex, a spun-bonded polyester fabric: Conservation Materials Ltd., 1165 Marietta Way, P.O. Box 2884, Sparks NV 89431, USA, (702) 331-0582.

Mylar polyester film: Carr McLean Ltd., 461 Horner Avenue,



Toronto ON M8W 4X2, Canada, 1-800-268-2123.

Reemay, a spun-bonded polyester fabric: Gaylord Bros. Canada, 1100 Gorham Street, Unit 11B, Newmarket ON L3Y 7V1, Canada, 1-800-667-1252.

Silicone release paper: Gaylord Bros. Canada, 1100 Gorham St., Unit 11B, Newmarket ON L3Y 7V1, Canada, 1-800-667-1252.

Tetex, a polyester fabric: B&SH Thompson and Co. Ltd., 8148 chemin Devonshire, Ville Mont Royal QC H4P 2K3, Canada, (514) 739-1971.

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