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Improved Methods of Authentication and the Resulting Shifts in Decision-Making in Parchment Conservation

INTRODUCTION

Shifts in decision-making in the conservation of cultural heritage can be understood by comparing former instructions in conservation literature with our current perception of the results of previous conservation treatments and the current ideas of what appropriate conservation treatments should be. Through understanding old methods and materials, we can estimate past conservators' objectives and gain insight into the complex environment of conservation as it existed then.

Technical changes, including better analytical methods and shifting societal norms, lead to different perspectives on cultural heritage and to the emergence of innovative treatments. One very recent example of a technical development relevant to the conservation of cultural heritage items is the decoding of proteomes and genomes that aid in the investigation of animal skins, which relies heavily on parchment manuscripts as a base of information.

To demonstrate this, the authors started with an analysis of Otto Wächter's 1982 work, *Restaurierung und Erhaltung von Büchern, Archivalien und Graphiken.* This narrowed the topic to parchment conservation, as recent molecular research applies specifically to this area. The question was: Did old conservation treatments alter parchment in such a way that biological information stored in the material was damaged, changed, or overlaid and consequently made uninterpretable? If so, could we, with improvements to current methods, "deconvolute" the data to read the original signal?

The choice of Wachter's book was based on two considerations: First, it was very influential in its time and, second, it is a difficult work to interpret if you were not a pupil of Otto Wächter himself, which the principal author happened to be.

Since Wächter's time, our knowledge of material features has improved greatly, as has our procedures for decision-making in conservation. Our view of old methods has changed in a way that allows us to understand that some treatments can have a significant impact on the biological information carried by materials, which is considered of added value in research today.

The project results have made scholars:

1. Understand how old methods and materials in conservation changed historical material.
2. Appreciate different types of biological data that can be recovered, which can be used to infer information about livestock management, craft production, and historical use of an object.
3. Understand how we might gather and interpret this palimpsest of biological and craft information, such as kind, sex, or breed of animal, breeding history of the flock or herd, the process of parchment manufacturing, etc.
4. Explore changes imposed by subsequent conservation and understand how to avoid conservation methods that either overprint with new biological signals or destroy the original ones and identify a conceptual framework for alternative methods.
5. Examine which types of modification induce changes that can be detected and isolated, thereby recovering the original biological signal.
6. Explore how new methods might fulfil conservation objectives without changing the original information carried by the material or alter the demands of conservation aesthetics.

METHOD

Wächter provides treatment recipes and procedures in a summary style, which makes it necessary to recall practical work with Wächter in the 1970s and 1980s in order to interpret what was actually meant in the text. In many cases, no solution concentrations and no description of how to apply a substance are given.

As a first step, all the materials had to be gathered or specifically prepared. Unfortunately, there are several materials that are not available anymore, of which natural sperm whale

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oil is the most significant to this research. Due to changes in environmental law, harvesting of sperm whale oil is now prohibited and therefore can no longer be procured.

In some instances, Wachter's original application techniques could be simulated without recreating the original condition issue while, in other instances, re-creation of the condition issue prior to undertaking his intended treatment method was necessary. This decision was based upon whether or not the research question (Did the conservation method and material alter the parchment and its internal information?) could be answered without re-creation or only by recreating the condition issue.

TESTING MATERIALS

In all cases, the re-creation of damage, conservation material, and conservation treatment method have been documented. All treatments were performed in an environment as closely resembling that of Otto Wachter's original environment as possible: all treatments were performed at around 18°C and with a relative humidity of approximately 50%. All parchment samples were made at the National Research and Development Institute for Textiles and Leather in Bucharest, Romania (Table 1).

All samples except one were derived from a single skin. Aged samples were used when treatment was intended to soften the skin. Aging was done for 60 days with a fluctuating temperature between 10°C and 35°C and a fluctuating relative humidity between 55% and 15%, changing every 12 hours.

Wachter's conservation recommendations for parchment fall into three main groups: cleaning or stain removal, softening of hard parchment, and repair (Table 2). Particularly fortunate was the fact that the authors still had a bottle of parchment glue made by Wächter himself [1], which could answer the questions: Did he produced the glue according to his own recipe? What parchment did he use for making parchment glue?

There were other materials—in particular, formaldehyde—which may promote changes in parchment structure by promoting crosslinking; however, they were prohibitive due to chemical restrictions and access.

HYPOTHESIS

In general, the hypothesis was summarized as follows: Wächter's materials and techniques suggest that we are in danger of altering the information we can extract from original material with today's means and measurements, as the approach to conservation treatments has changed over time. This hypothesis was considered from a philosophical-ethical viewpoint and from a scientific viewpoint.

Specifically, we presumed that all applications utilizing water (numbers 1, 3, 4, 5, 11, 13, 14, 20, 21, 29, 30, 31, 32, 33, 34, 35) would lower the shrinkage temperature of collagen fibers in the parchment, which is a feature that equates to damaging or lowering the quality of the parchment (being, in a way, a starting point of damage) and should be avoided in the course of a conservation treatment.

Soaking I	600% water at 20°C 4 hours
Drain fleshing (manual)	
Washing	400% water at 20°C; drained
Soaking II	600% water at 20°C, drain 600% water at 20°C 4% salt 0.2-0.4% detergent Stirred 3-4 hours; sat overnight
Drain	
Liming	400% water at 25°C 4% lime 4% salt 0.3% detergent pH 11.5-12
Post-liming	600% float at 25°C 2% lime 48 hours
Deliming	500% water at 30°C 1% ammonium sulphate Stirred40 minutes; sat overnight
Washing	400%-600% water at 20-25°C Stirred 60 minutes; sat overnight
Rinsing and stretching	

Table 1. Description of the manufacturing process of the parchment used for testing

Alterations to the biological information of parchment were also expected of all materials that contain DNA themselves (numbers 6, 7, 30, 31, 32, 33) and therefore would be added to the biological information profile of the original sample. Where use of DNA-containing materials is unavoidable, it makes sense to use a form that is as far distant as possible from the conservation target. Thus, it is sensible to avoid mammalian glues to repair cultural heritage objects made from mammalian tissues such as parchment and instead use isinglass (fish collagen), which is much less likely to obscure the original genetic signal than sheep or bovine gelatin. Conversely, in the treatment of fish leather, it would be more sensible to use cattle gelatin than isinglass.

In addition, the inorganic material used to chalk the parchment in the course of its production can potentially be traced geochemically. The use of earth alkali metals in conservation treatment can interfere with the biological information of the original material (numbers 8, 9, 10). The presence of borax may also interfere (number 26).

Furthermore, we should take into consideration that such finds would also have influence on our recent conservation decision-making and choice of conservation material and

Number	Sample preparation	Treatment applied to sample	Purpose	Observations	Hypothesis
1	An iron gall ink made after the recipe by Boltz von Ruffach was applied to the parchment on both sides with a stick at around 18°C room temperature and then the ink dried naturally.[2]	**Sodium hydrogen carbonate solution** (10% in water) was applied onto the ink line with a glass pipette. Barium hydroxide was not used due to its price.	Prevent ink corrosion		Lower shrinkage temperature.
2		Parchment was rubbed gently with eraser powder, a **Factis mix** (material from the 1980s, Archival Aids Draft Clean Powder DCP32lb by Ademco Limited), on both sides and then the powder was brushed off.	Dry clean		Factis crumbs will stay in the parchment structure by electrostatic forces and age slowly, giving the parchment an overall yellowish hue.
3		**Water: 70% ethanol 1:1 Vol %** mixed at room temperature. The parchment was immersed and massaged for two minutes with a brush, then taken out and placed on oil paper and weights were placed along the margins of the piece.	Wet clean		Lower shrinkage temperature.
4	Parchment was artificially aged for 60 days at a fluctuating temperature between 18°C and 35°C and fluctuating humidity between 55 and 10%RH, altering every 12 hours.	**Humidification chamber:** cold water mist was produced by natural evaporation of water from a basin for 2 hours; aged parchment was placed over bowl with cold tap water for 2 hours, then lightly pressed.	Soften		Lower shrinkage temperature.
5	Parchment treated like Sample 4.	**Glycerine** applied with hands.	Soften		Lower shrinkage temperature.
6	Old parchment glue with vinegar	Liquid **parchment glue** applied to parchment with a brush.	Soften		Alteration of information concerning animal.
7	Preparation of parchment glue: leftovers of parchment (animal not specified) cut into small pieces, cold water added, left to swell at least overnight (10 hours), then cooked in water bath for 24 hours. Heat solution (solution should not become hotter than 70°C, ideal temperature is 50°C); the water that evaporates must be substituted by new water constantly. Sift glue through a cloth. Add 7% vinegar, 1/3 glue, 1/3 alcohol, and shake.	**Parchment glue** applied to parchment with a brush.	Soften		Alteration of information concerning animal.
8a/b	Vegetable cooking oil used to create two stains.	**Benzine** mixed with **magnesium oxide or sepoilothe,** and applied onto the stain from the top. The poultice was left to dry at room temperature, then removed with a dry brush. Repeated twice.	Grease stain removal		Residues from the poultice might alter the information of any original treatment using inorganic powder (calcium carbonate, etc.). Information regarding the source of the powder might be irritated or made impossible.
9a/b	Vegetable cooking oil used to create two stains.	**Ether** dripped onto the stain from the top, with one stain on sepiolite and the other on magnesium oxide.	Grease stain removal		As 8/ab

(*continues*)

Table 2. Parchment conservation treatment materials and methods used by Otto Wächter

Number	Sample preparation	Treatment applied to sample	Purpose	Observations	Hypothesis
10a/b	Vegetable cooking oil used to create two stains.	**Chloroform** dripped onto the stain from the top, with one stain on sepiolite and the other on magnesium oxide.	Grease stain removal	The chloroform did not stay in the area where applied it, but ran all over the parchment sample.	As 8a/b
11	Author's blood applied to both sides of parchment and dried for 7 days.	Half of the stain was made wet with tap water from one side and put upside down over open bottle of 30% **hydrogen peroxide** for 1 hour at around 18°C.	Blood stain removal		Lower shrinkage temperature.
12	Ballpoint pen lines drawn on parchment.	**Dimethyl formamide** was dripped onto the area and the lines were rubbed off with a cloth.	Ink stain removal		
13	Parchment aged.	Aged parchment immersed into **milk** (3.5% fat) for 2 minutes, massaged, and then air dried.	Soften		Lower shrinkage temperature; slight fat-tanning.
14	Parchment aged.	Aged parchment immersed into 10% **urea** for 2 minutes, massaged, and then air dried.	Soften	The parchment became really stiff and not at all soft.	Lower shrinkage temperature.
15	Parchment aged.	Aged parchment immersed into **cedar oil** for 2 minutes, massaged, and then air dried.	Soften		Slight oil-tanning
16		Parchment dipped into **dimethyl sulfoxide**.	Stain removal		
17		Parchment dipped into **ammonia**.	Stain removal		
18		Parchment dipped into a solution of **soluble nylon** (from the 1980s) **in toluene** (supersaturated solution).	Fixative		
19		Parchment placed over the opening of a bottle holding 5ml 30% **hydrogen peroxide** and 3 drops of **ammonia** for 30 minutes.	Stain removal		
20	Wheat starch paste (1:4 wheat starch: tap water vol% boiled for 2 minutes, and then cooled to room temperature	**Paste** brushed onto flesh side of parchment.	Tear mending		Lower shrinkage temperature.
21	Wheat starch paste (Sample 20); after paste cooled, **Nipagin** added.	**Paste with Nipagin** brushed onto flesh side of parchment.	Tear mending		Lower shrinkage temperature.
22		Parchment dipped in 5% **oxalic acid** for 1 minute, taken out, and dried at room temperature without rubbing.	Rust stain removal	Parchment curled up while drying.	Shrinkage.
23		Parchment immersed into 3% **hydrochloric acid** for 1 minute, taken out, and dried at room temperature without rubbing.	Rust stain removal		
24		Parchment immersed in 10% **Titriplex** in water for 1 minute, taken out, and dried at room temperature without rubbing.	Rust stain removal		
25		Parchment immersed in 1:1 **hydrogen peroxide: ether** vol% for 1 minute, taken out, and dried at room temperature without rubbing.	Fly excrement removal		

(*continues*)

Table 2. Parchment conservation treatment materials and methods used by Otto Wächter (*Continued*)

Number	Sample preparation	Treatment applied to sample	Purpose	Observations	Hypothesis
26		Parchment immersed in warm 10% **borax** solution for 5 minutes, taken out, and dried at room temperature without rubbing.	Milk stain removal	When the parchment was dry, the crystals were shiny on the surface of the parchment.	
27		**Nitroverdünnung** (nitro-thinner is a mix of organic solvents such as ketones, esters, and alcohol) dropped over parchment three times on both sides and then the parchment was dried at room temperature.	Synthetic adhesive removal		
28		Parchment immersed into **acetone** for 1 minute, taken out, and dried at room temperature without rubbing.	Synthetic adhesive removal		
29		**Hot water and turpentine soap.** Parchment massaged for 1 minute with turpentine soap foam made with a brush first dipped into hot tap water and then moved over the turpentine soap. The soap was then washed off the parchment with warm water and the sample left to air dry at room temperature.	Cleaning ink stains		Lower shrinkage temperature.
30	Fish bladder soaked in cold water overnight and warmed in a water bath the next day over several hours. The fish bladder was from an old source in USSR.	**Isinglass** brushed onto parchment, then the sample was left to dry at room temperature.	Adhesive		Change of information about animal; lower shrinkage temperature.
31	Parchment leftovers were soaked in cold tap water for 2 days and then warmed in a water bath the next day over several hours.	**Parchment glue** brushed onto parchment, then the sample was left to dry at room temperature.	Adhesive		Change of information about animal; lower shrinkage temperature.
32	Parchment glue with vinegar and ethanol added. 1:1:1 parchment glue (as made for Sample 31): vinegar: ethanol.	As in 31.	Adhesive		Change of information about animal; lower shrinkage temperature.
33	**Parchment glue** (as made for Sample 32) mixed with small amount of stiff 20% **hydroxypropyl cellulose** in water and very small amount of **PVAC**. Six droplets of **toluene** were then added.	The "salat dressing" was brushed onto parchment sample and left to dry at room temperature.	Consolidate flaking paint layers		Change of information about animal; lower shrinkage temperature.
34	**Methyl cellulose** from the 1980s was soaked in water and, after swelling, mixed with **PVAC** (2:1 MC: PVAC).	Mixture applied onto surface of parchment, then the parchment was allowed to dry at room temperature.	Adhesive		Lower shrinkage temperature.
35	1:1 **wheat starch paste** (Sample 20): **parchment glue** (Sample 32); small amount of **Nipagin** was added.	Mixture applied to the surface of parchment, then the parchment was allowed to dry at room temperature.	Adhesive		Lower shrinkage temperature.

Table 2. Parchment conservation treatment materials and methods used by Otto Wächter (*Continued*)

techniques. If water is a material that endangers parchment severely, we should either avoid it or find alternative application techniques.

The instrumental analysis should verify whether or not the information carried by the parchment was obscured and, if so, in what way. This would allow for a sort of retranslation of the information gained into the information that was there originally. In an extreme case, all data gathered from the survey of manuscripts by means of instrumental analysis might need to be rewritten.

SURVEY

INSTRUMENTAL ANALYSIS

Peptide mass fingerprinting (PMF) was performed using matrix-assisted laser desorption/ionization—time of flight (MALDI-TOF) mass spectrometry (MS) to establish the species of animals used to make both the parchment and glue and to assess the level of damage (deamidation) present in the sample due to the manufacturing process. Testing was carried out using a noninvasive sampling technique based on triboelectric extraction involving the use of polyvinyl chloride erasers, which allows us to interrogate parchment manuscripts without having to use destructive techniques (Fiddyment et al. 2015).

Initially, the use of MALDI-TOF MS was chosen as it is fast, inexpensive, and a useful basic identification tool or screening method. PMF is based on the analysis of one protein (in this case, collagen) cut into smaller fragments (peptides) using an enzyme (in this case, trypsin). The mass of these peptides is measured using MALDI-TOF MS, which creates a profile or "fingerprint" of the protein, which can then be compared to a reference database. With this method, it was possible to determine the species used to make the parchment and also any additional species used to make the glue that might have been applied to the surface.

Our preliminary results are presented in Table 3. All samples were identified as goat, except for samples PE017 and PE018, where blood proteins mask the collagen. By this method, it is also possible to determine a general value of deamidation, a particular type of damage that occurs in the collagen molecule when the skin is exposed to hydrolytic chemical reagents during its production process, which is defined as the Parchment Quality Index (PQI).[3] This is expressed as a percentage, where a value of 100% corresponds to no deamidation, and therefore low or no exposure to chemical reagents, and a low percentage value points to high exposure and, subsequently, high damage to the molecule. Samples without a PQI value are due to issues with the obtained spectra or due to the collagen markers being masked by other proteins as is the case of PE017 and PE018. In this instance, where samples were treated with glue it was found that both the parchment and glue are made of the same species and, thus, it is much harder to determine where the damage is occurring (whether on the parchment as part of its production or from the glue) and will require further data analysis.

For selected samples, a more detailed analysis using liquid chromatography–tandem mass spectrometry (LC-MS/MS) will be performed. This method allows for in-depth sequence analysis of the proteins in a sample. This will give us highly detailed information on where in the protein this damage is occurring and how it differs, depending on the treatment used on the parchment.

It is hoped the information that was provided through our analysis will assist conservators in their decision-making and give us a greater understanding of the processes that affect parchment stability and deterioration.

CONSERVATION PHILOSOPHY ASPECTS

The opportunity to measure shrinkage temperature within the context of parchment conservation as a survey method for the identification of the state of decay was not available in the 1980s, nor was the possibility to identify the animal species used to make parchment. The Venice Charter mentioned the use of a suitable material for conservation, but even if the general idea was ground-breaking and still valuable today, no one involved in writing the charter in the 1960s could have imagined today's technical abilities, as indeed we cannot predict advances half a century from now (ICOMOS 1964). This means that the term "proper material" must be defined anew. It also means that all aspects made possible by technical innovation since this time could not be addressed by Wächter's conservation methods.

If we look at the types of treatment Wächter addressed with his instructions, which were cleaning, mending tears, and reattachment of flaking paint layers, we find them to still be mandatory conservation measures. The need for softening historic parchment is under discussion today. The question is: What would be the benefit of such a measure, both for the artifact and the reader? Cleaning and tear mending are also subjects of discussion today. Dirt, on the one hand, can contain harmful substances, such as mold spores and hygroscopic particles that can foster mold growth. On the other hand, dirt is considered a material that might hold information about the history of the artifact itself.

One example of this would be the results of the York Gospels survey, held in the York Minster Library and "[…] is the only surviving English Gospel book to contain the oaths taken by the deans, archdeacons, canons and vicars choral, dated to the fourteenth to sixteenth centuries, and is still used in ecclesiastical ceremonies today" (Teasdale et al. 2017). The authors performed protein and DNA analysis on it and were able to look at the metagenome (i.e., DNA from bacteria on the book) and we were able to say that it corresponded to the microbiome (bacterial community or environment) of human skin, which would make sense if it was extensively handled. However, we cannot attribute it to a particular bishop or time as this human DNA would have accumulated throughout history as a consequence of repeated handling.

Vnouček earlier pointed at the information value of dust (Vnouček 1991) and, later, Cédric Leliévre addressed "To dust or not to dust? Benefits and losses of dry-cleaning on manuscript registers" at the Care and Conservation of Manuscripts conference in Copenhagen in April 2018.

Engel showed the disadvantages of dry cleaning with eraser powder, which was recommended by Wächter, being the high number of crumbs staying with the artifact after the treatment. Electrostatic forces keep the small particles attached to parchment. While these particles become more yellow and brittle with aging, the overall appearance of the artifact becomes more yellow as well, because the small yellow dots work like pointillistic dots and alter the color.

Sample	Treatment	Species identification	PQI	Standard Error
PE001	6	Goat	93.83%	6.17%
PE002	6	Goat	89.79%	6.92%
PE003	Reference parchment A	Goat	83.85%	14.37%
PE004	Reference parchment B	Goat	88.03%	10.34%
PE005	1	Goat	80.37%	6.24%
PE006	2	Goat	81.92%	6.41%
PE007	Eraser powder only	Identification not possible		
PE008	3	Goat	80.11%	10.02%
PE009	4	Goat	80.39%	5.72%
PE010	5	Goat		
PE011	8a	Goat	80.83%	5.61%
PE012	8b	Goat		
PE013	9a	Goat	80.61%	6.05%
PE014	9b	Goat	77.68%	6.88%
PE015	10a	Goat	80.64%	6.19%
PE016	10b	Goat	79.21%	10.67%
PE017	11	Identification not possible		
PE018	11	Identification not possible		
PE019	12	Goat	81.36%	6.67%
PE020	13	Goat		
PE021	14	Goat	82.06%	5.61%
PE022	15	Goat	74.89%	13.48%
PE023	16	Goat	79.92%	5.98%
PE024	17	Goat	77.92%	11.15%
PE025	18	Goat	80.45%	10.14%
PE026	19	Goat	77.91%	5.48%
PE027	20	Goat		
PE028	21	Goat		
PE030	Reference parchment	Goat	76.89%	6.84%
PE031	Reference parchment	Goat	79.30%	5.15%
PE032	Reference parchment	Goat	79.67%	6.81%
PE033	Fragments I made glue of	Goat	92.22%	1.88%
PE034	22	Goat	76.19%	6.58%
PE035	23	Goat	89.27%	5.37%
PE036	24	Goat	81.30%	5.28%
PE037	25	Goat		
PE038	26	Goat	85.88%	4.77%
PE039	27	Goat	85.57%	4.49%
PE040	28	Goat	85.09%	4.25%
PE041	29	Goat	84.83%	6.91%
PE042	30	Goat	81.08%	11.08%
PE043	31	Goat	82.23%	5.02%
PE044	32	Goat	74.41%	8.65%
PE045	33	Goat		
PE046	34	Goat	83.03%	7.67%
PE047	35	Goat		

Table 3. Species identification and Parchment Quality Index of samples

Furthermore, the brittle crumbs work like small microabraders and mechanically damage parchment.

Mending tears might not be necessary in all cases as parchment, in contrast to paper, does not so easily continue tearing once torn. However, there might be possibilities where applying an adhesive is unavoidable. Using synthetic adhesives has been suggested, but the use of natural adhesives has advantages owing to their flexibility and other properties (Mayer 2002). However, natural adhesives contain water and endanger parchment by lowering the shrinkage temperature. As shrinkage temperature is a function of temperature and humidity, conservators can change the temperature of their environment during application. This has been done successfully by one of the authors for many years. The recommended procedure is to use a natural adhesive in a very cold environment.

Another issue is related to the specific collagen material in the glue. When Wächter writes "parchment leftovers" we know he had received old timpani heads from the Vienna Philharmonic to make glue. This signifies that he did not instruct his pupils to identify the source animal of the parchment scraps used to make the glue. It further signifies that a glue made of goat may be applied onto a manuscript page made of sheep skin. If the glue is used for a localized repair, survey results may be obscured; if it is for softening an entire charter made of parchment, the entire surface was covered with the parchment glue and may also obscure research results. To escape this problem, we suggest the use of isinglass, not parchment glue, to soften an artefact.

Finally, we looked back at nearly 40 years of professional conservation and rising public awareness of what proper conservation should be. We managed to implement the conservation theories by Brandi and Baldini and other forerunners in this field (Brandi 1978, Baldini 1963). The idea of a clean, straight, perfectly flat historic artifact was "relativated" by the knowledge that some of these goals can only be reached by actually damaging the artifact. This also holds true for the softening measures and materials suggested by Wächter. We know after René Larsen's research that treatment with water or water-containing substances and strong pressing thereafter makes the lively vital parchment page into a flat, semitranslucent folio of gelatin (Larsen, Poulsen, and Vest 2002). We find such gelatin examples in many libraries and archives. However, readers and museum visitors have now already grown used to seeing and accepting distorted, hard parchment manuscripts and fully value their authentic beauty.

RESULTS AND PERSPECTIVE

As a first result, we can conclude that the PQI from electrostatic zooarchaeology by mass spectrometry (eZooMS) samples allowed for both species identification and measure of deamidation. The conservation materials and methods used did not alter the parchment strongly enough to interfere with species identification. LC-MS/MS will allow for more in-depth sequence analysis of the proteins in these samples. This will give us highly detailed information on where in the protein this damage is occurring and how it differs, depending on the treatment used on the parchment.

Another suggestion in the hypothesis had been that the application of some of the products chould lower the shrinkage temperature of the collagen. For that, shrinkage temperature must be measured.

A third insight is that the original glue made by Wächter himself must have been goat glue, as otherwise the goat signal from the parchment would have been disturbed by signals of another species.

After this study, all samples were cut in half and were artificially aged. Tests will be conducted in the future on these samples.

There is much work to be done to understand the way in which 20th century conservation methods might have altered the information held in our cultural heritage material, of which only one material and one series of instructions have been discussed here. Nevertheless, we are already facing new challenges: nanocollagen as a conservation material (Bicchieri et al. 2018) and other nano products are used by conservators and librarians without having been fully vetted. Nano silver was applied to the shelves in Admont Monastery and was described in an oral presentation by Christian Moser at Arbeitskreis Austrian National Archives Vienna Meeting November 6-7, 2017 (Moser, pers. comm.). A test was also performed to identify the effect of this nano silver on parchment. The species could be identified, but the PQI did not yield a result. It is necessary that we fully understand the alteration of material by conservation methods and material. Only when we know what original information is disturbed, can we start to approach a change in decision-making in conservation.

NOTES

1. The authors would like to thank Helmgard Holle for having given us what Wächter had previously given her. Oil paper was kindly provided by the archives of the Technical University Vienna. The authors also thank Ralf Wittig for helping with some of the solvents needed.
2. "Good stable ink for writing texts you should prepare as the following:

Firstly find 4 or 5 good stable pots as we have it for urinating in the night. When you want to make ink take half a measure of good old rain water into the pot. Take also 2 quarters of a measure of good strong white vinegar and mix it into the rain water.

Then take 4 crushed gall nuts, which you have sifted through a mesh. Put this gall nut powder into another pot then pour half of the liquid from the first pot over the nuts and stir it well with a wooden stick. Take then 4 lots of well grinded vitriol, put it in again another pot and pour the second half of the liquid in the first pot over it. In the then remaining liquid in the first pot put 4 lots of well ground gum Arabic.

Cover these 3 pots well and have them rest for 3 or 4 days. However, stir each of the substances in each pot well several times a day with a wooden stick.

When the time is over, take the pot with the gall nuts and put it onto a moderate fire, so that it becomes hot but does not boil. In the moment when it is due to boil take it from the fire and leave it to cool down a bit. Pour it through a textile into the last pot. Do not press it through, but have it go through itself. Then add the substances from the other two pots into the pot and stir it all well.

Cover the pot and let it rest and let it stand for 3 days, but you should stir it well every day, so that the material mixes well. On the 4th day take the pot carefully so that the precipitations on the bottom do not come up and pour the liquid through a textile into a clean pot. There let it stand with a lid, and you have good ink." (Boltz, 1549)

3. The levels of deamidation are higher in reference parchment A (PE003 ~83%) and parchment B (PE004 ~88%) than either of the glues (number 6 (PE001 and PE002) ~91% and number 7 (PE033) ~92%). However, the errors are quite large on these numbers, which does not allow us to categorically say there is a real difference (especially for parchment B; in the case of parchment A, the difference is clearer). When a sample has a higher level of deamidation, this is because it has been exposed to lime for a longer period of time during the dehairing process (the alkali environment of the lime produces a side chain hydrolysis of the amide group of asparagines and glutamines, producing deamidation). Also, in the case of number 7 (PE0033), this is not actually glue but the fragments of parchment used to make the glue. Three separate pieces were analyzed, but only one of them gave a spectrum that allowed calculation of the PQI, so it cannot be determined if the overall glue would have that exact value as it is made up of different pieces.

REFERENCES

Baldini, U. 1978. *Theoria del restauro e unià di metodologia.* Florence: Nardini.

Bicchieri, M., F. Valentini, F. Pascalicchio, M. L. Riccardi, P. Colaizzi, C. Del Re, and M. Talamo. 2018. The solution to an unresolved problem: Newly synthesised nanocollagen for the preservation of leather. *Journal of Cultural Heritage*. doi:10.1016/j.culher.2018.03.002.

Brandi, C. 1963. *Teoria del restauro*. Florence: Nardini.

Boltz, V., and M. Heinrich. 1570. *Illumineirr buch künstlich alle Farben zu machen und bereidenn allen Briefmalern sampt andern solcher ku[n]ste[n] liebhabern nutzlich unnd gutt zu wissen: und wirt getteillt in seiben [sic] bücher*.

Fiddyment, S., B. Holsinger, C. Ruzzier, A. Devine, A. Binois, U. Albarella, R. Fischer, E. Nichols, A. Curtis, E. Cheese, M. D. Teasdale, C. Checkley-Scott, S. J. Milner, K. M. Rudy, E. J. Johnson, J. Vnouček, M. Garrison, S. McGrory, D. G. Bradley, and M. J. Collins. 2015. Animal origin of 13th-century uterine vellum revealed using noninvasive peptide fingerprinting. *Proceedings of the National Academy of Sciences of the United States of America* 112 (49): 15066–71.

ICOMOS. 1964. International charter for the conservation and restoration of monuments and sites. Venice, Italy: ICOMOS.

Larsen, R., D. V. Poulsen, and M. Vest. 2002. The hydrothermal stability (shrinkage activity) of parchment measured by the micro hot table method (MHT). In *Microanalysis of Parchment*, ed. R. Larsen. London: Archetype Publications Ltd. 55–62.

Mayer, M. 2002. Ultrasonic bonding: Eine methode zum schließen von rissen in pergament. *PapierRestaurierung* 3 (4): 19–22.

Teasdale, M. D., S. Fiddyment, J. Vnouček, V. Mattiangeli, C. Speller, A. Binois, M. Carver, C. Dand, T. P. Newfield, C. C. Webb, D. G. Bradley, M. J. Collins. 2017. The York Gospels: A 1000-year biological palimpsest. *Royal Society Open Science* 4 (10): 170988.

Vnouček, J. 1991. Can we manage to restore medieval books without any loss of information? *Internationaler Graphischer Restauratorentag* 7: 65-76.

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